Virtual Field Trips as physically active lessons for children

Emma Norris

Supervised by
Dr Nicola Shelton
Dr Sandra Dunsmuir
Dr Oliver Duke-Williams
Dr Emmanuel Stamatakis

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University College London

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Contents

I, Emma Norris confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Children spend a large proportion of their days in obligatory sedentary lessons: with notable consequences to health and educational outcomes. This thesis tested Virtual Field Trips (VFTs) as a new format of physically active lesson: integrating educational, globe-based content on classroom interactive whiteboards with related physical movements. It aimed to assess the feasibility of VFTs in primary school settings, before exploring their potential to increase children's physical activity, on-task behaviour and student engagement. Firstly, a literature review assessed current understandings of childhood physical activity and sedentary behaviour levels and effects on health and educational outcomes. This review also considered school-based intervention attempts to improve these outcomes and also introduced physically active lessons as novel interventions which integrate physical activity into school lessons. Secondly, a systematic review collated the methods and findings of published physically active lesson interventions. Thirdly, a qualitative study assessed teacher and pupil perceptions of a pilot physically active VFT, with identified considerations from this and the systematic review used to refine VFT development. These revisions were used to develop and test a pilot cluster-randomised controlled trial of VFTs named 'Virtual Traveller', featuring a six-week intervention period and three month follow-up. Accelerometer- and observation-assessed physical activity, observed on-task behaviour and questionnaire-assessed student engagement outcomes were measured in this intervention. A full process evaluation of the intervention assessed its delivery and the perceptions of participating teachers and pupils. Results show the Virtual Traveller intervention to have no effect on overall, school day or weekend day activity but to significantly improve children's lesson time physical activity. On-task behaviour was also significantly improved during Virtual Traveller sessions compared to control lessons. There were no effects of the intervention on self-reported student engagement. Prolonged effects were not seen at three month follow-up for any outcomes. Finally, a discussion reflects on the potential for VFTs as physically active lessons, implications for policy, critiques the thesis and identifies avenues for future research. This thesis presents the first example of a physically active lesson intervention

specifically developed to use existing classroom technologies. It provides evidence that VFTs as physically active lessons can be integrated into mainstream teaching to increase lesson time physical activity and on-task behaviour, without detriment to student engagement.

Key acronyms and abbreviations used in thesis

AVG	- Active Video Game
BCT	- Behaviour Change Technique
BCTT	- Behaviour Change Technique Taxonomy
BMI	- Body Mass Index
CARS	- Children's Activity Rating Scale
CI	- Confidence Interval
CMO	- Chief Medical Officer
COM-B	- Capability, Motivation, Opportunity – Behaviour model of behaviour change
CONSORT	- Consolidation Standards of Reporting Trials
CPM	- Counts Per Minute
EE	- Energy Expenditure
EPHPP	- Effective Public Health Practice Project
FGA	- Future Goals and Aspirations
FSL	- Family Support for Learning
HR	- Heart Rate
ICC	- Intraclass Correlation
IWB	- Interactive Whiteboard
KS	- Key Stage
LPA	- Light Physical Activity
METs	- Metabolic Equivalents
MLM	- Multilevel Modelling
MPA	- Moderate Physical Activity
MRC	- Medical Research Council
MVPA	- Moderate-to-Vigorous Physical Activity
OFSTED	- Office for Standards in Education, Children's Services and Skills
OMNI	- Children's OMNI scale of perceived exertion
OPTIC	- Observing Pupils and Teachers In the Classroom
PA	- Physical Activity
PE	- Physical Education
PSHE	- Personal, Social and Health Education
PSL	- Peer Support for Learning
RCT	- Randomised Controlled Trial
RE-AIM	- Reach, Efficacy, Adoption, Implementation and Maintenance framework
RPE	- Rating of Perceived Exertion
SB	- Sedentary Behaviour
SD	- Standard Deviation
SE	- Standard Error
SEI-E	- Student Engagement Instrument – Elementary Version
T0	- Baseline measurement period of Virtual Traveller intervention

T1	- First intervention measurement period of Virtual Traveller
T2	- Second intervention measurement period of Virtual Traveller
T3	- One week follow-up measurement period of Virtual Traveller
T4	- Three month follow-up measurement period of Virtual Traveller
TAM	- Technology Acceptance Model
TPA	- Total Physical Activity
TSR	- Teacher-Student Relationships
VFT	- Virtual Field Trip
VPA	- Vigorous Physical Activity
VPC	- Variance Partition Coefficient
WHO	- World Health Organisation

Chapter 1 Purpose and structure of thesis

1.1 Purpose of thesis

Physical activity levels of children in the UK are notably low, with children spending a large proportion of their days in obligatory sedentary lessons. There is strong evidence that physical activity has positive effects on health, cognition and education: all of key concern to educators. To optimise the health, wellbeing and learning of today's children, it is essential that schools integrate physical activity into their provision wherever possible. Physically active lessons are an emerging method of doing this, converting sedentary lesson time into active lesson time. The purpose of this thesis is to explore a new format of physically active lesson, called Virtual Field Trips (VFTs). These consist of educational, globe-based content delivered on widely available classroom interactive whiteboards, combining physical movement related to on-screen curriculum content. This thesis assessed physically active lesson literature with a systematic review, before using a mixed method approach to test the feasibility of physically active VFTs. To better assess the potential of VFTs as physically active lessons, a randomised controlled trial of VFT use in primary school education was developed and tested named 'Virtual Traveller'.

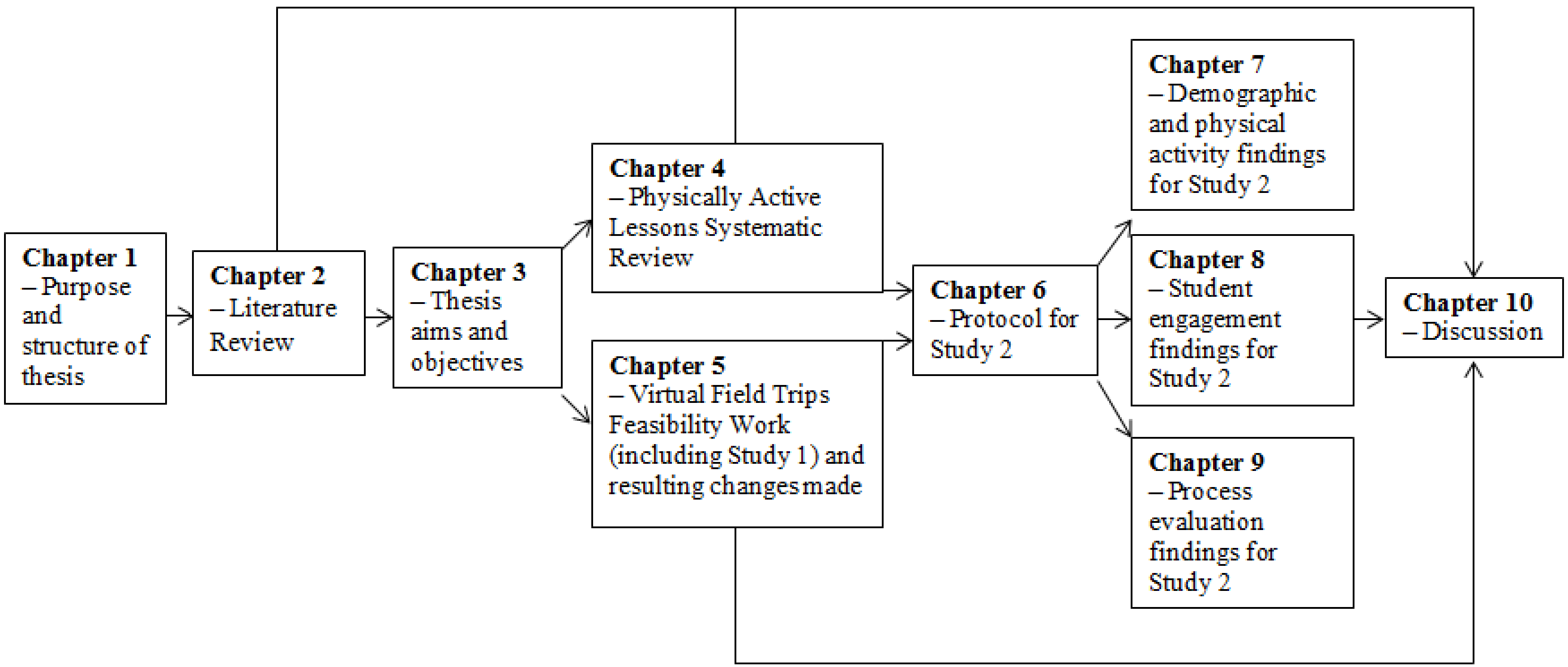
1.2 Structure of thesis

Chapter 2 reviews the existing literature into childhood physical activity and sedentary behaviour, school-based physical activity interventions, physically active lessons and Virtual Field Trips. Chapter 3 outlines the aims and objectives for the thesis. Chapter 4 reports a systematic review on existing studies investigating physically active lessons. Chapter 5 presents Virtual Field Trip feasibility work from qualitative teacher interviews and pupil focus groups: with required revisions prior to the main thesis intervention described. Chapter 6 outlines the protocol for the main thesis intervention, a randomised controlled trial with waiting list control group called 'Virtual Traveller'. Chapter 7 describes the demographic data and physical activity results from the Virtual Traveller intervention. Chapter 8 reports educational outcomes of student engagement and on-task behaviour from the Virtual Traveller intervention. Chapter 9 presents process evaluation of the Virtual Traveller intervention. Finally, Chapter 10 summarises the contribution of this novel work to wider research, practice and policy, as well as evaluating the body of work in the thesis (Figure 1-1).

1.3 Role of the researcher

The initial idea of Virtual Field Trips being used within classrooms as a physical activity intervention was conceived by Dr Nicola Shelton and Dr Oliver Duke-Williams, with support from Dr Sandra Dunsmuir and Dr Emmanuel Stamatakis. This idea secured UCL Crucible funding for this 1+3 PhD studentship. The researcher developed the aims and objectives for the research project. Recruitment for all studies was led by the researcher. The contents for the initial pilot study VFT session were developed, all research sessions run and all data analysed by the researcher as her MRes dissertation. The physically active lesson systematic review was devised and run by the researcher. For the feasibility teacher interviews and pupil focus groups; interview schedules, interviewing, transcription and analysis were performed by the researcher. All sessions for the main 'Virtual Traveller' randomised controlled trial intervention were devised and developed by the researcher, with support from consulting primary school teachers. Data collection sessions for the intervention were organised and managed by the researcher. All data was cleaned and analysed by the researcher. The write-up of this thesis is entirely the work of the researcher. Additionally, the researcher led the write-up and submission of four papers published to date from this PhD (1-4).

Figure 1-1: Thesis structure



Chapter 2 Literature Review

2.1 Introduction

Levels of obesity in UK children over recent years have been at their highest since records began (5). Of n=1,169,941 UK children assessed as part of the National Child Measurement Programme (NCMP) in 2015/6, 22.1% were overweight or obese in reception (aged 4 to 5) rising to just over a third at 34.2% in year 6 (aged 10 to 11) (6). Obesity in childhood is associated with a multitude of negative outcomes: including increased cardiovascular risk factors (7), lower academic attainment (8, 9), lower self-esteem and psychosocial health (10, 11) and reduced school attendance (12). Obese children are also more likely to become obese adults (13) and have greater chances of developing Type II diabetes, coronary heart disease and hypertension in adulthood (14).

Along with a healthy and balanced diet, physical activity is an important method of addressing obesity in children (15, 16). Current recommendations set by the UK Chief Medical Officers (CMOs) endorse that children and young people aged 5-18 years should be active for at least 60 minutes per day (17). Vigorous intensity activities including those strengthening muscle and bone are also recommended to be incorporated at least three days a week (17). These guidelines are also reflected in guidance of the World Health Organisation (WHO) (18). Recent research in n=1,113 UK primary caregivers found that only 21% knew the recommended physical activity guidelines for 5-18 year olds (19). This suggests that publicity and clarity of these guidelines is currently insufficient. Additionally, the UK is one of the few countries globally with recommendations on reducing SB (20). Current CMO recommendations also advise 5-18 year olds to minimise the amount of time spent sedentary (sitting or inactive) for extended periods (17).

This chapter examines the nature and prevalence of physical activity and sedentary behaviour in school-aged children (5-18 years) and ways to improve activity levels in school environments. Research in older ages is reported where evidence in school-aged children is limited or where wider context is required. The benefits of childhood physical activity on health, cognition and education are considered. Sedentary behaviour as an emerging influence on child health, education and wellbeing is then discussed. Existing strategies of increasing physical activity and reducing sedentary time within the school environment are examined. The emerging research focus on integrating physical activity into everyday teaching is highlighted. Potential for curriculum-based physical activity interventions to utilise existing school resources is shown. This finally leads to an introduction of Virtual Field Trips using classroom interactive whiteboards as methods of increasing children's physical activity and reducing their sedentary time.

2.2 Aims of the literature review

To provide context for the remainder of this thesis in a sample of children residing in Britain, this literature review aims to:

1) Define physical activity and sedentary behaviour

2) Review the associations and effects of physical activity and sedentary behaviour on child health, cognition and educational outcomes

3) Identify and assess existing school-based approaches to increasing physical activity and reducing children's sedentary behaviour

2.3 Childhood physical activity

Along with a healthy diet, tobacco and alcohol control and essential drugs; physical activity (PA) is recommended by The Lancet Non-Communicable Disease (NCD) Action Group as a priority intervention to reduce NCD levels (21). Related to this, the 2007 Foresight report commissioned by the UK Government Office for Science described physical activity as one of four categories of obesity determinants alongside appetite control, dietary habit force and psychological ambivalence (conflict between what people want and their desire to be healthy) (22).

2.3.1 Definition

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (EE: exchange of energy to enable biological functioning) (23). Terms such as 'physical activity', 'exercise' and 'sport' are often used interchangeably; however they represent very different concepts. Whereas exercise and sport are repetitive, highly active movements performed for health gains; physical activity captures all bodily movement (23).

Following the FITT acronym, PA can be measured in terms of four different dimensions: Frequency, Intensity, Time and Type (24). Frequency refers to how often an individual is physically active over a given time period. Intensity of PA refers to how much effort is required to perform a given activity and is typically assessed via metabolic equivalent (METs). A MET value is defined as the ratio of working metabolic rate to resting metabolic rate, representing the amount of oxygen required for a given activity in relation to sitting (1 MET) (25). Intensity can also be expressed by PA levels: time spent each day in predetermined intensity levels. There are three widely-used activity intensity levels: light PA (LPA), moderate PA (MPA) and vigorous (VPA; often grouped with MPA as moderate-to-vigorous activity or 'MVPA'). Each has its own MET definition to show the energy expenditure (EE) required (Figure 2-1). Time relates to the duration of physical activity within a timeframe. Type refers to what specific physical activities are done. In children, these can be broadly divided into incidental activities (associated with daily living such as walking to school) and purposeful, voluntary activities (such as sport or recreational activities) (26). Activity types can also be assessed more specifically (e.g running, swimming, walking). The context of activity types can also be explored, such as whether activity is performed inside or outside, at school, home or recreationally and whether it's performed alone or within a social group (27).

Figure 2-1: Activity intensities with their metabolic equivalents and example activities

Activity intensity	**MET definition (25)**	**Physical activity example**	**Effect on the body (28)**
Light	1.5 – 2.9	Slow-walking, daily self-care	Small increase to normal breathing rate
Moderate	3.0 – 5.9	Brisk walking, bike riding, playground activities	Child feels warm and slightly out of breath but can carry on with a conversation
Vigorous	≥ 6.0	Running, swimming and other sports	Child feels sweaty and out of breath, finding it difficult to carry on with a conversation

2.3.2 Physical activity measurement in epidemiology and public health

Physical activity in children can be assessed in a range of different ways. The methods adopted in any given study are typically determined by the age of the children, associated costs and time available. There are two main types of physical activity measurement, subjective and objective measurements (29). Subjective measurements rely on judgements from individuals on the activity levels of a specific child. Questionnaires ask children to report on their own activity levels or ask parents or teachers to provide proxy-reports. These measures are context-specific, asking respondents to reflect on a specific time-frame such as the previous week, month, during or after school. An example of a child physical activity questionnaire is the Physical Activity Questionnaire for Older Children (PAQ- C): a self-administered tool asking children aged 8-14 to recall their activity over the last seven days (30). Also, direct observations of physical activity involve the coding of children's activities by researchers in a given setting according to a pre-set tool (29). For example, the Children's Activity Rating Scale (CARS) rates observed activities into 5 intensity categories: stationary, stationary with limb or trunk movements, slow movement, moderate movement or fast movement (31).

Subjective physical activity measures can often be delivered quickly and cheaply, enabling larger sample sizes (32). However, the accuracy of such methods can be compromised in various ways. Questionnaires rely on the correct recall of past activity. This is especially problematic in children where activity is often sporadic and may less likely be remembered compared to other prolonged activity such as sports (32). Differences in linguistic and cognitive abilities in younger ages may make questioning difficult (29). Social-desirability bias may lead children to over-report their activity to please the researcher (33). A review of 61 PA questionnaires for children and adolescents found none to have acceptable validity and reliability (34). This demonstrates that extreme caution should be used when interpreting self-report PA findings. In observational studies a 'Hawthorne effect' may also be present: in that children aware that their activity is being assessed may alter their behaviour to be more active (29).

Objective measures use devices to provide activity assessments, attempting to combat biases inherent in subjective measures (33). Firstly, heart rate (HR) monitors attach directly to children's chests to provide an indirect estimate of PA (35) by indicating relative cardiovascular stress induced by activity (36, 37). However, HR monitor readings can have little explanatory value as different activity intensities produce large inter-individual variation in HR (35, 37). This combined with the intimate nature of the technique has led to other electronic motion sensor measures being more commonly used in child PA literature (29).

Pedometers are cheap and simple devices attached to the hip used to measure mileage and step-counts (38). Accelerometers measure activity across all levels of intensity with different devices assessing via various axes (39). They can be placed on the hip or wrist: although hip-based measurement has been shown to be more valid, reliable and acceptable to children (40, 41). They are typically worn from between one to seven days either in-school or for whole days (39). The most commonly used and validated brand of accelerometers in epidemiological and public health research is Actigraph (39). For example, the GT1M Actigraph (CSA, Shalimar, FL; Figure 2-2) is a bi-axial accelerometer, assessing movements on the vertical (V) and anterior-posterior (A-P) axes. It is small, lightweight (3.8cm x 3.7cm x 1.8cm; 27g) and commonly used with children (42). Devices also exist that combine accelerometers with HR monitors, such as the Actiheart (CamNtech, Cambridge, UK) (37). There has also recently been an explosion of activity monitors on the mass market (43); however research has found little evidence for their validity or reliability. For example, a recent study of 40 adults simultaneously wearing nine devices found high error in step and activity intensity estimations for commercially advertised devices such as the Fitbit One (44) and Jawbone Up (45, 46).

Figure 2-2: Actigraph GT1M accelerometer

These objective measures allow detailed, free-living activity information to be captured in real-time. However, unlike subjective measures they do not provide information on what activities were actually performed nor their context (29). Although objective measures reduce self-report bias, there are many other opportunities for bias and indeed error. Participants completing assessment periods may be different from those who do not (47). Devices can be cumbersome to wear, which can produce issues with device wear compliance (39). A weakness of accelerometers specifically is their weaker sensitivity to non-ambulatory movements (such as cycling) and on-the-spot movement, compared to accelerating, travelling movements (48). There is a lack of standardisation on how accelerometers are used or how data is interpreted (39). This means different algorithms used to interpret raw data can produce very different PA explanations (37, 47). Also equipment can be initially expensive to purchase, limiting applicability in diverse contexts (39).

2.3.3 Physical activity levels in UK children

PA levels in UK children are very low. Data from the Health Survey for England (HSE) provides the largest regular collection of children's PA levels in England. It is a yearly cross-sectional survey that assesses different health and social care measurements and includes representative adult and child samples. The 2012 HSE is the most recent to measure PA in children, assessing n=2,043 via parent- (ages 2-12) or self-report (ages 13-15) questionnaires administered by trained interviewers (49). In 2-4 year olds, only 9% children met CMO guidelines of a minimum of three hours PA a day, with 84% of children classified as demonstrating 'low activity': doing less than an hour PA a day (50). In 5-15 year olds, only 18.5% children met CMO guidelines of a minimum of one hour PA a day, with 39% classified as demonstrating 'low activity': less than half an hour of activity a day (50). Other representative sources of activity levels in UK children have used more objective measures. The 2008 HSE assessed child physical activity using accelerometers and found 33% of boys and 21% of girls to meet CMO guidelines (51). Data from n=6,497 7-8 year olds participating in the UK's Millennium Cohort Study included accelerometer data collected for at least 10 hours over 2 days. 51% of these children met CMO guidelines: again a much higher figure than self-report HSE methods (52). These findings are highly interesting and unusual, as self-report methods are typically associated with over-reporting of activity levels (29, 53).

PA levels in children vary greatly by demographic variables. Firstly sex is a key factor, with girls consistently less active than boys. In self-reported HSE 2012 data, girls were less active than boys in all assessed age-groups (50). For example, at ages 8-10, 26% of boys met PA recommendations compared to just 16% of girls. In the accelerometer-assessed Millennium Cohort Study, 63% of 7-8 year old boys met recommended PA levels compared to just 38% of girls (52). These findings have been replicated in countless other large cohort (54, 55) and cross-sectional studies (56, 57). Reasons for this sex difference have been relatively under-explored, with most research only focusing on quantifying the scale of the problem (56)

Secondly, PA levels decline with chronological age in children: a relationship described as the 'most consistent finding of PA epidemiology' (58). In accelerometer data from the 2008 HSE, 51% of boys and 34% of girls at ages 4-10 met CMO recommendations compared to only 7% of boys and 0% of girls aged 11-15 (51). In the UK's Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people (SPEEDY) population based study, n=769 children provided accelerometry data for at least 3 days at the ages of 10, 11 and 14 (59). During this time, MVPA and total PA (TPA) decreased in all time-segments (e.g after school and weekends (59)). A meta-analysis of 26 studies assessing the year-on-year decline of PA from childhood into adolescence (ages 10-19) found a mean PA change per year of -7.0% (95% CI -8.8, -5.2) (60). Both these studies found significantly greater decreases with age in girls than boys (59, 60), following the trend of aforementioned sex findings. This steep decline of PA with age in children is especially worrying given that activity levels have been shown to track into adulthood. For example, analysis of questionnaire data from the 1970 British Birth Cohort Study data at ages 10 and 42 (n=6,458) showed sports participation at age 10 increased the likelihood of PA at age 42 (RR 1.10; 95% CI 1.01, -1.19) (61). The potential for low activity levels to persist into adulthood highlights the need for early interventions in childhood to establish active habits and reduce later activity deficits (62).

There is some evidence for PA differences by ethnicity in UK sample: with Asian students assessed as least active (52, 63). Other demographic PA differences in children have been less consistent, including overweight status (50, 64), UK region (50, 52) and socioeconomic status (63, 65). These varying demographic associations highlight that studies must ensure thorough collection of such data to help explain differences in children's PA. It must be noted that as all described studies used different instruments to assess physical activity: their findings are not directly comparable to each other.

2.3.3.1 Physical activity levels during the school day

Children spend between 6 and 7 hours a day, five days a week at school (66). As such, a large body of observational research has examined patterns of children's activity during the school day. Firstly, children's PA levels during school travel have been assessed. Active travel is typically defined as cycling or walking, compared to passive travel by car or public transport (67). In children aged 2-15 in HSE 2012, 64% of boys and 67% of girls walked but only 6% boys and 1% girls cycled to or from school at least once in the last week (50). In the UK's SPEEDY study, likelihood of active travel to school was shown to decrease by increasing distance to school, with this threshold increasing with age from 1,421m at age 10 to 3,046m at age 14 (67). During travel time in the same cohort (n=839), safe places to cross roads around school have positive associations with MPA (β coefficient: 0.83; p=0.022) and VPA (β=0.56; p=0.001) (66): showing the effects of environment of PA levels within active travel. Children of both sexes who walk and cycle to school also experience health benefits (n=6,085 from the East of England Healthy Hearts study) demonstrating significantly higher fitness in 20-metre shuttle run tests than passive transport users (68).

Secondly, PA levels during lesson time have also been assessed. Lesson times have been shown to be highly sedentary across all ages (69). For example, recent analysis of prospective, observational data from the SPEEDY study found lesson time to be consistently highly sedentary across ages 10-14, whereas a decrease in PA was found during these ages in all other time-segments (e.g weekend, lunch-time) (59). PA levels are also surprisingly low during Physical Education (PE) lessons. The UK government recommends 2 hours of PA to be delivered each week in primary schools (70). However this is only voluntary guidance, as under the Education Act 2002 (71) the Secretary of State is barred from enforcing minimum study requirements for any particular subject. The Office for Standards in Education, Children's Services and Skills (OFSTED) recommends that 50% of PE time should be physically active (72). However, numerous studies have found this not to be the case. UK research has found accelerometer-assessed MVPA levels in PE to be as low as 9.5% in 8 and 9 year olds (73). As with PA generally, girls demonstrate lower PA levels in PE (74). This has been discussed as indicative of a typically 'male-focus' in PE, with provided sports such as football and cricket more popular and culturally acceptable in males (75). A large survey into PE practice in 232 countries by the United Nations found PE and PE teachers to have lower perceived status that other academic subjects in most countries, with PE often cancelled to make way for other subjects (76). This highlights that PE may typically be seen as an inferior subject, despite positive effects on health, education and wellbeing (Section 2.3.4). With

OFSTED now revising their guidelines to assess PA opportunities in school (77) (Section 2.6.2), it can be hoped that improvements in the levels of activity and status of PE will improve.

Levels of PA during break-time (often referred to as 'recess' in the American literature) have also been assessed. Recess allows children free time to be as active as they choose in self-selected peer groups, as opposed to more enforced sports and activities of PE (78). Relatively high levels of MVPA have been shown during recess; however sex differences are still present. For example, one observational, accelerometer study found that boys spent 39.5% and girls recorded 23.4% of recess time in MVPA (OR=2.55, 95% CI 1.69, 3.85) (79): with some studies finding greater MVPA levels in recess than PE (56, 79). Observations and group-interviews in five English schools found different activities to be indicative of greater recess MVPA between sexes. Greater levels of MVPA were found when boys participated in sports with large groups and when girls performed pro-social interactions (such as helping others) in small-to-medium groups (80, 81). The free activity choice inherent to recess may hence encourage greater levels of PA from self-selected activities, as opposed to enforced activities of PE (56).

Despite recess being an evidently important opportunity for PA, recess in the UK has been drastically reduced over recent years. Survey assessment of a nationally representative sample of English schools found only 26% of primary schools to have Key Stage 2 (KS2: blocks of school years in UK National Curriculum) afternoon break in 2006 (82) compared to 50% in 1995 (83). A reduction in recess and lunchbreak duration was also found in all Key Stages during this timeframe, with reductions in length of lunchbreaks not offset by increased morning break length (82). A meta-synthesis of 18 qualitative studies suggested the main reason for this recess reduction is the competing demands experienced by schools (84). Increasing importance has been set on academic assessment but not for PA. Break-times in the school day have hence been reduced to meet these primary academic targets (84, 85). Taken collectively, this body of observational evidence shows that there is substantial room for improvement to increase PA levels in schools (86). This relative inactivity is occurring despite various UK government policy initiatives attempting to increase activity in school contexts and more generally (Section 2.6). It is clear from this work that school-based intervention attempts must be carefully interwoven with other concerns of schools and teachers.

2.3.4 Physical activity effects on health, cognition and education in children

Physical activity has been associated with a range of benefits in children and is an essential element in the prevention and reduction of obesity and associated morbidity and mortality (16). Benefits from PA are holistic and wide-ranging, providing health-related as well as social, cognitive and educational advantages (87).

2.3.4.1 Physical and mental health outcomes

The constitution of the World Health Organisation (WHO) defines health as “a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity” (88). Under this definition, numerous studies have shown the benefits of chronic (regular repeated and habitual) PA in children on a wide range of health outcomes.

2.3.4.1.1 Physical health outcomes

Firstly, children with greater levels of MVPA have been shown to have reduced cardiovascular risk (89). Data from the International Children’s Accelerometry Database (ICAD): pooling data from 14 studies (n=20,871) showed greater levels of PA to be associated with reduced waist circumference, systolic blood pressure, fasting triglycerides, high-density lipoprotein cholesterol, and insulin (90). A recent systematic review of 11 studies (n=10,748) showed children with higher MVPA levels to have lower levels of systolic and diastolic blood pressure and triglycerides (91). Children with greater total PA (TPA) and VPA also have been shown to have increased cardiovascular fitness (92, 93). A dose-response relationship is evident: with greater levels of MVPA being associated with greater cardiovascular benefits (94).

Additionally, numerous studies have found greater PA levels to be associated with reduced overweight and obesity in children. Cross-sectional research utilising the ICAD dataset pooling 20 studies from 10 countries, (n=27,637) showed TPA to be inversely associated with being overweight or obese in ages 7 and over (55). As seen for cardiovascular outcomes, a dose-response relationship of MVPA on overweight or obesity was seen for children of both sexes (55). A recent paper from the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) compiled cross-sectional data from 12 countries of varying incomes (n=6,539). It showed MVPA (OR: 0.49, 95% CI 0.44, 0.55) and VPA (OR: 0.41, 95% CI 0.37, 0.46) to be associated with lower odds of obesity independent of sedentary behaviour (95). Additionally, attaining at least 55 minutes a day of MVPA was associated with reduced obesity in this multi-national sample (95), supporting current global guidelines (Section 2.1). A systematic review found 38 out of 48 cross-sectional studies to show a significant negative association between objective PA and adiposity (body fat) (96), showing the consistency of this relationship. Recent cross-sectional research has also shown greater proportions of accelerometer-assessed MVPA bouts (n=396) to be associated with lower BMI percentile and waist circumference (both $p<0.01$) compared to children demonstrating more sporadic MVPA bouts (97). Other cross-sectional studies have shown MVPA to be associated with lower body fat mass ($p<0.001$) (98), skinfold thickness and waist circumference (99).

There are some important issues with this current research basis for PA and adiposity. Firstly, studies typically focus on BMI as a proxy of adiposity, rather than more direct measurements of body composition and fat distribution (100). Studies often lack objective whole-day PA measures, instead using subjective self-report measures within school-time only (101). Also, although authors of this cross-sectional literature have described high levels of habitual PA to be 'protective' against higher levels of adiposity (96); these claims seem presumptuous given that they can give no evidence for causation (101). Longitudinal work provides greater ability to show associations between physical activity and health developing overtime. A longitudinal study assessing change in health outcomes between 11-12 years and 15-16 years in n=4,639 from the UK's Avon Longitudinal Survey of Parents and Children (ALSPAC) cohort study found MVPA to be beneficially associated with body fat mass, HDL cholesterol and insulin (102). However, a meta-analysis of six prospective studies examining the relationship between PA and fat mass found no evidence of a significant association (103). This suggests that strong cross-sectional evidence may not be consistently supported by prospective study designs. The 'inverse causality hypothesis' suggests that this lack of causal evidence may conversely show obesity to predict lower PA (101). This has been supported by other studies, prospectively showing greater fat mass to predict lower accelerometer-measured PA, but not vice versa (104) and with Mendelian randomisation showing increasing fatness to lead to causal reduction of total PA and MVPA (105). Adiposity may hence be a better predictor of lower PA than the other way round. However, more prospective research with larger cohorts is required to test this association.

2.3.4.1.2 Mental health outcomes

There is clear evidence for positive effects of physical activity on children's mental health. A review of four reviews featuring twenty five studies identified physical activity as having small beneficial effects on depression and anxiety, as well as limited, positive, short term effects on self-esteem (106). However it has been noted that as with physical health outcomes, many studies are cross-sectional in nature and so cannot provide evidence on causality (106). Relatedly, a meta-analysis assessed the results of seventy-three studies featuring 246 effect sizes exploring relationships between physical activity and mental health (107). Physical activity randomized controlled trials (RCTs; k=30) were found to significantly reduce children's depression (d=-.41, SE=0.13), anxiety (d=-.35, SE=0.18), psychological distress (d=-.61, SE=0.30) and emotional disturbance (d=-.33, SE=0.88). They were also found to significantly improve children's self-esteem (d=.29, SE=0.08) and self-concept (d=.16, SE=0.10) (107).

2.3.4.2 Cognitive and educational outcomes

A wide range of research has investigated the relationship between PA, education and cognition in children: spanning sports science, neuropsychology, education and public health. Benefits have been shown to result from both acute PA: in the form of short sessions of activity and chronic PA: in habitual activity over time (108).

2.3.4.2.1 Cognitive outcomes

PA has been shown to benefit numerous brain processes in children that support daily living and learning (109). The majority of research has explored the effects of physical activity on executive functioning in children (106). Executive functioning refers to the control of thought and action within individuals, typically assessed experimentally via inhibition (resisting distractions to retain focus), working memory (mentally holding and manipulating information) and cognitive flexibility (also known as shifting or multi-tasking: the ability to move from one task to another) performance tasks (110). Executive function has been found to be important for academic achievement in children (111) and key for functioning in later life (112). Cross-sectional research examining the effects of chronic, habitual physical activity has consistently found more active children to be faster and more accurate at executive function tasks, such as inhibition-testing flanker tasks (113, 114): responding to the direction of a central target amid distractors (e.g., “>>>>>, >><>>>”). Such findings have also been replicated in prospective research, with greater MVPA in n=4,755 at age 11 (controlling for total PA and confounders) associated with better executive function performance at ages 11 and 13 (54).

Studies have also assessed the effects of acute physical activity interventions on executive function: assessing the transient effects of one-off or repeated activity sessions on cohorts of children (115). For example, one study tested executive function in n=87 after a 30-minute jogging intervention compared to controls, finding significantly greater inhibition, working memory and shifting (116). There may also be interaction between PA and executive function, with some interventions found to only have positive effects on executive function in children of higher fitness (117). Three general pathways between physical activity and executive function have been proposed (115). Firstly, it may be that cognitive demands inherent in PA and exercise, such as co-operation and response to ever-changing task demands, may help stimulate executive function (115). Secondly, cognitive demands arising from complex motor movements of PA and exercise may strengthen the neural circuits associated with executive function (115). Finally, physiologic changes resulting from PA and exercise, such as goal-directed behaviours and co-ordination of motor movements may strengthen the neural circuits associated with executive function (115). There is arguably need for a greater prospective research base before these pathways can be truly assessed.

Neuropsychological research has also provided evidence of the relationship between PA and cognitive outcomes (118). Originally inspired from findings in mice (119), habitual PA has been shown to have a significant influence on the human brain in various ways. Firstly, differences in brain structure have been suggested via functional magnetic resonance imaging (fMRI) scanning. Habitually active and fit children have been shown to have a larger dorsal striatum in the basal ganglia: an important structure for cognitive control compared to lower active children (120). Additionally, more habitually active children have been shown to have increased prefrontal and parietal activation than lower-fit children: brain areas important for executive function (114). Similar effects have also been seen in adults (121). An issue with this existing body of neuropsychological research are studies' relatively small sample sizes, with samples often between n=20 to n=60. This is a common issue in neurological research due to the expense and complexity of fMRI scanning and analysis (122). Additionally, the cross-sectional nature of this research evidence does not provide directional associations between PA and brain structure or processes to be made. However, this emerging body of work does provide interesting and otherwise unattainable suggestions as to the associations between PA and physical differences in the brain.

2.3.4.2.2 Educational outcomes

These neuropsychological findings shed interesting light onto potential physical changes within children's brains associated with PA. However, we must also explore how these neurological differences may translate into real-world behavioural impacts between active and less active children. A large evidence base has explored the effects of both chronic and acute physical activity on a range of educational outcomes in children.

Firstly, academic achievement has been found to be higher in more active children. Academic achievement is usually assessed in such studies by official test grades: typically monitored in schools by educational bodies and of primary concern to educators (123). Habitually active children have been shown in numerous studies to have greater academic achievement than less active children. In longitudinal data from the ALSPAC study, PA was assessed in n=4,755 children at age 11 with 7 day accelerometry and academic achievement assessed at ages 11, 13 and 16 via compulsory Standard Assessment Test (SATs) and General Certificate of Secondary Education (GCSE) test scores (124). In models fully adjusted for variables such as total PA volume, age and birthweight, increases in percentage of time spent in MVPA predicted increases in English performance in all assessed ages and both sexes. No effect of MVPA on Maths and Science academic achievement was seen in boys of any age, whereas a positive association was seen in girls for Science at ages 11 (β=0.14 (95% CI 0.03, 0.25) and 16 (β=0.14 (95% CI 0.07, 0.21) (124). This suggests a long term, positive effect of MVPA specifically on academic achievement, especially for girls and within English teaching. Contrasting research testing short periods (acute) PA interventions rather than regular periods (chronic) PA has found greatest effects on achievement in Maths (123). A recent meta-analysis also showed Maths test results to be the most significantly improved educational outcome with PA interventions, with an overall effect size (ES) of d=0.44 from 13 studies (SE=0.09, 95% CI 0.27, 0.61) (125). Intelligence Quotient (IQ) (k=19, d=0.39, SE=0.06, 95% CI 0.16, 0.34) and reading achievement (k=14, d=0.36, SE=0.11, 95% CI 0.14, 0.58) were also shown in this meta-analysis as positively and significantly associated with acute PA interventions (125).

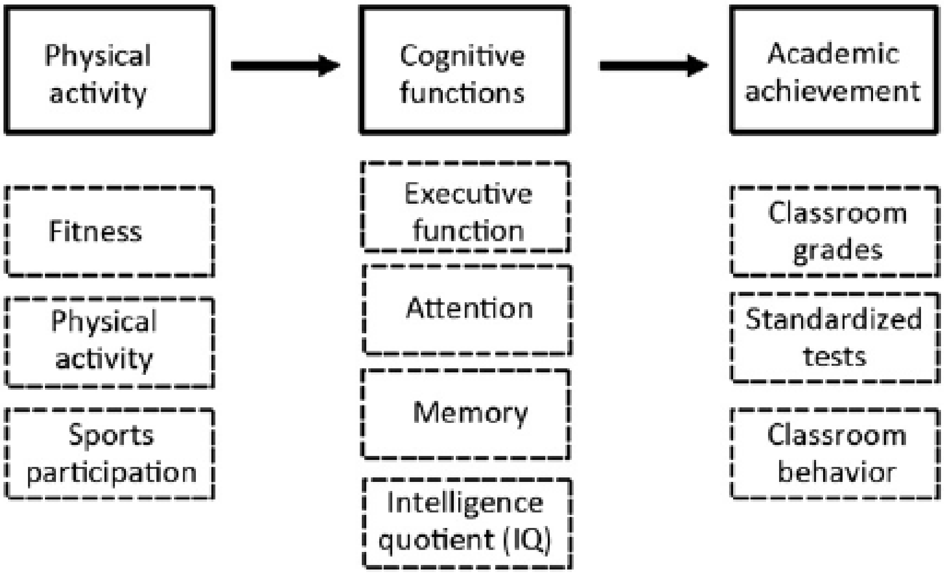
A seminal review assessing PA and cognition in children by Sibley and Etnier in 2003 found a significant overall effect size (ES; pooling variances assuming equal population variances) (126) from 44 studies of Hedge's g=0.32 (SD=0.27; where g= Mean of experimental group – Mean of control group / SD pooled) (127). This ES included a variety of cognition and achievement outcomes. A significant ES of g=0.30 (SD=0.22) was found for the 33 studies assessing achievement specifically, g=0.20 (SD=0.31) for the seven studies assessing Maths test scores and g=0.17 (SD=0.47) for the 12 studies assessing verbal test scores (127). More recent reviews have shown similar overall ESs. Fedewa and Ahn's meta-analysis of 196 ESs from 59 studies applied a mixed-effect model to account for the included cross-sectional and correlational study designs, finding an overall ES of d=0.35 (SE=0.04, 95% CI 0.27, 0.43). These findings indicate that PA programs on the whole have a small, positive and significant impact on cognition and academic achievement. Another review assessed PA's relationships with academic achievement in 53 observational and 35 experimental studies. It found positive associations between variables within 69 (78.4%) of the 88 identified studies and negative associations in only five (5.7%) studies (123). No significant difference of PA on academic achievement was found in 20 (22.7%) studies, replicating other work showing PA to not compromise academic performance (128).

PA has also been shown to improve classroom behaviours and cognitions that can improve academic achievement. On-task behaviour (defined as motor or verbal behaviour appropriate to the learning situation (129)) assessed by researcher observations of classroom behaviour has been shown to increase with PA, including after recess (130) and active classroom breaks (129, 131, 132). More active children have also been shown to have lower school-related stress (133) and reduced fidgeting and self-stimulating behaviours in children with autism and attentional disorders (134, 135). Taken alongside the other positive findings for other cognitive and educational outcomes, this body of evidence shows the importance of PA in optimising children's educational development.

A tentative model of the relationship between PA, cognition and academic achievement in children has been proposed by Howie and Pate (123). This proposes PA as including general PA, fitness and sports participation to effect cognitive functions such as executive function and attention, producing subsequent effects on academic achievement as measured by standardised testing and school grades (Figure 2-3). Although this model has face validity in visualizing PA's impact on educational outcomes, there seems to be insufficient evidence assessing the relationship between all three main outcomes.

There are common issues with research into PA and health, cognition and educational outcomes. Firstly, the observational and brief experimental study designs typically used do not allow dose-response effects to be calculated (136). This prevents insight into the optimal level of PA required by children to benefit all outcomes. Prospective studies with standardised PA dosage are arguably complex to design but would provide optimal insight into true effects. Secondly, measures used to assess PA, health, educational and cognitive outcomes vary greatly in their validity and reliability (136). Additionally, research settings can be questioned. Neurological research in particular is confined to inauthentic lab settings rather than schools or day-to-day living (136). The adequacy of presented sample

Figure 2-3: Relationship between physical activity, cognitive function and academic achievement (123)



sizes is often unclear in this field of research, with *a priori* calculations rarely reported (137). Finally, it has been suggested that the overwhelming evidence for PA's positive effects may be partially the result of publication bias (125): a greater likelihood of an article being published if it features significant findings (138). However, Fedewa and Ahn's review (125) assessed this potential bias via funnel plot analysis (139) and found no evidence for it.

Although study designs in many experimental studies may not be optimal to conclusively demonstrate causation, the strong body of evidence from meta-analytic and cohort research clearly demonstrates the power of PA on health, cognitive and educational outcomes. This collection of findings has led to international statements of support for the positive effects of PA in children on health from the World Health Organisation (18) and on academic achievement from the Society of Behavioural Medicine (140) and the Centers for Disease Control (141). Additionally, the UK's OFSTED educational inspection body has recently revised their inspection framework to include judgements on PA as an aspect of health and wellbeing (77) (Section 2.6.2). PA opportunities provided by schools are hence now being officially assessed within UK education as a vital component of education and health. These discussed findings collectively have important implications for both public health and educational practice. It is clear that there is a great range of PA benefits for individuals and society to benefit from. PA is a wise investment for health, wellbeing and education, providing knock-on social and financial gains at a population level (87).

2.4 Childhood sedentary behaviour

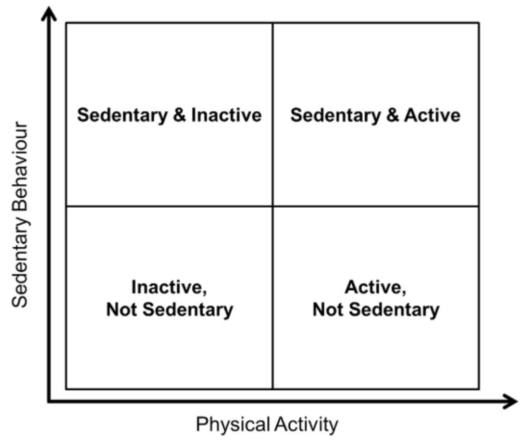
Over the last decade, an increasing body of research has explored the effects of sedentary behaviour (SB) on health, wellbeing and educational outcomes. In adults, SB is recognised as the forth leading risk factor for global mortality, causing 6% of deaths globally (18). Although the development of SB research in children has arguably lagged behind adults, emerging negative associations on a range of outcomes have been found to date.

2.4.1 Definition

The term 'sedentary behaviour' (SB) refers to activities during waking hours that involve sitting or reclining (24), eliciting ≤1.5 METs in adults (142). There is current debate on whether this classification is appropriate for use in children. Using indirect calorimetry methods (where levels of oxygen (O_2) and carbon dioxide production (CO_2) levels are measured in a room calorimeter (42)), some authors have found SB MET scoring to be equivalent in children e.g 1.17 METs for TV viewing (143). However others have reported greater accuracy using a threshold of 2.0 'adult-METs' or 1.5 'child-METs': calculated by dividing the activity-related VO_2 by the participant's age- and sex-specific Resting Energy Expenditure (REE) (144). Given the relative infancy of SB research in children, this debate may be set to continue.

Following the SITT acronym; SB can be measured in terms of four different dimensions: Sedentary behaviour frequency (the number of sedentary bouts in a given duration); Interruptions (pauses or breaks, such as getting up from the sofa whilst watching TV), Time (duration of sitting) and Type (mode of sedentary behaviour, such as reading, or screen-time: TV viewing, computer gaming) (24). Sedentary behaviour and physical activity are distinct constructs (145). Individuals can demonstrate very different patterns of activity via their varying degrees of either construct. For example, a child may be highly sedentary but still meet PA recommendations (145) (Figure 2-4). As such, it is important to measure and assess both SB and PA to give as accurate a picture of an individual's overall activity (145).

Figure 2-4: Sedentary behaviour and physical activity as separate constructs (145)



2.4.2 Sedentary behaviour measurement in epidemiology and public health

SB in children is assessed by both subjective and objective methods. Subjective questionnaires have been used to measure the time and context of SB, as well as the types of sedentary activities undertaken (146). For example, the Adolescent Sedentary Activity Questionnaire (ASAQ) assesses SB across screen, educational, travel, cultural- and social-activity types in 11 to 15 year olds (147). However as with PA subjective methods (Section 2.3.2), these questionnaires rely on recall which is prone to error (146).

As accelerometers provide data on the full spectrum of PA intensity (39) (Section 2.3.2), they are also used as a method of objective SB measurement (148). However, accelerometers cannot assess the context of sedentary behaviour, such as whether it is performed within educational, recreational or occupational settings (29). They also cannot assess transition from sitting to standing, defining SB as simply a lack of general movement (149). However, the potential for thigh-worn accelerometers to estimate sitting in adult samples has recently been investigated (150), which may have promise for child populations in the future. Other techniques exist that focus on SB specifically. Inclinometers are electronic devices recently developed to measure posture and transitions between sedentary and standing behaviours (151). Examples include the ActivPal (PAL Technologies Ltd: Glasgow, UK): designed to specifically measure postural changes, sedentary time and lower intensity activity (152, 153). The device is attached to children's thighs using Tegaderm tape but surprisingly has been found to be relatively acceptable in children for periods of up to seven days (153, 154). The ActivPAL has also been shown to highly correlate to observational (153) and waist- (152) and thigh-worn Actigraph (150) SB measures in children. However, there are various limitations to these emerging techniques. They are currently more expensive than accelerometers, which may limit their use in larger studies (155). Also as with PA measurement, there is potential for bias across objective SB data collection and analysis (47).

2.4.3 Sedentary behaviour levels in UK children

Levels of sedentary behaviour in many of today's UK children are higher than desirable. HSE 2012 data (n=2,043) derived from parent- or self-report questionnaires, identified average daily SB to be 3.25 hours on weekdays, compared to 4.1 hours on weekends (50). However, it must be noted that school-time was excluded from questioning and so this does not include sedentary class time. By contrast, data from the UK's Millennium Cohort Study (MCS; n=6,497) that included school sedentary time, found that 7-8 year old children spend an average of 6.4 hours a day in accelerometer-assessed SB (52). Although different measurement techniques were used in the two studies, this seems to indicate the large contribution of school SB to daily levels. The ISCOLE study compiling research from twelve countries found UK children (n=407) to exhibit even higher levels of accelerometer-assessed SB then previously observed: at 8.3 hours a day (SD=1.0) compared to the study average of 8.6 (SD=1.2) (156). The extent of SB across the range of low to high income countries included in the ISCOLE analysis is markedly high and depicts how ubiquitous sedentary culture is globally.

SB levels in children have been shown to differ according to demographics. As with PA (Section 2.3.3), the most pervasive demographic influence on SB in children is chronological age. This trend is especially prominent for TV screen time, with self-reported cross-sectional HSE 2012 data (n=2,043) showing weekday and weekend watching to increase in both sexes from childhood to adolescence. For example, weekday TV viewing in girls increased from 1.5 hours a day in ages 2-4 to 2.2 hours a day as children move into adolescence at ages 13-15 (50). This pattern of high SB increasing across childhood is also evident in larger international studies (55, 156). Sex is another important demographic, with girls found to be significantly more sedentary than boys at all ages (50, 52, 55). The household socio-economic position (SEP) of children has also been found to be a significant factor in the UK. Accelerometer data from HSE 2008 of n=587 children aged 5-15, showed that children in the highest (most advantaged) SEP category spent 16 minutes a day less (95% CI 6, 25; p=0.003) watching TV than those in the lowest SEP category; yet they also spent 7 minutes a day more (95% CI 2, 16; *p*=0.01) in non-TV SB (such as reading) (157). This reflects how the associations between sitting and SEP differ by SB type. All of these demographic trends have been found to persist into adulthood (158). Hence it seems apt that interventions to reduce SB in children should target all ages, girls and children of lower SEP as those at greatest risk of higher levels of sitting. A common issue with the majority of SB research in children and indeed adults is its over-reliance on self-report measurement (146). Although self-report measures are useful to determine SB type and locations, triangulation with objective methods is essential to provide more direct and accurate measurement of actual behaviour (159). With the ever-reducing costs of accelerometers and inclinometers for objective SB monitoring (160), the volume of triangulated measurement evidence should be set to expand in future years.

2.4.4 Influence of sedentary behaviour on health and education

Evidence over the last decade has highlighted the importance of SB on negative health outcomes (161, 162). In adults, analysis using one of the largest cohort studies in the world: the European Prospective Investigation into Cancer and Nutrition (EPIC) study (n=334,161; 4,154,915 person-years), found that avoiding all inactivity would theoretically reduce all-cause mortality by 7.35% (95% CI 5.88%, 8.83%) (163). This is just over double the potential reduction possible by avoiding obesity (BMI >30), estimated to reduce mortality by 3.66% (95% CI 2.3%, 5.01%) (163). A seminal paper in The Lancet by Lee and colleagues calculated that inactivity causes 9% (range 5.1%-12.5%) of premature mortality worldwide: over 5.3 million of the 57 million deaths occurring globally in 2008 (164). The elimination of physical inactivity would increase the world's life expectancy by 0.68 years (range 0.41-0.95) (164). With such huge population-based levels estimated with the total removal of SB, it is clear that efforts to encourage even reductions in inactivity may be beneficial for public health. Emerging research has assessed the role of SB on health and educational outcomes in children: with important implications for teaching practice.

2.4.4.1 Physical and mental health outcomes

There is far less research into SB effects on health in children than in adults. Indeed, the evidence available to date suggests that SB may be less associated with cardio-metabolic disease risk factors in children than in adults (145). However, a growing body of research has assessed the effects of SB in children and youth on a range of health and wellbeing outcomes.

In n=6,539 9-11 year olds from the ISCOLE study, the odds of being obese were significantly higher in those demonstrating higher SB levels (OR: 1.19, 95% CI 1.08, 1.30). A large qualitative systematic review by Tremblay and colleagues of 232 studies and n=983,840 examining childhood SB and health indicators, found that watching TV for more than 2 hours a day was associated with higher BMI and decreased fitness (165). A meta-analysis of four RCTs aiming to reduce SB and with BMI as their primary outcome, found a significant effect of -0.89 (95% CI -1.67, -0.11; p=0.01), showing reduction of SB to have tangible effects on obesity (165). However, this effect was found to be lower at -0.060 (95% CI -0.098, -0.022) in a more recent meta-analysis of 67 SB interventions with both randomised and non-randomised trial designs (166), indicating a small but significant effect. Experimental evidence in lab conditions has shown positive effects of brief breaks of light activity during sedentary time. For example, interrupting SB every 30 minutes with brief 3-minute walks significantly reduced insulin ($p<0.001$) and glucose levels (p=0.018) in a sample of n=28 healthy weight children (167). However, such experimental studies include small sample sizes due to time costs and expensive, blood assay analysis for biological outcomes. Types of SB have been shown to have differing effects on health outcomes. For example, cross-sectional data of n=2,527 6-19 year olds from the American National Health and Nutrition Examination Survey (NHANES) found high TV use but not high computer use to be a predictor of high cardio-metabolic risk score after adjustment for MVPA and other confounders (168).

However, contrasting research provides a much more unclear picture of SB's effects on health compared to PA. SB has been shown to be unrelated to children's health risk factors (169) and obesity (170) in other cross-sectional studies. Longitudinal studies assessing changes over five months (171) and four years (102) have also found no relationship between SB and health risk. This varied collection of findings is driving forward a continued research attempt to understand relationships between child SB and health outcomes. As this epidemiological research continues, interventions to reduce SB and increase the more validated outcomes of TPA and MVPA seem warranted (172).

Mental health in children has been more consistently shown to be effected by SB. A systematic review of 91 studies (73 cross-sectional, 16 longitudinal and 2 RCTs) found strong evidence that high screen-time was positively associated with hyperactivity and attention problems (in 11 out of 12 studies) and lower psychological wellbeing and perceived quality of life (QoL) (11 out of 15 studies) (173). More inconclusive findings were found for overall SB effects on depressive and anxiety symptoms, self-esteem and eating disorders (173).

Some issues are common amongst this research. As found in PA studies (Section 2.3.3), SB measures are often collected on a self-report- rather than objective-basis (101). For example in the large systematic review of SB and health indicators, 223 out of 232 studies used indirect measures such as parent-, teacher- or self-report questionnaires to assess SB (165). Such subjective methods contribute participant bias, which can be better avoided with more direct, objective methods such as accelerometers (29). Additionally, large datasets assessing SB effects on health in children are largely cross-sectional and hence do not provide causational information (106). More prospective epidemiological research with larger cohorts is required to test these associations.

2.4.4.2 Cognitive and educational outcomes

As seen for SB health outcomes, the evidence for the effects of SB on cognitive and educational outcomes is still emerging compared to the stronger support basis of PA. However, key across this limited literature is the impact that different types of SB have. Recreational SB such as TV viewing and gaming have more negative effects on cognition and educational outcomes than other academic SB such as reading. A recent systematic review explored the effects observed in 37 studies (n=14,487) of SB on cognitive development (such as language development, attention) in ages 0-5 years (174). From the 31 observational and 6 experimental studies synthesised; greater screen time (mostly assessed as TV viewing) demonstrated detrimental associations in 38% and beneficial effects in only 6% of reported associations with cognitive development outcomes. This is compared to reading, which demonstrated 0% detrimental and 60% beneficial associations (174). Authors of this review stressed the weak study quality evident in 27 out of 37 studies: primarily the result of selection bias, subjective data collection methods and a lack of blinding in experimental studies (174). To the author’s knowledge, no such equivalent review on cognitive outcomes in older children has been performed. However, this collation of early evidence does indicate the diverse effects of SB types on cognitive and educational outcomes.

Cross-sectional studies have examined the relationship between SB and educational outcomes. In a study with a Finnish cohort of n=277 schoolchildren aged 10-13, self-reported screen time had a negative association with grade point average (GPA, p=0.002), after adjusting for relevant confounders (175). In the aforementioned large systematic review of SB effects by Tremblay, SB was found to be associated with lower self-esteem (k=14), lower pro-social behaviour (k=18) and lower academic achievement (k=35) (165). However as seen for cognitive outcomes, it seems the type of SB also has crucial effects on educational outcomes. Recent research of n=845 from the English ROOTS prospective cohort study found that self-reported screen time was significantly associated with fewer GCSE grade points at age 16 (-9.1 (95% CI -14.5, -3.7; p=0.003) (176). However, non-screen based SB of reading and homework increased GCSE grade points (24.7 (95% CI 17.3, 32.0; p<0.001) (176).

2.4.5 Relationship between physical activity and sedentary behaviour in children

As we have seen, PA and SB can be conceptualised as separate constructs that have independent effects on health, cognition and educational outcomes (145). However, research has shown that levels of one of these constructs can interact with levels of the other. The most prominent way that SB and PA levels have shown to interact is via the 'ActivityStat Hypothesis' (177). This posits that when PA increases or decreases in one domain (such as within school-time in children), there is a biologically driven compensatory change in another domain (such as the home) to maintain a stable overall level of energy expenditure over time (177, 178). Such compensation is described by the hypothesis to exist as a form of homeostatic mechanism: an intrinsic bodily function as found in regulation systems for blood pressure, glucose levels and so on (177). Hence, this suggests PA and SB levels to vary within individuals, rather than across demographics or environments (179). It is important to note that this is a biological rather than a behavioural hypothesis, with such compensation produced by internal regulatory processes rather than conscious or unconscious thought (180). The timeframe for this compensatory effect can vary (177). For example, if a child misses a PE session at school and hence increases their sedentary time, an equal compensatory increase in PA may not be exhibited until hours, days, weeks or indeed months afterwards (177, 178). These compensations may occur according to seasons (e.g. increased sedentary time in winter) (181) or age (e.g. increased sedentary time as get older) (58, 178).

A range of research has explored the potential for this compensatory interaction between SB and PA in children. Observational studies have provided evidence for this hypothesis. For example, a cross-sectional study assessed three groups of English children from schools with very different timetabled sports and PA provision (179). It found no difference in accelerometer-assessed PA or SB between observed groups. Authors posited that this lack of activity variety between environmentally-determined groups served as evidence for the ActivityStat hypothesis: showing that PA and SB levels are determined by internal processes in the individual child rather than externally influencing factors (179). Additionally, a recent study of n=235 8-11 year olds found that an increase of 10 minutes inclinometer-assessed stepping on one day was significantly associated with fewer minutes of stepping (9 minutes; 95% CI -11.5, -6.2 minutes) and standing (15 minutes; 95% CI -18.8, -11.1 minutes) the following day (182). This suggests that whether subconsciously or consciously, individual children seem to account for being more active by reducing their subsequent activity. A systematic review of studies assessing the ActivityStat hypothesis across all ages identified 5 out of 8 studies in children to support it (178).

Other experimental evidence has found evidence to contradict the ActivityStat hypothesis. For example, a study of n=76 8-10 year olds provided two non-consecutive 'active' school-days with outdoor recess and PE classes and two 'restricted' days with indoor computer-based recess and no PE (183). Accelerometer PA assessment during these days found that children did not compensate for sedentary school days by increasing their PA levels after school (183). These findings are troubling as they suggest that sedentary time may not be compensated for by active time, as suggested by the ActivityStat hypothesis (177).

A growing but inconclusive evidence base exists considering the ActivityStat hypothesis (178). However, some key concerns limit the strength of this research. Firstly, the large basis of accelerometry research on this topic may be inappropriate. Given that the hypothesis relates to complex biological processes of energy expenditure, other measurement techniques such as doubly labelled water method that are designed to measure metabolic rate rather than general PA may be more appropriate (29, 183). Secondly, much supporting research for the hypothesis is observational rather than prospective: preventing the causality of compensation to be assessed (178). Additionally, most studies assessing the hypothesis provide relatively small, specific and unjustified sample sizes which limit their potential generalisability (178). If accurate, this hypothesis and supporting findings would have huge implications for activity interventions. It effectively posits that attempts to intervene on PA and SB levels are pointless: as any change in action will be subsequently erased by an equivalent opposite reaction. However as has been discussed (Section 2.3.4), activity interventions can have effective and lasting implications for a range of health, cognitive and educational outcomes in children.

2.5 Determinants of children's physical activity and sedentary behaviour

It is clear that many UK children are highly inactive (Section 2.4.3). However, to design interventions to increase activity levels, we must first understand the wider context in which this sedentary lifestyle exists. As well as aforementioned demographic determinants of activity such as sex and age (Section 2.3.3); a myriad variety of other factors bear influence on children's activity levels across environmental, genetic, psychological and social spheres (184). Although an in-depth consideration of all determinants is beyond the scope of this PhD, a summary of current evidence is provided.

2.5.1 Environmental determinants

In societies such as the UK, radical societal changes have emerged over recent decades that affect the way we work, learn and travel. Nowhere is this more prominent than in the use of technology. Over the last 70 years, television has become commonplace in UK homes, with the last 25 years seeing mass computer use emerging in the home, school and workplace. As argued by Kirchengast in her intriguing paper 'Physical Inactivity from the Viewpoint of Evolutionary Medicine' (185), the ubiquity of technology in all aspects of our lives has transformed our need for activity. She argues that although previously the human species was motivated to be physically active by life necessities of hunger, thirst and danger: being active is now merely a choice (185). Where previously only individuals that were physically active could survive long enough to reproduce, today's population can comfortably thrive with minimal physical exertion (185). The sudden changes we have engineered in our surroundings over recent decades means that we now exert less energy. Indeed, it has been argued that this trend towards inactivity is 'partially the result of our own ingenuity' (186): a creation of our own innovation. As a species, we have quickly and happily adapted to this sedentary lifestyle. However, as we see from extensive aforementioned research, our ‘indoor, overfed, sedentary existence is maladaptive’ (185). We have surrounded ourselves in an inactive environment which we are now identifying is harming and indeed killing us.

These rapid societal changes have affected activity in today’s children. As television- and computer-use have become more common in the home, the environment that modern children experience in their daily home lives has changed. Outdoor play hobbies previously common in childhood have subsequently been replaced by sedentary activities with this influx in technology (187). Outdoor roaming space has also reduced in children (188), due to heightened restrictions and safety concerns around children's independent mobility (189, 190). A recent study found that outdoor time does indeed have a strong effect on SB and PA in children. Children who self-reported spending all of their after-school time outdoors demonstrated less sedentary time (539 ± 96 min/day vs 610 ± 146 min/day, $p<0.001$), more MVPA (61.0 ± 24.3 min/day vs 39.9 ±19.1 min/day, $p<0.001$) and were more likely to reach the recommended 60 minutes a day MVPA (OR 2.8; 95% CI 1.3, 6.4; $p<0.01$) than those who reported no time outdoors (191). Other environmental factors found to effect children’s activity levels include transitioning through the education system (192). Research has identified large differences between primary and secondary school environments, including secondary schools reporting shorter breaks but higher sports facilities compared to primary schools (193). Pupils transitioning from a primary school which supports activity into a similarly supportive secondary showing significantly greater activity levels than pupils without (192). Also the weather is a key environmental determinant of activity, with rainfall (194) and reduced daily light exposure (195) significantly reducing children’s PA and increasing SB.

2.5.2 Genetic determinants

Twin cohort research has assessed the comparative influence of environmental and genetic determinants on children’s PA. These compare the similarity between genetically identical twin pairs (monozygotic, MZ) and fraternal pairs (dizygotic, DZ) who share around half of their genes (196). For example, research from the UK’s Twins Early Development Study (TEDS) in n=161 9-12 year olds twin pairs found that shared environmental effects accounted for 73% (95% CI 0.63, 0.81) of objectively-assessed PA, with no significant genetic effect (197). A recent systematic review of 7 twin studies found 60% of PA to be explained by shared environment and 21% by genetic factors (198). Taking all findings into account, authors proposed that PA levels in daily life are predominantly explained by environmental factors, but that genes may express themselves when children have opportunities for sporadic, autonomous activity (198).

2.5.3 Social and psychological determinants

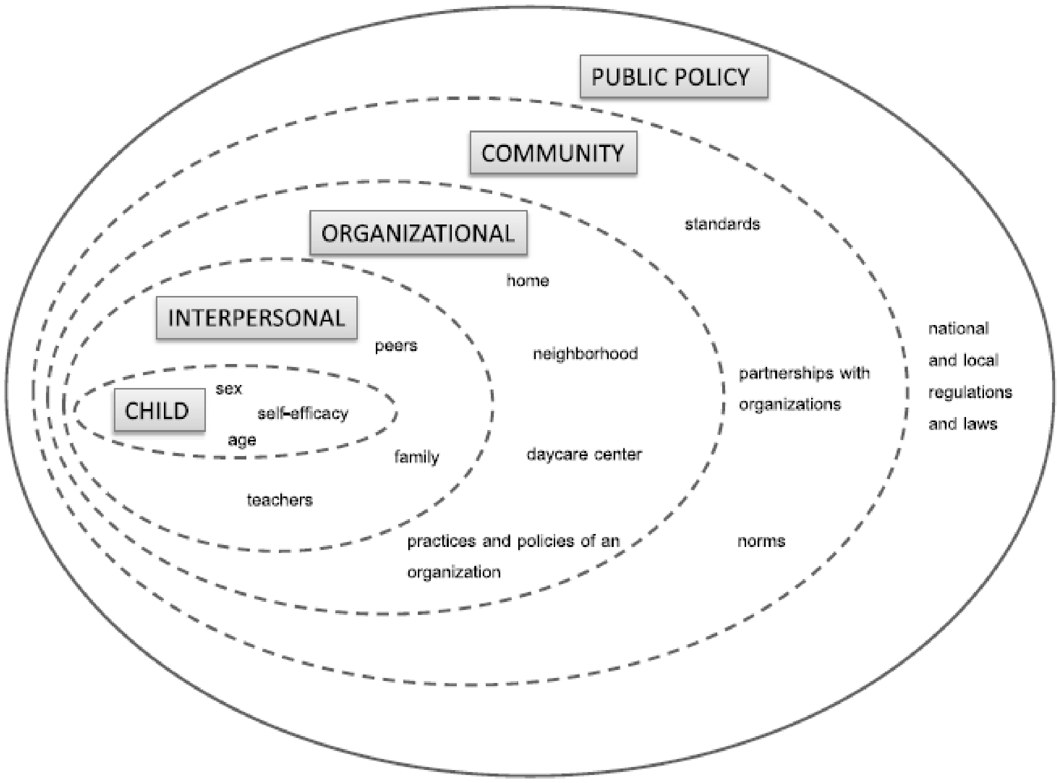
The social context that children inhabit has also been found to have influences on their PA and SB. Firstly, activity is importantly influenced by children's families. Levels of deprivation shared by the family have been shown to affect activity. For example in the UK's Health and Behaviour in Teenagers Study, children of lower socio-economic status (SES) tertile were shown to demonstrate MVPA on 0.47 days less than the highest tertile (n=4,320; $p<0.001$) (63). Also in this sample, the lowest SES tertile demonstrated 2.29 hours per week more SB than the highest tertile ($p<0.001$) (63), showing effects of deprivation on both activity and inactivity. In the nationally representative sample of the HSE 2008, similar effects were seen for SB (157) but not MVPA (51). Family relationships also have key influences on children's activity. Perceived family functioning has been shown to be positively associated with weekday MVPA (199), suggesting activity may be important in family relationships. Older siblings have been shown in qualitative research to act as role models in influencing children's activity and SB choices (200). Parent relationships have also been implicated as important in children's activity. For example, 'hyper-parenting' styles that strive for children's success are negatively associated with PA (201): with parents encouraging homework and academic extra-curricular activities rather than activity. Parental rules have also been shown to be important for SB; with children whose TV viewing is limited by their parents exhibiting less TV- and total screen-time (202).

Activity is also influenced by children's peers. Studies assessing social networks have shown similar PA levels (203) and similar PA and SB choices (200) between friends and their peers. Children with lower friendship difficulties also report greater MVPA and lower SB than children with higher difficulties (199): suggesting the influence of social relationship quality on activity. How children think and feel about themselves and activity also influences their individual PA levels (65). For example, children's PA self-efficacy (confidence in their ability to be active) is positively associated with actual PA levels (204). A range of psychological theories developed for wider health behaviours have been applied to help explain PA behaviour (184). These focus on psychological elements such as attitudes and intentions towards health behaviours in Theory of Planned Behaviour (205, 206) or control over PA in Self Determination Theory (207, 208). However, these have a narrow focus and are often applied secondarily from adult-specific theories (184).

2.5.4 Socio-ecological theories of physical activity and sedentary behaviour

It is clear from this brief examination that a wide range of factors influence children's activity levels (209). However, a recent systematic review of 37 studies assessing sedentary behaviour determinants in children found that most did not assess the full range of potential factors (210). Although this may be a complex expectation given the range of determinants at play; this lack of interconnected evidence makes it difficult to assess the individual contribution of determinants. Various integrated tools and models have been developed to help researchers and practitioners make sense of this complex array of determinants. The most prominent of these are Socio-Ecological models that assess intrapersonal behavioural factors, interrelationships between individuals and wider social, physical and policy environments (211, 212) (Figure 2-5). Compared to more specified aforementioned models, these more complex models recognise that the individual operates within a system of restrictions and expectations far beyond their control or consciousness. Demographic and genetic variables are intertwined with psychological variables such as perceived PA barriers or self-efficacy, which are in- turn interwoven with social and cultural variables, such as parental or school support for PA (209). This consideration of the full range of correlates and determinants goes far deeper into explaining the complex relationships behind childhood PA levels (213). Appreciation of this broader context helps aid intervention development: allowing us to perceive and address specific relational pathways across these environments (214). A recent systematic reviewed 23 studies of child PA interventions based on socio-ecological models (215). This found that most studies showed modest but significant increases in PA levels or reductions to SB. This provides promising indication of the inclusion of both intra- and inter-personal considerations in child PA intervention development.

Figure 2-5: Socio-ecological model of physical activity determinants in children (215)



2.6 Children Physical Activity guidance and policy in England

To help the public achieve aforementioned Child Medical Officer (CMO) guidelines for child physical activity of at least 60 minutes per day (17), the UK government have produced various policies and guidance documents over recent years.

2.6.1 General guidance

Firstly, general guidance has been produced to address activity in the public. Examples include the 2010 'Healthy Lives, Healthy People' White Paper from the emerging Coalition government (216). This outlined a vast array of new attempts to 'empower' individuals with guidance (e.g PA guidelines), information (e.g the National Child Measurement Programme), encouragement (e.g Change4Life media campaigns) and tailored support, whilst working with sport partnerships (216). However, evidence for these measures is far from positive. For example, the Change4Life multimedia campaign primarily addressing diet and PA has been shown to have little effect on behaviour change (217), whilst receiving criticism for its funding from PepsiCo and other unhealthy global food brands (218). The 2011 'Start Active, Stay

Active' report (219) attempted to action the propositions of this new White Paper. Designed to be used by professionals, practitioners and policy-makers, it summarised research evidence for PA across the life-course. It stressed the need to establish healthy, active habits in childhood; however there was arguably little guidance on strategies to actually increase PA. Public Health England have recently tried to address this by providing direct evidence-based intervention suggestions to specifically increase children's PA (220). To date, schemes emerging from this report include the '10 minute Shake Up': a Change4Life-branded intervention providing ideas for short, active breaks during the school summer holidays (221). Although evaluation of this scheme is pending, the scheme evidently does draw on the growing evidence for breaking up sedentary time in children.

2.6.2 School-specific policy

Education-specific organisations and policy have made efforts to increase PA provision in schools (222). Examples firstly include the government's introduction of the first National Curriculum for Physical Education (NCPE) in 1992 (223): four years after the rest of the National Curriculum was launched from the Education Reform Act (224). The NCPE has been recently revised along with a wider curriculum overhaul (225) but has been critiqued for its lack of health promotion focus and lack of preserved mandatory PE time (85). Secondly, the National Healthy Schools Programme (NSHP) launched in 1999 aims to encourage and reward schools for increasing sport and physical activity, diet, wellbeing and addressing overall health inequalities. Schools work towards detailed auditing, target setting and action planning to improve the health of their students: ultimately earning Healthy Schools accreditation for this (226). Thirdly, the School Sport Partnership (SSP) initiative linking PE and school sports with local and national facilities was introduced by the Labour government in 2002 (227) and was positively received by Office for Standards in Education, Children's Services and Skills (228) and other evaluation bodies (229). However funding was subsequently axed in 2010 (230) by the then Coalition Government Education Secretary Michael Gove. In an attempt to address these concerns, the Primary PE and Sport Premium was introduced under the Coalition government (231). This devotes an extra £150 million per year into school sports funding until 2020: equating to £8,000 per school plus £5 per pupil (231). A recent survey of 1,119 schools showed 74% to have added new sports into PE and 87% to have increased PE teaching quality since the funding began (232). However, schools also stressed great concern about sustaining these changes if funding is subsequently removed (232). Although sport provision seems to be increasing in schools, this relies entirely on continued governmental funding and support.

School-orientated policies have largely attempted to increase sports participation, both extra-curricular and in PE. However, the evident current low levels of PA within PE and children's general day-to-day living (Section 2.3.3), show these techniques alone are insufficient. Other non-sport and non-PE strategies are also needed to ensure the broadest range of pupils enjoy and maintain a physically active lifestyle. Such comprehensive school PA strategies are stressed in guidance from other official bodies such as the National Institute for Health and Care Excellence (233) and Public Health England (234). The recent childhood obesity policy (Section 2.6.3) has also indicated that physical activity will be assessed within OFSTED observations from September 2017 (235). This emphasises the need for health advocacy by education professionals and should encourage them to integrate healthy living across the school day.

2.6.3 New government childhood obesity proposals

The government launched its 'Childhood Obesity: Plan for action' (235) in August 2016, featuring fourteen action points primarily addressing food and physical activity. Although reported in the media as launched to coincide with Britain's success at the Olympics (236), it was also notably released during the government's summer recess with no visible support from the Prime Minister or Secretary of State for Health (237). A key component of this new strategy is a 'Soft Drinks Industry Levy' on sweetened drinks, with money generated from this pledged to fund school sports initiatives and healthy breakfast clubs from 2018 (235). This is expected to raise around £520 million in the first year (238), indicating a potential strong source of maintained school sport funding. The plan also set aims for all children to meet their daily sixty minutes activity (17) via 30 minutes of in-school activity and 30 minutes of activity outside of school facilitated by parents and carers (235). However, this plan has been widely critiqued by health experts and campaigners (237) as well as by mainstream media itself (239). Despite health secretary Jeremy Hunt billing the upcoming scheme as a 'game-changing moment, a robust strategy' in February 2016 (240), what was actually published feels weak and uncomprehensive. A leak of government documents revealed that the strategy was diluted ahead of its release by incoming Prime Minister Teresa May, with promising commitments such as developing a 'broad social movement' to help children live healthier lives removed (241). The published strategy features a distinct lack of practical steps to implement proposed changes. How exactly will sugar tax funds be allocated to school sports funding? How will families and carers be empowered to facilitate children's activity outside of school? Stronger policies such as taxing unhealthy foods, banning advertisement of foods high in salt, sugar and fat and limiting numbers of fast food outlets near schools have all been avoided (237). In a scenario resplendent of the tobacco lobby, processed food manufacturers have appeared successful in using their power to weaken resulting obesity policy (239).

2.6.4 General critique of policy attempts

There has been much criticism of the UK government's attempts to address physical inactivity in children. A critical analysis described PA policy in England as a fragmented and varying cycle (242). The authors describe the continuing re-imagining of policy to more reflect changes in political parties and government direction, rather than truly attempting to improve and sustain population-level activity levels (242). Constant revision of PA policies and targets surely serves only to confuse the public. In their recent 'Moving more, living more' report following the London 2012 Olympic Games, the government attempted to directly address this existence of fragmented activity policy (243). They stated 'Never again will we allow physical activity to occupy a silo in any one department' (243) (pg. 5). Additionally, Milton and Bauman argued that although large attempts to review PA standards and recommendations have been funded (219), there has been minimal attempt to disseminate or address their findings (242). A strong child-focused critique of UK activity policy was provided by Weiler and colleagues (85). Previous government attempts to address child PA are described to be effectively lip-service, with no set plan, no mandatory PE or curriculum time and no serious financial investment (85). Such issues are still prevalent in the recent child obesity policy (235), with no clear action plans provided. This lack of PA strategy cannot continue. UK activity levels for children of all ages are truly shocking. It is the work of researchers to share and promote our findings of effective PA interventions to ensure effective approaches are funded and utilised by the government.

2.7 School-based physical activity interventions

Given aforementioned low levels of physical activity in today's children (Section 2.3.3) researchers are keen to develop and test effective interventions to encourage long-term activity. A recent Delphi exercise where 24 international PA experts rated the need for varying child PA and SB research topics, identified the development of sustainable and effective interventions as the highest priority (244). Schools provide an ideal environment for such child PA and SB interventions. They allow frequent access to children over regular, extended periods of time, facilitating the development of healthy habits (222, 245). They also allow children's health to be addressed in an inclusive way, reducing healthy inequalities by intervening across class- and school-level populations (246).

Schools' potential for health promotion has been recognised in international health guidance. For example, the WHO Health Promoting Schools Framework encourages active learning amongst a range of other initiatives, to help foster health, wellbeing and learning within a healthy school environment (247, 248). More specific to PA, the United States' Comprehensive School PA Program provides guidance for school staff on how to integrate activity across the typical school day (249). In the UK, guidance from the Association for Physical Education (AfPE) provides whole-school approaches to schools to help promote healthy, active lifestyles (250). Despite international guidance on PA promotion in schools, there is currently no national UK strategy for promoting physical activity behaviours in children (85). It is vital that we identify the most effective school-based interventions to promote to education professionals.

2.7.1 Range of school-based physical activity interventions

There are a range of opportunities to increase PA across the school day, including before- during- and after-school (86). A multitude of potential options for effective school-based PA interventions have hence been explored (251).

2.7.1.1 Active travel interventions

Active travel interventions have sought to increase physically active journeys to and from school (252). For example, the Beat the Street intervention involves uses novel technologies in Near Field Communication and Radio Frequency Identification tags as students 'tap in' at points around their local area as they walk or cycle to school (253). However there is arguably more anecdotal than experimental evidence into effective active school travel interventions at present (251).

2.7.1.2 Recess and lunch break interventions

Interventions within recess (break-time) and lunch breaks have been tested, providing typically simple and cheap interventions requiring minimal resources (254). For example, simply giving children the choice to play on the school field rather than playground alone significantly increased MVPA in a small (n=25) repeated-measures UK study (p=0.001) (255). Higher overall increases were found in girls' field-based PA: showing the potential of such simple interventions on girls' habitually lower PA levels (Section 2.3.3) (255). Active Video Games such as Xbox Kinect have been tested as recess and lunch-time activities, showing largely positive effects on physical activity levels although study quality is often low (256). Also, the provision of loose recyclable materials in the playground has been associated with increased MVPA during recess time (257), with long-lasting effects seen at 8 months from their introduction (258). In a systematic review, 5 out of 9 identified RCT or controlled trial recess interventions demonstrated a positive intervention effect on child PA (254). However, there is large heterogeneity in intervention formats and study designs for recess studies, making it difficult for firm conclusions to be met (259).

2.7.1.3 PE interventions

As surprisingly low levels of PA during PE have been identified (Section 2.3.3.1), interventions have sought to adjust PE to encourage increased activity. For example, one study sought to maximise active PE time by changing game rules in dodgeball, tag and other games: such as enabling eliminated children to still be active (260). Over 50 sessions using this approach, the overall percentage of children spending 50% lesson in MVPA increased in 4 out of 6 games, including up to 53.1% in dodgeball (260). This is an example of how simple and free interventions within existing PA scheduling in schools can drastically increase PA levels.

2.7.1.4 After-school interventions

Additionally, interventions have also attempted to increase after-school PA using extra-curricular clubs and services. Examples include the FITKids intervention: an RCT providing a 2-hour PA intervention programme for 9 months to 8-9 year olds (110). This study was novel in its wide range of assessed intervention effects, finding significantly improved fitness, cognitive function (assessed as inhibition and cognitive flexibility) and brain function (110). However, after-school interventions have had varying effects. For example, the Bristol Girls Dance Project: a 20-week after-school dance programme for Year 7 girls (n=508) found no significant differences in PA between intervention and control participants (261). Additionally despite including tuition from a qualified external dance instructor, only one third of participants attended two thirds or more of the dance sessions (261). This shows the difficulty in maintaining pupils' attendance at after-school programmes and that complex and fairly expensive interventions do not guarantee success in improving PA levels. A recent meta-analysis (k=6) assessing the effects of after-school physical activity interventions found a non-significant, pooled intervention effect at follow-up of +4.84 min/day of MVPA (95% CI -0.94, 10.61)(262). There hence seems a lack of consistent evidence for positive effects of after-school interventions.

2.7.1.5 Lesson time interventions

Other interventions have attempted to increase activity during lesson time. Such interventions seem especially poignant given the typical sedentary nature of modern teaching (59). Increasingly popular is the testing of standing desks: allowing students to adjust between sitting and standing time within the classroom (263). A recent study comparing brief pilot studies in the US, Australia and UK suggested that PA benefits may only be seen in classes that solely feature standing desks (264). Also a recent systematic review of eleven school standing desk interventions found consistent evidence for overall energy expenditure only (in 3/3 studies), with mixed effects on sitting, standing and step-counts (265). It is yet to be seen how these findings translate into real-world implications given the associated costs of the desks (266).

'Active-' or 'Brain-breaks' are other interventions used to integrate activity as breaks from curriculum lessons. These short 5- or 10-minute sessions of activity are intended to provide breaks from academic work and sedentary time to increase attention (267). A popular free-to-use example of active breaks is 'Go Noodle' (268), integrating 5 to 10-minute activity sessions with gamification in points, level-ups and customisable avatars. However, PA does not always improve with such interventions. For example, the 'Bizzy Breaks' intervention provided n=90 Irish students with one 10-minute PA break for five consecutive days (269).

Pedometer-assessed steps were found to be significantly lower in both intervention and control groups at follow-up compared to baseline, although this reduction was significantly less in intervention pupils (269).

Finally, 'Whole School approaches' provide complex interventions uniting elements across a given school setting to increase PA. For example, the 10-month GreatFun2Run intervention in UK 7-11 year olds (n=589) incorporated educational teaching resources, interactive website, 1 mile school run and walk events, a local media campaign and a summer activity planner (270). Compared to four control schools, the four intervention schools demonstrated significantly improved body composition and pedometer- and accelerometer-assessed PA levels during the intervention (all $p<0.05$) (270). Whole-school interventions in countries such as Finland and Poland have also shown positive improvements to pupils' physical activity (271).

Collectively, school-based interventions have generally demonstrated positive effects on health, PA and educational outcomes. A Cochrane review of 44 studies testing the effects of school PA interventions (n=36,593) found them to increase MVPA during school hours (OR 2.74, 95% CI 2.01, 3.75) (245). However it found no evidence for improvements to BMI and noted that all studies featured high to moderate overall risk of bias (245). Another systematic review of 43 studies examining associations between school-based PA and academic performance found 50.5% of reported associations to be positive and 48% to be non-significant (272). This suggests that the addition of PA into the school day does not have a detrimental effect on academic achievement. This has important implications for educational practice, as it suggests that physical activity can be increased during the school day with either a positive effect or at least without a negative effect on important academic outcomes.

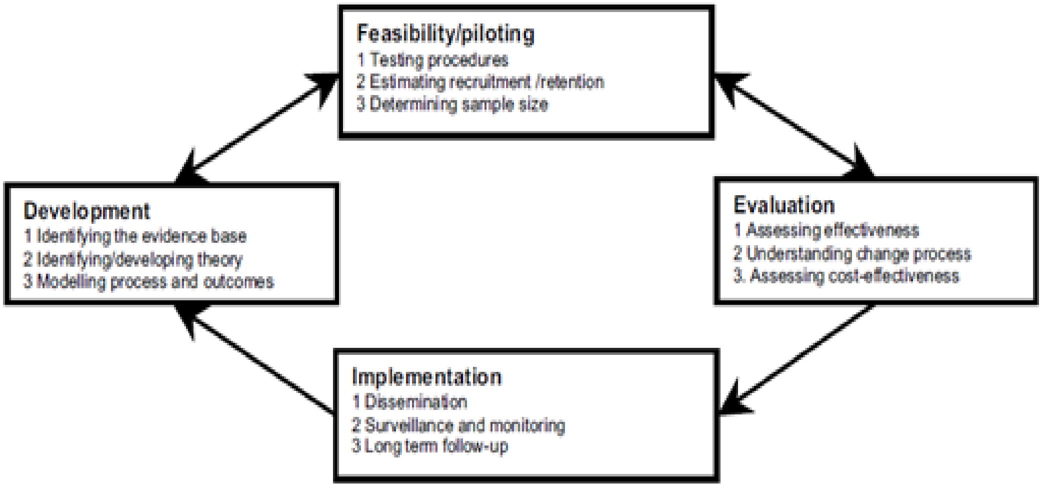
2.7.2 Limitations of school-based physical activity interventions

There is mixed evidence for long-term behaviour change in school-based PA interventions. For example, a review of fourteen studies with a minimum of 6 months follow-up found PA change to be maintained in 10 out of 13 studies with a difference of between 3 and 14 minutes per day (273). However insufficient evidence was found for changes in fitness and fundamental motor skills (FMS: such as throwing, catching, jumping) (273). Another recent meta-analysis of fourteen studies found MVPA (k=12) and TPA (k=10) to be no different from controls or pre-intervention assessments in follow-up of 6 months or longer (274). This lack of effect over a lengthy period demonstrates that continued involvement may be required to sustain intervention improvements.

Various issues are present with this current evidence base. As found with child obesity prevention interventions generally (275), there is large heterogeneity in the study designs used to test school-based interventions (245, 276). The quality of assessment methods also vary greatly, with PA measurement ranging across highly subjective self-report to observational, pedometer and accelerometer measures (245). PA levels are typically only assessed during school-time (101, 276), preventing assessment of wider habitual behaviour. A lack of control groups in some studies (267, 277) and small sample sizes (269) provide findings that may be overly optimistic (276). It is also often difficult or impossible to action blinding in school-based PA interventions due to the obvious nature of any changes (274). This accompanied by a potential mere measurement effect or 'Hawthorne effect' in PA data collection (278), may mean interventions are inherently biased (274).

The processes behind interventions are often unclear in school-based PA studies. According to Medical Research Council (MRC) guidelines (279, 280); interventions should be developed, described and evaluated in a standardised manner to maximise validity and reliability (Figure 2-6). Firstly at the Development stage, school-based PA interventions are often reported to arise from top-down processes, beginning with ideas of the researchers rather than input from pupils and teachers (281). It is essential that service users are involved at all stages of intervention development to maximise its relevance and uptake (69). Studies also typically lack a theoretical basis or a lack of clear understanding of the mechanisms involved in behaviour change (282). Secondly at the Feasibility and Pilot stage, sample size calculations are often not provided (276): giving no idea of the suitability of participant numbers.

Figure 2-6: Key elements of development and evaluation process in health interventions (279)



At the Evaluation stage, analysis often focuses on the effects of outcomes alone (276) without evaluation of processes that may have contributed to differences in these outcomes (283). In child PA interventions, such process evaluation criteria would include how many children attended each intervention session and how many intended sessions were actually implemented by teachers or other staff as intervention providers (284). A review of five meta-analyses of implementation effects in 542 health interventions found stronger effects on outcomes to be associated with greater implementation (285). It also found that negative effects may occur if interventions are implemented differently from the way intended (285). A review of school-based PA interventions found 11 out of 15 studies to report significant positive associations between implementation and health outcomes (284): showing increased intervention implementation to result in greater intervention effect. These findings highlight the important detail that process evaluation can add to intervention assessment. Additionally, costing of interventions is rarely given: making full appraisal of their potential by schools impossible (245). At the final Implementation stage, long-term follow up of 6 months or over is often lacking (274), with little evidence of any interventions being subsequently maintained in real-life settings. For example, a systematic review of seven studies (n=10,099) found evidence for accelerated weight gain on children during summer holidays (286), suggesting potentially limited maintained health gains of school-based interventions.

2.7.3 Facilitators and barriers of school-based physical activity interventions

With any intervention, it is important to assess the facilitators (supporting factors) and barriers (limiting factors) that may have influenced implementation (279). School-based PA interventions have been evaluated using pupil and teacher focus-groups or interviews to explore the full range of these considerations (84, 284). Indeed, a recent systematic review identified 22 categories of factors that influence the implementation of school-based PA interventions (284). At the micro level in school- and classroom-settings, there are various barriers to initiating and maintaining school PA interventions. Time is consistently recorded as the most important barrier (284), with teachers reporting difficulty in integrating PA around pressing academic targets. In the case of active breaks, some teachers have reported 'chaos' and reduced classroom control when attempting to return back to task (287). This contradicts other research finding higher levels of PA leading to increase subsequent on-task behaviour (132). Space restraints in classrooms (287), staff turnover (288), lack of equipment (84) and pupil attitudes of activity as 'uncool' (289) are other important small-scale barriers to consider. Micro-level aspects that have facilitated PA interventions include schools and teachers perceiving PA promotion as their responsibility (288, 289). Teacher motivation to encourage PA (290) and experience of teaching PE (291) also facilitate the implementation of school PA interventions.

At the macro level within the education sector and wider social settings, various barriers have been identified. Most importantly, schools are under multiple pressing demands that make PA integration difficult (222). A focus on exam results, school assessments and league tables have been related to high teacher stress (292): making PA interventions an additional burden (222). Whereas academic standards are formally assessed, PA has not been (84) although this is now changing following recent changes to OFSTED assessments (Section 2.6.2). Accordingly, some educators believe too much accountability is placed on schools to address relatively unmonitored health outcomes, instead of being the responsibility of parents (293). PA promotion may also have a lower priority than other health issues such as diet and hence less likely be addressed given these restrictions (290). A 'compensation culture' arguably present in today's society means that any PA-related accidents in schools may be attributed to staff and expose them to litigation risks (84, 222). Entrenched pupil and teacher experiences of educational time as sedentary make the addition of activity integration difficult (84). Exercise and PA have historically been used as rewards and punishments in schools, rather than as a part of typical practice (289). All of these factors make using the school environment to routinely increase PA challenging. Macro-level factors found to act as facilitators to school PA interventions include support across the school body towards daily activity, in terms of funding and maintained teacher training (290). Such attitudes can affect school's uptake and maximisation of government PA initiatives (Section 2.6) and research interventions (294). This evaluation work shows a range of factors to account for when developing school-based PA interventions. By attempting to minimise barriers and accentuate facilitators, researchers can hope to maximise implementation and give interventions the greatest opportunity to succeed.

2.8 Physically active lessons

Physically active lessons are an emerging type of school-based PA intervention (295). These integrate teacher-led educational content with physical movements to make academic time more active (296). These are distinct from active breaks (Section 2.7.1.5), which feature bursts of activity but are not connected to the curriculum (297). Examples include doing a certain number of movements to practice counting in pre-school children (298) or using movements to act out a story (295). Physically active lesson programmes currently available for schools to purchase include the American 'Take 10!' (295) and the British 'EduMove' (299). Relative to other school PA interventions (Section 2.7), there is minimal research to date on the health and educational effects of physically active lessons.

2.8.1 Movement integration in education: past and present practices

The integration of movement into pedagogy is not necessarily a new idea (69). The American educational reformer John Dewey developed the concept of Experiential learning in the late nineteenth and early twentieth centuries (300). Experiential learning refers to the process of learning through action and experience as opposed to via rote (301). Dewey was the first to advocate the benefits of activity beyond the PE classroom, to benefit children across the curriculum (301). The concept of Experiential Learning has since been elaborated on by other psychologists (302, 303), although its' central premise remains the same. Piaget later adapted these ideas as part of his stages of child development: describing active learning via movement, trial and error as essential during his ‘concrete operational stage’ of 6-12 year olds (304).

In his theory of Multiple Intelligences (MI), Gardner described ‘bodily kinesthetic’ intelligence to represent some individual’s preference for movement and touch in learning (305). The general premise of MIs as representing distinct learning capabilities in individuals has more recently been widely absorbed into teaching consciousness in the form of Learning Styles (306). Similarly under this approach, ‘Kinesthetic’ learners are seen to process information related to movement and touch better than via visual or auditory methods (307). Both models have been widely debated as being too simplistic in their representations of learning and intelligence (306, 308) and supported by anecdotal- rather than research-based evidence (309). Despite their questionable basis, a recent study found 93% of UK teachers (n=137) to believe in the concept of learning styles (308). Hence, there seems to be an embedded perception in modern teaching that pupils respond to- and have preferences for different types of learning. The addition of activity into teaching time may hence be acceptable to teachers who believe in movement integration as appealing to kinaesthetic learning styles.

Another widely publicised programme described as ‘active learning’ that has received a lot of criticism is Brain Gym. Described as ‘educational kinesiology’, this American programme consists of simple, physical movements that developers purport to activate ‘whole-brain learning’ and improve educational outcomes (310). An example movement is ‘Brain Buttons’: resting one hand over your navel and rubbing the hollow area under your collarbone with the thumb and fingers of your other hand vigorously for 30 seconds, whilst looking from left to right (310). A review of publications promoted by Brain Gym as supporting their programme found 64% of ‘papers’ to be published in their own pay-walled Brain Gym Journal (formally called Brain Gym Magazine) only, with no peer reviewing or quality research (311). Arguably, the exaggerated claims made by the company damage the reputation of other movement-based activities which do have ascertained, scientifically-validated positive effects on health and education (308, 312). It is important to acknowledge the existence of companies such as Brain Gym to understand the ways teachers may have previously experienced movement integration in teaching.

Arguably the most well-known example of active pedagogy comes from Montessori schools: first launched in Rome in 1907 (313). These were developed to encourage independent learning at children's own pace, whilst accentuating the connection between movement and learning (313, 314). Around 700 Montessori schools function in the UK today, typically accepting children aged 0-6 years old (315). Recent studies have found less objectively measured SB (316) and greater LPA and MVPA (317) during the school day in Montessori versus traditional preschool teaching, after adjustment for confounders including parental educational level. American-based research found that children studying in Montessori schools in the fifth grade (10-12 years old) achieved significantly higher Maths and Science scores in their high school study compared to typical curriculum schools (318). It must be noted that these studies are cross-sectional and based on relatively small sample sizes. However, these positive findings for health and educational outcomes seem to provide support for the prolonged existence of Montessori education into the twenty-first century.

Forest schools are another smaller-scale example of schools embracing activity in their teaching. These have an ethos for long-term outdoor active learning, particularly focusing on skill-development in woodlands (319). Originally imported from American and Danish teaching, Forest Schools have existed in the UK since 1993 (320). Existing primary schools become Forest Schools by hiring a Level 3 Forest Schools Practitioner (319). Case studies of UK Forest Schools have found they provide important opportunities for children to be active and interact with woodland environments, as well as learning academic and practical skills (320, 321). However, Forest and Montessori schools represent relatively niche teaching practices. This may be due to a shift towards sedentary learning in the 1950s and 60s, where seated rote-based learning become perceived as most effective (322). Given the largely sedentary teaching prominent in the modern classroom (Section 2.4.3), it seems that this closed view seems to permeate today to some extent.

2.8.2 Potential for physically active lessons according to current literature

Previous active break research has recommended the need to maximise educational relevance to increase school-based uptake (323). In multi-component PA interventions, curriculum-based PA is reported to be used most often by teachers (324). These sessions hence seem to be desired by schools. Educational assessment bodies have recently sought to assess physically active lesson effects (325, 326), showing interest beyond academia and into wider educational enquiry. However, the emerging evidence base into physically active lessons has not yet been synthesised. This PhD will explore the potential of physically active lessons to promote health and educational outcomes in primary-school settings.

2.9 Virtual Field Trips

Given this aforementioned interest in physically active lessons, novel programmes that are based on their principles are needed. To help in the development of such programmes, we must be sure to consider using resources already possessed by modern classrooms. This will help lower associated intervention costs and help make sessions as accessible as possible. As seen in all modern settings (Section 2.5.1), technology is a key feature of both classrooms and teaching practice. Accordingly in the context of health, the global Sedentary Behaviour and Obesity Expert Working Group (327) recommend using technology to reverse the sedentary behaviour, arguably prompted by technology itself. Technology has already been used to reduce sedentary time in children in other ways, such as Active Video Games (328) including the use of Nintendo Wii and Microsoft Xbox Kinect within school time (256). Smartphone apps designed to promote and monitor physical activities on-the-go have also been developed to reduce sedentary time (329). A key example is the recent launch of the widely popular Pokemon Go mobile app, where users need to move and explore outside environments to capture, grow and train Pokemon creatures (330). Early research has compared step data from American Microsoft Band activity monitor users thirty days before and after their initial use of Pokemon Go (331), also comparing the activity of adult Pokemon Go players (n=792) with non-players (n=26,334) (332). The study found regular, engaged users of the app to increase their activity by 1,473 steps a day on average, representing a 25% increase in their prior activity levels. Increases in activity were seen across different user demographics, with authors estimating Pokemon Go to have added 144 billion steps to US physical activity after its initial launch (332). Further research in children and adults is imminent but Pokemon Go as a technological intervention has undoubtedly captured mass public interest in walking and exploring environments (333). As such, there seems to be potential to utilise existing classroom technologies such as interactive whiteboards to provide physically active lessons.

2.9.1 Interactive whiteboards

Interactive whiteboards (IWBs) are now a pervasive feature in modern school classrooms and teaching. In the UK, this is partly due to government investment such as the Department for Children, Schools and Families (DCSF) 'Schools Whiteboard Expansion' project in 2003/4, investing £10 million for IWBs to be installed in 21 Local Authorities (334, 335). Most recent published figures show that over 70% of UK school classrooms contain IWBs (336), however figures have likely increased since this time. IWBs allow information to be presented in a range of interactive audio and visual formats: maximising appeal to students (337, 338). Their multi-modal functionality can support the needs of learners who find text difficult and can support the visualisation of difficult taught concepts (334, 337). They also act as a 'digital hub': allowing peripheral technology such as webcams to be integrated into teaching (337).

Evaluative research has explored the use and associate effects of IWBs on teaching. In a sample of teachers receiving IWBs in the Schools Whiteboard Expansion project (n=113); 78% reported creating their own IWB resources and 64% reported using ready-made internet resources (335). Teachers mostly described using their IWB as a data projector, a surface for dynamic touch-based teaching or to enhance the size or clarity of presenting information to their class (334). Issues with IWBs as a new classroom technology were also explored. 62% of teachers reported IWB sessions to take longer to prepare and 34% reported difficulty in finding support if the technology failed (334). Additionally, internet firewalls in schools designed to filter internet content for pupils' safety can often also restrict the content that teachers can include in IWB sessions (339). Despite these perceived difficulties, noticeable improvements in academic progress have been found following the introduction of IWBs. In primary schools participating in the Schools Whiteboard Expansion project, increased progress of up to 7.5 months was found in Key Stage 2 (KS2) Science for the lowest achieving boys. Additionally, increased progress of five months for boys and 2.5 months for girls was found in KS2 Maths, with interestingly no effect seen in KS2 English (334). Although evidence has shown the benefits of IWBs on academic attainment, existing physically active lesson research has not yet utilised this available equipment. Development of interactive whiteboard sessions to encourage pupil activity could help unlock further potential in these largely under-utilised resources. They would also allow schools to address OFSTED-assessed personal development and health skills (77).

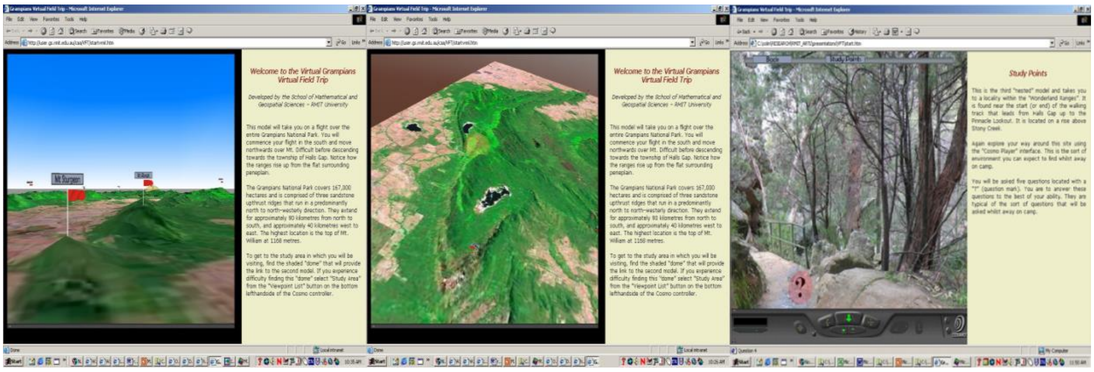
2.9.2 Background to VFTs in tertiary education

Virtual Field Trips (VFTs) may hold untapped potential as a physically active lesson format. With development starting in the late 1990's using desktop computers (340), VFTs allow individuals or classes to explore virtual scenes from around the world (341, 342). With an inherent geographical basis, these developed environments allow pupils to interact with virtual maps, landmarks and objects supplemented with educational multimedia (343, 344).

VFTs were first developed as a means of experiential learning for geography university students (302, 340, 344). By providing students with an interactive experience, it was hypothesised that VFTs would enable more 'hands-on' geographical learning in a style closer to laboratory or fieldwork, as opposed to typical 'lecture-hall' teaching (344-346). VFTs were also hypothesised to reduce risk assessment paperwork and the financial costs to students associated with fieldwork: often perpetuating socioeconomic status (SES) inequalities (346). Computer-based VFTs were hence designed to enable students to explore and interact with locations of geographical interest (344, 347). Locations chosen for VFT development were often physically unreachable due to time and monetary constraints, or due to temporal constraints in the case of history and archaeology topics (343, 345, 346). Alternatively, some locations were due to be visited in fieldwork shortly after the VFT. The computer-based VFT hence served as a tool to prepare students and improve efficiency of fieldwork (344, 346). Such preparation with VFTs intended to reduce the 'novelty space' of the fieldwork situation: the loss of educational value from the high cognitive load of a novel environment (348, 349).

To date, VFT research has largely examined potential use in universities (344, 345, 347), with studies published in environmental education or educational computing journals. An example of such a VFT includes Arrowsmith's geographical tour of the Grampians National Park in Western Victoria, Australia (344) (Figure 2-7). This VFT was developed as a preparatory tool for students before fieldwork, with 3D mapping developed using GPS data collected from a previous student cohort. The session consisted of 'nested' virtual environment models at three different levels: an introductory level of the entire park, a specific area of the park where most of their fieldwork would be undertaken and a final level provided site-specific details of smaller areas of interest. Flags were positioned throughout the model to indicate places of interest, with a fly-through guided tour of the park integrated to provide a general overview of flagged areas. Digital landscape panoramas were added to the site-specific models, with lecturer information and formative questions added using HTML hotlinks (344).

Figure 2-7: Screenshots of Arrowsmith VFT with first-, second- and third levels of park views (left to right) (344)



Arrowsmith's study focuses primarily on the development of the session rather than its evaluation (344). By providing statements for seventeen students to rate on a 5-point Likert scale, authors found positive perceptions of the VFT. However as found in other research (342, 350), students stressed that VFTs should not be used to replace physical fieldwork. This lack of evaluation is typical in the VFT literature, with little (343) or no assessment (347) of session effects on academic outcomes or student enjoyment.

2.9.2.1 Use of VFTs in schools

Academic interest in VFTs for use in schools has been sparse. A brief introduction to this potential was provided by Beal & Mason (350). They hypothesised that VFTs could be used to reduce the administration and red tape associated with physical field trips, as well as utilising expensive school technology. They also described potential developmental benefits in encouraging younger pupils to be less egocentric, in learning about other people and places (350). However this discussion piece was published in a small-scale educational journal 'Meridian' from NC State University and seems to have gained minimal attention.

Existing examples of VFTs in school settings are hugely limited. They also differ in format from those used in tertiary education: moving away from the geographical basis previously described. In secondary-school children, VFTs in research have been used as a form of science communication and careers advice. For example, the 'zipTrips' intervention virtually connected middle school classrooms to university scientists via webcams (351, 352). These live 45-minute interactive programmes contained in-studio audience sessions with other student cohorts, live webcam interaction with scientists, pre-recorded segments and integrated activities. Research into these sessions was run in sixth to eighth grade (ages 11-13) middle school pupils in rural Indiana USA, with ZipTrips™ focusing on biology careers and scientists. Supplemental online resources provided additional short videos from scientists of all career levels, discussing their career paths and research (351, 352).

Primary school VFTs have been as under-developed and researched as secondary school VFTs. To the author's knowledge, only three studies have tested varying forms of VFTs in primary-school children. Firstly, the 'E-Junior' programme was a developed, gaming underwater programme described as a 'Serious Virtual World' (353). As with zipTrips (352), this VFT is very different to those developed for university students. Based around the Spanish curriculum, it was developed to introduce sixth grade (ages 10-11) children to natural science and ecology by exploring the Mediterranean Sea. The programme was linked with up to four navigational impact paddles, allowing students to navigate their chosen fish avatars through the virtual sea. Another study compared effects of both Real and Virtual Field Trips in 9-11 year old children (354). On individual PCs, n=12 students completed exploration of a virtual trail and the actual trail in a counter-balanced design. No significant differences were found in enjoyment by pupils in either trip (354). An additional primary-school study was described as a VFT intervention but actually featured technology-free 'read-aloud' sessions of story books (355).

Apart from research-based use, an exploration into current UK teaching practices in online forums found a limited range of VFT tools and resources to be used (356). The most popular seems to be Google Earth (357, 358): a virtual globe-based programme with 3D maps and labelled points of interest (359). Some online tools described in these forums enable exploration of museums and artefacts, such as the National Gallery (360) and Google Art Project (361). Other resources enable guided exploration through the internet via themed pre-screened web links. However, these are primarily designed for American (362) or New

Zealand (363) curriculum and audiences. This anecdotal and research formats and uses of VFTs are clearly varied, with a need for consistency in VFT definitions.

2.9.3 Evaluation of VFTs

Across all age-groups, evaluation of VFTs is extremely limited. The research evaluation that does exist has been largely positive. Studies have found increased student engagement and enjoyment during VFT sessions (343, 352, 353). Understanding of program content has been found to significantly increase (343, 352) or be equal to typical teaching (353). However, examination of understanding and attainment has been simple. In some studies, VFTs have been criticised by students and developers themselves as being too complicated and time-consuming to warrant common use (343, 345). Limitations with teacher computer literacy may also prevent VFTs from being used or developed (342). However, it must be noted that the use of readily-available VFT sessions using online resources have not been studied experimentally. It is clear that this disorganised and limited research base currently provides too crude information on VFT effects. As identified in online teaching forums, VFTs in various forms are being used in typical teaching. However, research has not yet developed or evaluated these in a systematic way.

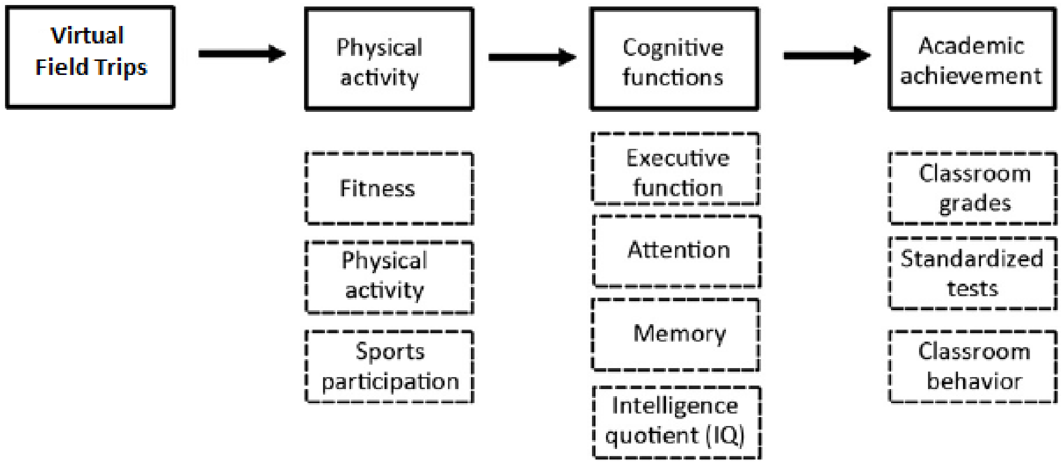
2.10 Discussion

This literature review has identified various key concerns to be addressed in this PhD. First and foremost, current physical activity and sedentary behaviour levels are markedly low and well below recommended guideline levels. This is despite various UK government policy initiatives attempting to increase activity in school contexts. Secondly, this inactivity has huge implications for population health, wellbeing and cognition. However, attempts have been made to address this severe issue from governmental bodies and school-based interventions. In this review, effective strategies as well as barriers and facilitators of this work have been identified. This has allowed identification of physically active lessons as potentially effective PA interventions in school contexts. In considering the context of modern teaching, the novel use of interactive whiteboards to facilitate physically active lesson activity has been proposed. Finally and taking all aforementioned research into account, it was suggested that Virtual Field Trips may be effective physically active lessons utilising classroom interactive whiteboard technology.

There seems scope to extend the limited use of VFTs in school use for a number of reasons. Firstly, given the aforementioned ubiquity of interactive whiteboards (IWBs), they seem a prime candidate for VFT provision. Secondly, the broad range of topics covered in the National Curriculum (364) provides a wide range of opportunities for VFTs to be integrated. Thirdly, the recent popular movement in children's gaming technology towards Active Video Games such as Nintendo Wii and the Microsoft Xbox Kinect (328) shows an interest in physically active technology from today's children. AVGs have also been implemented in schools as activity and educational interventions (256).

Finally and as a key precedent to this research, VFTs have untapped potential to integrate physically active learning. VFTs have previously been entirely sedentary (344, 345, 347, 365), however given the inherently explorative and geographical nature of VFTs they seem prime candidates as physically active lessons for school-aged children. Children could stand throughout and 'walk', 'run' or 'fly' through virtual scenes embedded with educational elements. These would not aim to be an alternative to actual, physical class trips (342, 350) but would instead provide a new teaching tool allowing activity whilst remaining in the classroom. No research has yet assessed the potential of school-based VFTs to increase children's physical activity. Under Howie & Pate's aforementioned model of physical activity's myriad associated effects (123) (Figure 2-3), VFTs as a PA intervention may also be associated with changes to cognitive and educational outcomes (Figure 2-8). There is a need for rigorous study in primary teaching environments to assess if VFTs can be used to reduce SB and instigate PA without being detrimental to other cognitive and educational outcomes.

Figure 2-8: Potential impact of physically active VFTs impact on health and educational outcomes; extension of Howie & Pate, 2012



This PhD will assess the potential of VFTs as physically active lessons in various ways. A synthesis of literature on physically active lessons is firstly performed with a systematic review in Chapter 4. This will identify current techniques used to integrate activity into classroom teaching, the quality of this research and facilitators and barriers of their use. From this, a VFT physically active lesson intervention will be piloted (Chapter 5) and any resulting revisions made. A full-version intervention will then be developed and delivered (Chapter 6), with the remainder of the PhD analysing physical activity (Chapter 7) and educational outcome data (Chapter 8) as well as implementation findings (Chapter 9). A discussion will then outline implications of the results for research, practice and policy, whilst critiquing the methods used (Chapter 10).

Chapter 3 Thesis aims and objectives

3.1 Identified gaps in the literature

The literature review on physical activity levels and interventions in children (Chapter 2) has identified a clear need for effective methods of increasing children's physical activity and reducing sedentary time. School-based interventions were identified as holding great potential to capture a captive, mass child audience over repeated exposures (Section 2.7). The review identified various gaps in related literature that will be addressed during this PhD.

3.1.1 Extent and quality of physically active lesson research

There remains an unclear evidence base for physically active lessons (Section 2.8). As they integrate physical activity within curriculum content, physically active lessons are fundamentally designed to address activity and educational outcomes. It is yet unclear what physically active lesson interventions have been tested and how, what their effects are and what the quality of this research is. This PhD will start by synthesising the evidence base for physically active lessons. This will allow improved interventions to be developed and give support for their use as part of typical pedagogy.

3.1.2 Untapped potential of school technology to facilitate physical activity

Technology such as interactive whiteboards, are now ubiquitous within school teaching provision. Although evidence has strongly supported the use of interactive whiteboards to improve academic attainment (Section 2.9.1), their potential to integrate physical activity into lesson time has not yet been explored. This PhD will test the feasibility of a developed interactive whiteboard intervention for improving physical activity and educational outcomes in primary-school children.

3.1.3 Virtual Field Trips within primary schools

Virtual Field Trips (VFTs) in various guises have been integrated within higher education, particularly within humanities teaching (Section 2.9). Although potential for VFTs has been indicated within primary school teaching (Section 2.9.2.1), they have not yet been researched within this context. The wide availability of interactive whiteboards within today's classrooms and free, readily-available tools to develop VFT sessions such as Google Earth, make VFTs rife for exploration as a primary school teaching tool.

3.1.4 Effects of physically active VFTs

Existing VFT publications have focused on the development of sessions from a predominantly Computer Science perspective, rather than evaluating their effects on specific outcomes (Section 2.9.3). To truly assess VFTs as educational tools, research is needed that develops and tests VFTs following a bottom-up, iterative process. Additionally, developed Virtual Field Trips (VFTs) have to date been developed as sedentary, exploratory teaching schools for university students (Section 2.9.2). VFTs have not yet been explored as physically active lessons, with potential for movement to be integrated within simulated travel movements between locations and to answer curriculum content questions. The effects of a developed physically active VFT programme is needed to assess their efficacy for population-level teaching.

3.2 Aims and objectives

To address these gaps in the research literature identified, this thesis addressed the following research aims:

1) Review the extent and quality of current physically active lesson research
2) Explore whether Virtual Field Trips are feasible within primary school classrooms as physically active lessons for children
3) Evaluate the effects of physically active Virtual Field Trips on children's physical activity
4) Evaluate the effects of physically active Virtual Field Trips on children's sedentary time
5) Evaluate the effects of physically active Virtual Field Trips on children's on-task behaviour
6) Evaluate the effects of physically active Virtual Field Trips on student engagement
7) Evaluate the processes underlying a developed physically active Virtual Field Trip intervention

3.3 Research questions and hypotheses

This PhD work also sought to address the following research questions:

1) What research currently exists to test physically active lessons?

2) Are physically active Virtual Field Trips feasible in classroom teaching?
3) Can Virtual Field Trips increase physical activity?
4) Can Virtual Field Trips reduce sedentary time?
5) Can Virtual Field Trips introduce physical activity without compromising on-task behaviour?
6) Can Virtual Field Trips improve student engagement?
7) To what extent will a physically active Virtual Field Trips intervention be implemented in primary-school teaching?

At the outset of this PhD, there was limited evidence on the effects of physically active lessons on children's health and educational outcomes. Accordingly, only two tentative hypotheses were set for this PhD, applied given the larger body of school physical activity intervention research (Section 2.7):

1) Physically active Virtual Field Trips will increase children's physical activity
2) Physically active Virtual Field Trips will not compromise on-task behaviour

Chapter 4 Physically Active Lessons Systematic review

The original review was published in Preventive Medicine (3) (Appendix 4A). To date it has been cited in over fifteen published papers, as well as in a recent briefing on school physical activity by Public Health England (234).This chapter presents the findings from an updated search performed in April 2016, excluding work published from a Masters project preceding this thesis (2).

4.1 Introduction

Reviewing the wider literature of school-based physical activity interventions (Section 2.7) identified physically active lessons as an emerging area of research interest. Studies were set in different school environments, utilised a range of developed interventions and assessed various outcomes. However, a review of the effects of these programmes on physical activity, health and educational outcomes had yet to be published. Additionally, no quality assessment of published studies existed.

Following the 'Development' stage of the Medical Research Council intervention guidelines (279), an in-depth exploration of the existing physically active lesson literature was required. This would allow collation of the specific evidence base, identify any theoretical basis used in this literature and ascertain outcomes to assess in future VFT work. This chapter presents a synthesis of physically active lesson research in a systematic review, to allow full assessment of the methods and results of existing studies. Strengths and weaknesses of identified papers could then be assessed to provide recommendations to account for where possible in VFT research. This systematic review will hence address thesis Aim 1 and Question 1 (Chapter 3).

4.2 Research questions

This systematic review sought to answer the following research questions:

i) What methods do physically active lesson interventions use?

ii) What effects do these interventions have on physical activity, health and educational outcomes?

iii) What is the quality of physically active lesson intervention studies?

4.3 Objectives

The objectives of this systematic review were to:

i) Assess the current methods used to assess a) physical activity, b) health, c) educational outcomes in physically active lesson interventions

ii) Understand the analysis techniques used to assess effects of physically active lessons

iii) Assess observed effects of physically active lessons on a) physical activity and b) educational outcomes

iv) Explore the study quality and risk of bias in these identified interventions.

4.4 Methods

4.4.1 Search strategy & information sources

A systematic search for original research articles was conducted using ERIC, PubMed, PsycINFO and Web of Science electronic databases. This was originally done in March to April 2014 (3) and re-done to provide an update of the literature in April 2016. Abstracts and titles were searched with three separate search strings representing: 1) physical activity, 2) class or lesson and 3) children. Examples from all databases are given in Appendix 4B). In a change to the first iteration of this systematic review (3), 'movement' was added as a term within the physical activity search string, to reflect papers describing physically active lessons as 'movement integration' (69) (Section 2.8.1). Reference lists of identified papers were searched. Grey literature from the websites of two UK (Play England & Institute of Education, University of London) and two US organisations (Active Living Research & Active Academics) involved in child physical activity research were also searched. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed (366).

4.4.2 Inclusion and exclusion criteria

Randomised and non-randomised intervention studies were sought that evaluated the effects of implemented physically active lessons on health, physical activity and/or educational outcomes. The following inclusion and exclusion criteria were applied:

1) Physically active lessons: classroom-based sessions containing both physical activity and educational elements were included. Studies based in labs or testing physical education, physical activity breaks without educational content, after-school or recess-interventions were excluded.

2) Complex interventions: physically active lessons as part of complex (multi-component) interventions were excluded to isolate the effects of these lessons alone.

3) Study design: intervention studies that featured a control group or a pre-post assessment of the same participants were included. Reviews and protocol studies providing no intervention results were excluded.

4) Sample: child and adolescent samples were included regardless of age. Studies solely investigating special populations (such as disabled or obese children) were excluded as such conditions may have impacted physical activity and educational outcomes differently.

5) Outcomes: studies testing any physical activity, health or educational outcomes were included. Studies reporting process evaluation outcomes only were excluded.

6) English language papers were included.

Papers in press were included. Authors were contacted for full-text papers when related conference proceeding titles or abstracts were found.

4.4.3 Data extraction

Data extraction and assessment took place between March and April 2016. Paper characteristics including study design, sample characteristics and findings were extracted into a developed Excel spreadsheet. Reported results were assessed in terms of their statistical association ($p<0.05$) of physically active lessons and physical activity or educational outcomes. Effect sizes were reported where provided in each study. If effect sizes were not provided, Cohen's *d* was calculated with the means and SD of study intervention and control groups, using the formula *d*= (intervention group mean – control group mean) / (pooled SD) (367, 368). Due to the large heterogeneity of outcomes measured and the relatively high risk of bias in identified studies, this review does not feature a meta-analysis (369).

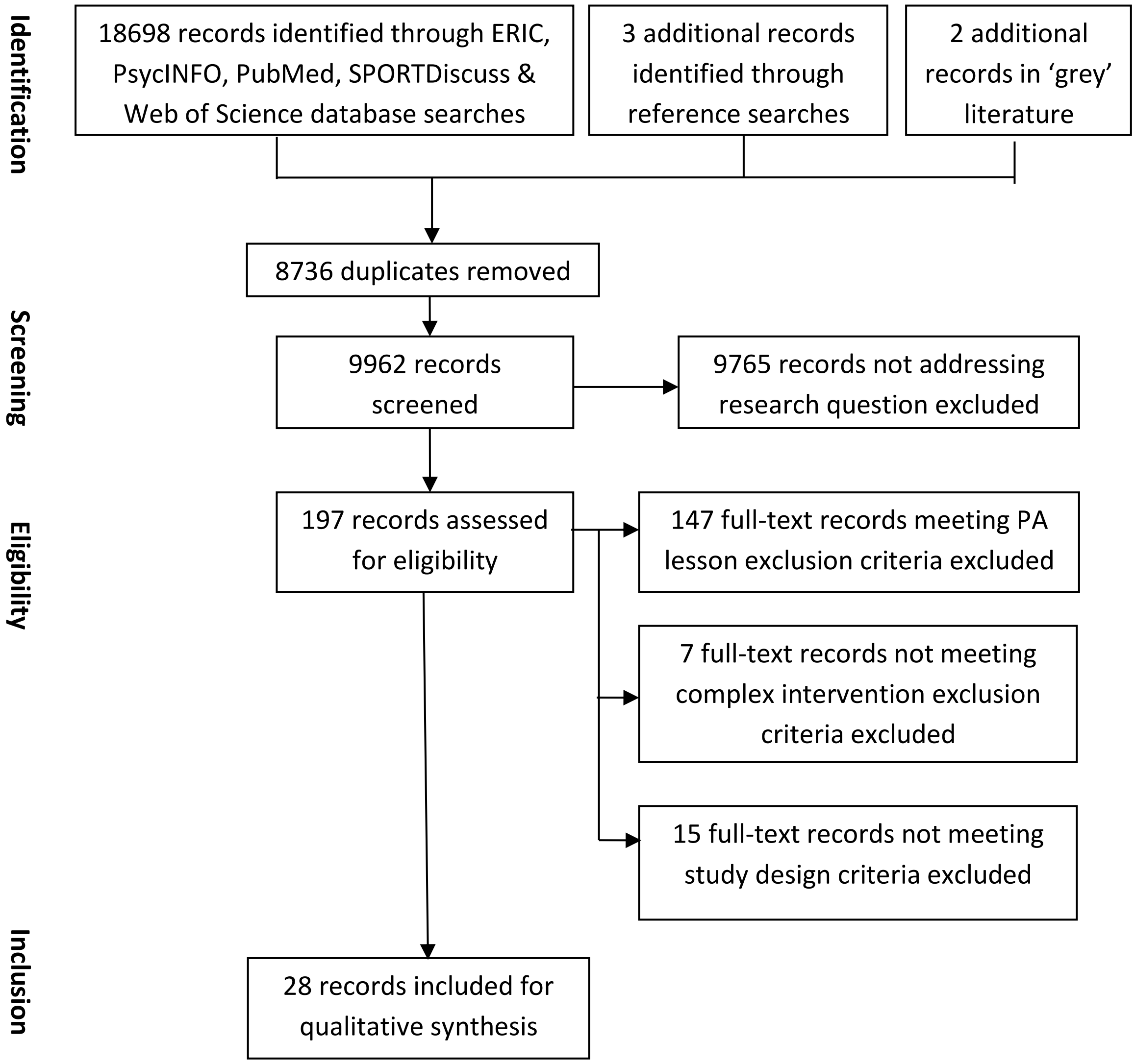
4.4.4 Methodological quality and risk of bias assessment

It is commonplace in health-related systematic reviews to evaluate risk of bias and study quality in included studies. "The Quality Assessment tool for Quantitative Studies" (370) (hereby called EPHPP after developers the Effective Public Health Practice Project) was selected for this purpose in this review. It is recommended by the Cochrane Library as developers of high-quality healthcare reviews in their systematic review handbook (369). It has also been found to have excellent inter-rater agreement for overall assessments (371). The EPHPP features a six-component rating scale for interventions and assesses selection bias, study design, assessment of confounders (e.g sex), data collection methods (reliability and validity) and reporting of blinding, withdrawals and dropouts. Strong, moderate, or weak scores were awarded in each category. An overall rating was then applied for each study, with a "strong" rating representing no weak ratings overall, a "moderate" rating representing one weak rating, and a "weak" rating representing two or more weak ratings.

4.5 Results

In total, 18698 citations were identified from electronic database records, 3 from reference searches and 2 from grey literature (Figure 4-1). Twenty-eight records met all inclusion criteria in this updated systematic review. This is as opposed to the eleven records identified in the original iteration in Spring 2014 (3), showing the increase in physically active lesson research publication in the last two years. Fifteen of the twenty-eight records were run in the USA, 4 in the Netherlands, 3 in Australia, 2 in Greece, 1 in the UK, 1 in China, 1 in Ireland and 1 in New Zealand. Eight studies were described as either feasibility (298, 325, 372, 373) or pilot studies (374-377). The twenty-eight records were from twenty-

Figure 4-1: Record flow of systematic review



two study cohorts, with (277, 378), (379-382), (129, 383) and (384, 385) featuring the same study participants.

4.5.1 Study design

Eighteen studies used a controlled trial design (298, 325, 373, 375, 377, 379, 381-382). Of these, fourteen cluster-randomised individual classes to either intervention (physically active lessons) or control groups (132, 298, 325, 373, 377, 379, 382-386, 390-392). Seven studies used a pre/post-test design, where all participants undertook a baseline, intervention and post-intervention period (129, 277, 372, 374, 376, 378, 380). Two studies used quasi-experimental designs (393, 394) and one used an alternating treatments design (395).

Two out of the twenty-eight studies assessed a physically active lesson intervention group alongside other intervention groups (393, 394). Thirteen studies assessed outcomes on multiple occasions during their respective intervention periods (298, 376-379, 382-385, 391-393, 395). Four studies included an extended post-intervention follow-up period (373, 376, 389, 394) of between 6 weeks (394) and 3-months (389). A summary of all included studies is provided across Table 4-1 (studies assessing physical activity and health outcomes only), Table 4-2 (studies assessing educational outcomes only) and Table 4-3 (studies assessing physical activity or health and educational outcomes.

4.5.2 Sample sizes and demographics

Study sizes ranged from n=21 (375) to n=988 (373). A total of n=6,457 were tested across all twenty-eight included studies. Of these, n=4,168 were tested for health and physical activity outcomes, including BMI (n=1,207) and fitness (n=499). Educational outcomes were tested in n=3,787, including academic achievement (n=2,287), on-task behaviour (n=769), intelligence (n=615), executive functions (n=499), session knowledge recall (n=199) and language skills (n=126).

Twenty-two studies were performed in primary schools (n=5,981), five were run in pre-schools (298, 384, 385, 393, 394) (n=346) and one in secondary schools (386) (n=130). Participant ages ranged from 3 (298, 384, 385, 394) to 14 years (386). In the twenty studies that reported participants' sex, percentages ranged from 29.25% males (389) to 59.1% males (377). Only eight studies reported participants' ethnicity. Two studies reported 100% African

American samples (384, 385), whereas all others featured over 50% White samples (129, 277, 378, 383, 386) of up to 92% (390). Participant's baseline BMI status was reported in five studies (129, 373, 383, 387, 390).

4.5.3 Intervention structure

Most intervention periods ran from between 1 school week to 3 months (132, 277, 298, 372, 374, 376-377, 378, 386, 390, 392, 393-395). Two studies only featured a one-off lesson (129, 375), with others extending to 1- (387, 389), 2- (379, 382) or 3-academic years (383). Two studies did not report the length of their interventions (373, 389). Most physically active lessons were described to last for 10 minutes (277, 298, 325, 373-376, 378, 383, 386-389), others lasting up to 30 minutes (379, 380-382, 385, 390) and five studies reporting sessions to last up to an hour (377, 392, 393, 395).

4.5.4 Intervention content

Age-appropriate content in Maths, literacy and Social Sciences was used in most studies, with two studies assessing foreign language sessions (393, 394). One study featured virtual walks as the basis for physical activity and educational content (372), using a geographical basis similar to those proposed in VFTs. Accompanying additional equipment were used in some studies, including Microsoft PowerPoint presentations (379, 380-382), an instructional CD (373), activity cards (389, 391), notebooks (383), tracking posters and stickers (387) and developed 'Jump In!' mats with 2x2 ft squares for pupils to jump on corresponding correct answers (375).

Twenty-three studies developed their own intervention, including 'Fit en Vaardig op school' (Fit and academically proficient at school), a programme of 20-30 minute sessions featuring 10-15 minutes of Maths and 10-15 minutes of language content (379, 380-382), Active Classrooms (374), Encouraging Activity to Stimulate Young Minds (EASY Minds) (377, 392), Children's Hospital at Montefiore Joining Academics and Movement (CHAM JAM) (373) and Physical Activity Across the Curriculum (PAAC) (383). Five studies used existing physically active lesson programmes, namely Take 10! (277, 378), Energizers (132, 386) and Texas ICAN (129). Only five studies reported involving teachers in their intervention development (375-377, 384, 385).

Eighteen studies provided detailed examples of intervention activities to allow replication (298, 325, 372, 375, 378, 379, 382, 384, 386, 389, 391-395), with two of these providing full lesson plans (325, 374). One study charged participating intervention schools $180 to participate (389), another rewarded pupils with a free sports centre pass and teachers with unspecified payment (376) and one held a lottery prize of a year's gym membership to participating teachers (391).

Only two studies featured theoretical justifications for their choice of outcomes. One study (395) used Self-Determination Theory (396) to assess changes in intrinsic motivation (doing something for its enjoyment rather than for external pressures) with physically active teaching. Another study (374) used the COM-B (Capability, Motivation, Opportunity – Behaviour) model of behaviour change (282) to inform process evaluation measures in teachers and pupils (more about this model can be found in Section 5.4.1.1). Two studies only briefly discussed theory in passing. One (376) mentioned the Social Ecological Model (397) (as described in Section 2.5.4) as describing the importance of physical and social environments on individual behaviour. Another study (386) vaguely suggests physically active lessons as applicable to 'Brain-based learning theory' (398): which promotes teaching strategies that support brain functioning.

4.5.5 Teacher training

Physically active lesson interventions were delivered by experimenters in four studies (392, 393-395) and by teachers to their own classes in twenty-four studies. Of these teacher-delivered interventions, only two studies did not describe teacher training as provided (373, 387). Length of teacher training ranged from 30 minutes (374) to one full day (129, 376-377, 379, 380-382).

4.5.6 Process evaluation

Process evaluation was reported in sixteen out of twenty-eight studies, using a variety of methods. Teacher self-report intervention implementation logs were mostly commonly used (277, 298, 373, 374, 376-377, 378, 381, 383, 386, 389, 391). Teachers were typically asked to report on which sessions were delivered, when and how long sessions lasted, with some also asking teachers to note how many pupils were present and to provide simple session ratings and potential improvements. Implementation rates recorded from teacher logs ranged from 55% (389) to 95% (385). Other studies asked participants to evaluate physically active lesson interventions, using teacher- (374, 383-385, 392), headteacher- (383) and pupil questionnaires (377). One study used a write-and-draw technique (374), using pupil's drawn interpretations of physically active lessons to inform subsequent focus group conversations. Teacher interviews (325, 373), teacher focus groups (383) and pupil focus groups were also used (325, 374).

Ten studies also used observations of intervention sessions to assess the success of sessions (325, 373, 377, 378, 381, 383-386, 391). Three studies reported that teachers observed to be more active than other teachers during physically active lessons also had pupils who were more active (383-385). One study used a framework for their process evaluation methods (373), aligning their evaluation according to the RE-AIM framework against Reach, Efficacy, Adoption, Implementation and Maintenance criteria (399) (See Section 5.4.6 for more details on the RE-AIM framework).

4.5.7 Use of sub-groups for outcome measurement

Seven studies featured sub-groups to analyse some outcomes, with four of these doing so for physical activity monitors (277, 374, 376, 383, 387) one for heart rate monitors (380), one for academic achievement measures (383) and one for on-task behaviour (132) (Tables 4-1; 4-2; 4-3). Random selection of sub-group participants was only described in two studies (132, 374), with two studies reporting biased selection by class teachers (376, 387). Only one study analysed baseline variances between sub- and total-groups, finding no significant differences (383).

4.5.8 Analysis used in identified studies

It was important to understand the analysis techniques used in existing physically active lesson research. This was to assess the quality of study analysis in the area and provide examples of in-depth analysis to replicate in subsequent VFT intervention work.

4.5.8.1 Sample size calculations

Sample size calculations are important for intervention studies to determine the number of participants needed to detect a treatment effect. *A priori* sample size calculations are key to ensure that samples are not too small to prevent any existing effects from being identified, or too large and wasting time and resources (400). Sample size calculations were evident in only seven out of twenty-eight identified studies (325, 373, 377, 379, 382, 383, 386). Studies that did not perform such calculations tended to have smaller samples, shorter intervention lengths, less complex analysis and be pilot or feasibility studies. GPower (401) and Optimal Design (402) software programmes were described as used in two studies (325, 386). All but one study based their sample size calculations on a minimum power size of 80%, except one (325) which only used 45% power. As effect sizes are unclear in this relatively novel research area, two studies from the same authors (379, 382) used an effect size of 0.44 in their calculations gained from personal communication from a previous study (383). Another study (377) based their calculations on observed SD changes in accelerometer counts per minute from their pilot study (392).

4.5.8.2 Analysis used

Most of the twenty-eight identified studies analysed their data statistically, with one study only examining descriptive data (374). The majority of studies used relatively simple analysis in the form of *t*-tests and repeated measures or mixed model ANOVAs with little assessment or adjustment of potential confounders such as sex (See Section 4.5.12 on risk of bias). Some studies with more complex, longitudinal designs used linear mixed model analysis to assess changes over time, adjusting for confounders (377, 383, 392). However, in most studies of larger sample sizes and increasing complexity, statistics were used that accounted for the hierarchical structure of school-based interventions. Some health research settings typically do not allow individual-level randomisation to conditions. For example in schools, interventions will usually be delivered simultaneously to class or year-groups for ethical and practical reasons (403).

These simple analysis techniques can be problematic as they do not account for potential clustering of outcome results by logistical or hierarchical groups such as school class-groups (404). Individuals belonging to the same cluster will likely be of similar demographics and backgrounds, as well as elicit similar levels of outcome change and intervention compliance (405). For example in school contexts, the degree of teacher engagement with a given intervention may elicit different degrees of outcome change in pupils in a given class (404).

Multilevel modelling (MLM) is a popular statistical approach to address this problem. In school-based interventions, MLM allows combined analysis of both individual (pupil) and group-level effects (class and/or school), giving a more accurate representation of data variability sources (406). This simultaneous analysis of different levels of social hierarchy provides fuller interpretation of socially patterned data (407). Many school-based public health interventions in the wider literature have used MLM to give more realistic interpretations of intervention effects (257, 408, 409).

MLM was used to analyse data in five identified physically active lesson studies (373, 379, 380, 382, 391). All studies described first performing preliminary descriptive statistics and simple t-tests to compare intervention group effects of each outcome and time-point using SPSS (410) or STATA (411). They then described MLM analysis to be performed using STATA or specialised software such as MLwiN (412). Studies arranged their data for MLM according to hierarchical levels of school (level 3), individual child (level 2) and measurement period (level 1) (379, 380, 382). Studies generally described steps of analyses very clearly, except for one that described MLM as used but provided no evidence of this in their presented results (373). One study used a different technique of intention-to-treat analysis with a clustered sandwich estimator to account for the hierarchical data structure (325). This method is better suited to assessing clustered data with higher levels of attrition (413).

4.5.9 Physical activity outcomes

Physical activity differences with physically active lesson provision were assessed in eighteen of the twenty-eight identified studies (Tables 4-1; 4-3). One study (390) assessed activity in intervention group participants only and so these findings are not included in this section. Seven studies assessed PA only (277, 298, 372-374, 376, 389), ten assessed PA alongside educational outcomes (129, 132, 377, 379-380, 383-385, 392, 394) and one assessed PA alongside health outcomes (387).

4.5.9.1 Physical activity outcome measurement

As discussed in Section 2.3.2, various measurement tools exist to assess physical activity. Most studies assessed physical activity outcomes via direct measures. Five studies assessed PA with pedometers only (129, 132, 372, 373, 389), providing step-count measurements. Five studies used accelerometers only (374, 377, 383, 392, 394), providing time-specific data on activity intensity. Two studies used physical activity observations only (384, 385), namely the well-validated System for Observing Fitness Instruction Time (SO-FIT) tool (414). Three pupils in each class were randomly selected to be observed using momentary time sampling observations for 20-second intervals lasting up to 20 minutes. Trained observers rated activity on a 5-point scale from lying down to jogging/running (384, 385). Other studies triangulated direct measurements of physical activity, combining accelerometers with pedometers (277, 376), activity monitors with self-report questionnaires (387) and activity monitors with observations (298).

PA monitors were worn for four (277, 383, 389, 392) or five consecutive school days (129, 373, 374, 391) or during school days featuring physically active lessons only (132, 298, 372, 376-377). All but one study (383) assessed PA with devices during school time only, providing no information on potential before- or after-school compensation effects of physically active lessons (178). Two studies assessed activity during physically active lessons only (387, 394). All but two studies using accelerometers (383, 394) reported using cut-points validated in child samples to analyse raw activity data, including Evenson (415) and Sirard (416) cut-points. A review of cut-points eligible for use in physically active lesson contexts can be found in Section 5.4.4.1.

4.5.9.2 Physical activity outcome results

Fifteen out of eighteen studies assessing physical activity outcomes found positive effects of physically active lessons on their overall study samples (132, 277, 298, 373, 374, 376-377, 380, 383-385, 387, 389, 392, 394). These positive effects were robust across data collection measures of accelerometers, pedometers and observations. One of these had samples too small to allow significance testing (374) and another described results as ‘significant’ but without presenting any statistics (387). Another found increased physical

Table 4-1. Physically active lesson interventions assessing health and physical activity only

Paper	Country	Intervention	Intervention period	Study design	Sample	Outcome	Result
Erwin et al. (2011a) (376)	USA	Physically active Maths classes = 10 min 1x a day	13 days	Pre- and post-intervention testing	1 school n=75, 8-12 years Subgroup: n=7	1) Pedometer (Walk4Life, LS 2505) Sub-group: 2) Accelerometer (Actigraph GT1M)	1) + Significantly more steps in intervention classes than baseline (*p*<0.001; *d*=1.52) 2) + Significantly greater activity counts (*p*<0.01), light activity (*p*<0.01) than baseline - No difference in MVPA pre- and post-intervention
Erwin et al. (2011b) (389)	USA	Physically active breaks with some educational content = 5-10 min 1x a day	1 academic year (8 months)	Non-randomised Controlled Trial	2 schools n=106, (n in groups not given) 8-11 years	1) Pedometer (Walk4Life, LS 2500)	1) + Only in 'compliant' classes adhering to recommended 1 physically active lesson a day, recorded 33% more steps compared to control (*p*<0.001; partial η^2 = 0.12.)
Goh et al. (2014) (277)	USA	Take 10! = 10 min activity, no set scheduling	8 weeks	Pre- and post-intervention testing	1 school n=210, 8-12 years Subgroup: n=72	1) Pedometer (Yamax, CW-600) Sub-group:	1) + Significantly more steps in intervention classes than baseline (*p*<0.01; *d*=0.49) 2) + Significantly greater MVPA in intervention classes than baseline (*p*<0.01; *d*=0.24)

						2) Accelerometer (Actigraph GT1M, GT3X)	
Liu et al. (2008) (387)	China	'Happy 10' = 10 min activities, at least 1x a day	1 academic year (9 months)	Non-randomised Controlled Trial	2 schools n=753, n=328 intervention 6-12 years Sub-group: n=80	1) Developed questionnaire + BMI Sub-group: 2) Zhi-Ji UX-01 monitor	1) - BMI increased in both groups 2) + 'Significantly' more energy expenditure and duration (figures not given)
Martin & Murtagh (2015) (374)	Ireland	'Active Classrooms', 10 minutes 1x a day	5 days	Pre- and post-intervention testing	1 school n=28 8=9 years Subgroup: *n*=20	1) Sub-group: Accelerometer (Actigraph GT3X or GT3X+)	1) + No significance testing but lower sedentary and higher light, moderate and vigorous PA in intervention group
Oliver et al. 2006 (372)	New Zealand	Virtual walk = length & frequency not given	4 weeks	Pre- and post-intervention testing	1 school n=61, 8-10 years	1) Pedometer (Yamax SW-200 Digiwalker)	1) - No difference in steps between intervention and baseline periods in whole sample + Least active girls significantly increased steps during intervention (*p*=0.02)
Reznik et al. 2015 (373)	USA	'CHAM JAM' CD = 10 min audio	Undefined	Cluster randomised controlled trial	4 schools, n=988, n=500 intervention	1) Pedometer (Yamax SW-200 Digiwalker)	1) + Significantly greater steps at follow-up in intervention group than control (*p*<0.005; *d*=0.24)

		activities, 3x a day			5-7 years		
Trost et al. 2008 (298)	USA	‘Move and Learn’ = 10 min activities, 2x a day	8 weeks	Cluster randomised controlled trial	1 pre-school centre n=42, n=20 intervention 3-5 years	1) Accelerometer (Actigraph 7164) 2) Observation – OSRAP tool	1) + Significantly more MVPA during class time but only in latter half of intervention period (*p*<0.05) 2) + Significantly more MVPA during interventions in circle time (OR=2.6), free-choice outdoor time (OR=1.4) & free-choice indoor time (OR=1.2, *p*<0.05) than equivalent control time

Notes: ‘+’ denotes a positive reported relationship, ‘-‘ denotes no relationship and ‘X’ denotes a negative relationship between physically active lessons and the given outcome

Table 4-2: Physically active lesson interventions assessing educational outcomes only

Paper	Country	Intervention	Intervention period	Study design	Sample	Outcome	Result
Fedewa et al. 2015 (391)	USA	Physically active lesson cards = One 20 min activity 1x a day	8 months	Cluster randomised controlled trial	4 schools, n=460, n=156 intervention 8-11 years	1) Fluid intelligence: SPM test 2) Academic achievement: Measures of Academic Progress standardised test	1) - No differences between groups 2) + Intervention group significantly higher Maths achievement scores (*p*<0.01) + Intervention group significantly higher Reading achievement scores (*p*<0.01)
Goh et al. 2016 (378)	USA	Take 10! = 10 min activity, no prescribed number per day	8 weeks	Pre- and post-intervention testing	1 school, n=210 8-11 years	1) On-task behaviour: 5 sec observations	1) + Increased by 7.2% post-intervention (*p*=0.001)
Graham et al. 2014 (375)	USA	Jump In! = One 10 min Maths session on designed mat	1 day	Non- randomised Controlled Trial	1 school n=21, n=13 intervention 7-8 years	1) Post-session knowledge questionnaire	1) - No differences between groups
Helgeson, 2014	USA	Energizers	4 weeks	Cluster randomised controlled trial	1 school n=130,	1) EasyCBM® reading	1) - No differences between groups

(386)		= 10 min activities, 10 across study period			n=86 intervention 11-14 years	comprehension assessment test	
Miller et al. 2015 (325)	UK	Physical Activity integrated into Maths and English = 10-15 min, 2x a day	6 months	Cluster randomised controlled trial	5 schools n=372, n=205 intervention 8=10 years	1) Literacy: Progress in English (PiE: short form) or InCAS tests 2) Maths: Progress in Maths (PiM) or InCAS tests	1) - No differences between groups 2) - No differences between groups
Mullender-Wijnsma et al. (2015b) (381)	Nether lands	'Fit en Vaardig op school' (Fit and academically proficient at school) = 20-30 min 3x a week	22 weeks	Non- randomised Controlled Trial	6 schools n=228, n=104 intervention 7-9 years	1) Maths skills (speed test arithmetic) 2) Reading skills (1-minute test)	1) X Control group significantly higher for Grade 2 Maths (*p*<0.01) + Intervention group significantly higher in Grade 3 Maths (*p*<0.01) 2) X Control group significantly higher for Grade 3 Reading (*p*<0.01)
Mullender-Wijnsma et al. (2016) (382)	Nether lands	'Fit en Vaardig op school' (Fit and academically proficient at	2 years	Cluster randomised controlled trial	12 schools, n=499, n=249 intervention 7-9 years	1) Reading ability: One-Minute Test	1) - No differences between groups 2) + Intervention group significantly higher scores (*p*<0.001; Hedge's *g*=0.51)

		school) = 20-30 min 3x a week				2)Math speed: Speed-Test 3) Spelling ability & 4) Maths ability: Child Academic Monitoring System	3) + Intervention group significantly higher scores (*p*<0.001; Hedge's *g*=0.45) 4) + Intervention group significantly higher scores (*p*<0.001; Hedge's *g*=0.53)
Reed et al. 2010 (390)	USA	Physical Activity integrated into core curriculum = 30mins a day, 3x a week	3 months	Cluster randomised controlled trial	1 school n=155, n=80 intervention 9-11 years	1) Fluid intelligence: SPM Test 2) Academic Achievement: PACT Tests	1) + Intervention group had significantly higher average fluid intelligence (*p*<0.05) 2) + Intervention significantly higher Social Studies scores (*p*=0.004) - No differences between groups in Maths, Science or English
Toumpaniari et al. (2015) (393)	Greece	Physical activity integrated into foreign language lessons = 1 hour, 2x a week	4 weeks	Randomised quasi-experimental design with 3 groups	2 preschools n=67, n=23 intervention 4 years	1) Cued recall	1) + Intervention group significantly greater scores than gesturing alone (*p*<0.001) and control (*p*<0.001)
Vazou et al. (2012) (395)	Greece	Physical activity integrated into 2 out of 6	2 weeks	Alternating treatments design;	8 schools n=147 10-13 years	1) Perceived academic motivation:	1) + Interest and enjoyment significantly increased after active lesson (*p*<0.01)

		consecutive lessons = 45 min sessions containing 10 min activity		pre-post intervention testing		Intrinsic Motivation Inventory	+ Perceived competence and effort significantly increased after active lesson (*p*<0.05) - No difference to perceived value of lesson or feelings of pressure

Notes: '+' denotes a positive reported relationship, '-' denotes no relationship and 'X' denotes a negative relationship between physically active lessons and the given outcome

Table 4-3. Physically active lesson interventions assessing physical activity and educational outcomes.

Paper	Country	Intervention	Intervention period	Study design	Sample	Outcome	Result
de Greef et al. 2016 (379)	Nether lands	'Fit en Vaardig op school' (Fit and academically proficient at school) = 20-30 min 3x a week	2 years	Cluster randomised controlled trial	12 schools, n=499, n=249 intervention 7-9 years	1) Fitness: Eurofit tests including 10x5m shuttle run 2) Executive functions: Golden stroop test, Backward digit span, Modified Wisconsin card sorting test	1) – intervention group larger improvement in speed-co-ordination (*p*=0.002) but less improvement in static strength (*p*<0.001) 2) – no differences between groups

Donnelly et al. 2009 (383)	USA	PAAC: Physical Activity Across the Curriculum = 2-10 min activities 1x a day	3 years	Cluster randomised controlled trial	24 schools n=454, (n in groups not given) 7-9 years Sub-groups: PA: n= 167 Academic: n=203	Sub-groups: 1) PA: Accelerometer (Actigraph 7164) 2) Academic: WIAT-II-A academic achievement test 3) All pupils: BMI	1) + intervention group more active overall (13%, *p*=0.007), sig more activity during school day (12% *p*=0.01), weekends (17%, *p*=0.001), more MVPA (27%, *p*<0.001) 2) + intervention group sig better scores in intervention in all areas 3) + Dose response relationship – schools with >75 min PAAC/wk sig less increase in BMI at 3 years than schools < 75 min PAAC/ wk
Grieco et al. 2009 (129)	USA	Texas ICAN = One 10-15 min activity	1 day	Pre- and post-intervention testing	1 school n=97 8-10 years	1) PA: Pedometer (Omron HJ 105) 2) Time-on-task: 5 sec observations	1) - At-risk of overweight (*d*= -0.43) & overweight (*d*= -0.65) took fewer steps than normal weight group 2) + No significant increase of TOT after intervention lesson compared to decrease in TOT after control lesson
Kirk et al. 2014 (384)	USA	Physical Activity integrated into	6 months	Cluster randomised controlled trial	2 schools n=72, n=51 intervention	1) PA: SO-FIT observations	1) + significantly increased observed physical activity in intervention group (*p*<0.01)

		teaching = 2x 15 mins a day			3-5 years	2) Early Literacy and Language skills: Research and development of individual growth and development indicators tool	2) + significantly increased alliteration and picture naming skills in intervention group (both $p<0.01$) - no difference in rhyming skills
Kirk & Kirk. 2016 (385)	USA	Physical Activity integrated into teaching = 2x 30 mins a day,	8 months	Cluster randomised controlled trial	2 schools n=54, n=39 intervention 3-5 years	1) PA: SO-FIT observations 2) Early Literacy and Language skills: Research and development of individual growth and development indicators tool	1) + significantly increased observed physical activity in intervention group ($p<0.05$) 2) + significantly increased rhyming and alliteration (both $p<0.01$) - no difference in picture naming skills
Mahar et al. 2006 (132)	USA	Energizers = 10 mins, 1x a day	4 or 8 weeks	Cluster randomised controlled trial	1 school n=243, n=135 intervention 5-11 years	1) PA: Pedometer (Yamax SW-200) Sub-group: 2) On-task behaviour: 10 sec observations	1) + significantly more steps during intervention ($p<0.005$) 2) + significantly increased by 8% post-intervention ($p<0.05$)

					Sub-group: n=87, 8-11 years		
Mavilidi et al. (2015) (394)	Australia	Physical Activity integrated into foreign language teaching = 1x 15 mins a day, 2x a week	4 weeks	Randomised quasi-experimental design with 4 groups	15 preschools, n=111, n=31 intervention 3-5 years	1) PA: Accelerometers: Actigraph GT1M, GT3X, GT3X/BT 2) Free recall 3) Cued recall	1) + significantly higher CPM and MVPA compared to control (both *p*<0.001) and gesturing conditions (both *p*<0.001) 2) + significantly higher compared to control (*p*<0.001), gesturing (*p*<0.05) and non-integrated conditions (*p*<0.01) 3) + significantly higher compared to control (*p*<0.001) and gesturing (*p*<0.05)
Mullender-Wijnsma et al. (2015a) (380)	Nether lands	'Fit en Vaardig op school' (Fit and academically proficient at school) = 20-30 min, 3x a week	22 weeks	Pre- and post-intervention testing	4 schools n=81, 7-9 years Sub-group: n=67	1) On-task behaviour: 5 sec observations 2) Sub-group: HR monitoring (brand not given)	1) + significantly higher post-intervention sessions compared to post-control sessions (*p*<0.05) 2) + significantly greater MVPA in intervention sessions (*p*<0.05)
Riley et al. (2015) (392)	Australia	'Encouraging Activity to Stimulate	6 weeks	Randomised controlled trial	1 school n=54,	1) PA: Accelerometers: Actigraph GT3X	1) + significantly less SB and higher MVPA in intervention Maths lessons (both *p*<0.001)

		Young Minds (EASY Minds)' = 60 min, 3x a week			n=27 intervention, 10-12 years	2) On-task behaviour: 15 sec observations	+ significantly higher MVPA across school day in intervention group (*p*<0.001) 2) + significantly higher in intervention compared to controls (*p*<0.05)
Riley et al. (2016) (377)	Australia	'Encouraging Activity to Stimulate Young Minds (EASY Minds)' = 60 min, 3x a week	6 weeks	Randomised controlled trial	4 schools n=240, n=142 intervention, 10-12 years	1) PA: Accelerometers: Actigraph GT3X 2) On-task behaviour: 15 sec observations 3) Maths performance: Progressive Achievement Test 4) Attitudes towards Maths: Fennema-Sherman math attitude scales	1) + significantly less SB (*p*=0.01) and higher MVPA (*p*=0.009) in intervention Maths lessons + significantly less SB across school day in intervention group (*p*<0.05) 2) + significantly higher in intervention compared to controls (*p*=0.011) 3) – no differences between groups 4) – no differences between groups

Notes: '+' denotes a positive reported relationship, '-' denotes no relationship and 'X' denotes a negative relationship between physically active lessons and the given outcome

activity only in classes ‘compliant’ with the recommended one physically active lesson a day guidance (389). Of the three studies not finding positive effects on physical activity, one found no difference between whole sample physical activity outcomes (372), one found mixed findings across various fitness outcomes (379) and another only compared PA between BMI groups, finding significantly more steps in normal weight compared to overweight groups (129).

Data showing the effects of physically active lessons on physical activity intensity (SB, LPA, MVPA) was reported in ten studies, via accelerometry (277, 298, 374, 367-377, 383, 387, 392, 394) or heart rate measures (381). The majority of these studies found MVPA to be significantly higher during intervention lessons than typical teaching (298, 377, 392, 394), with some studies providing no significance testing (374) or any statistics (387) to support their findings. The greatest proportion of MVPA during physically active lessons was identified in the only study to use heart rate monitoring: assessing 60% of intervention lessons to be in MVPA (381). Greater MVPA in intervention pupils was also shown in some studies across the wider school day (277): such as 27% greater overall MVPA in the RCT of Donnelly and colleagues (383). Only two studies provided results across the full spectrum of physical activity intensity, from SB to MVPA (377, 392). They both found physically active lessons to elicit significantly less SB, and significantly more LPA and MVPA than typical teaching. The smaller pilot study found SB to significantly reduce and MVPA to significantly increase across the school day (392), whereas only SB was found to be significantly reduced in the full-scale study (377).

To assess changes in outcomes with repeated exposure to physically active lessons, physical activity was assessed multiple times during interventions in ten studies (298, 376-379, 383-385, 392-393). Seven of these found any activity changes elicited by physically active lessons to not significantly reduce during the intervention period (277, 376, 379, 381, 384, 385, 389). Two studies found physical activity to actually increase in the latter stages of their respective intervention periods (298, 392) and one study did not report results for within-intervention changes (383). Only one study assessed physical activity outside of school-time, with it finding intervention pupils to demonstrate 17% more overall weekend activity than control pupils (p=0.001) (383). Extended post-intervention follow-ups were only present in four studies, with two reporting physical activity changes to be maintained in the overall intervention group of up to 3 months (373, 389), or in classes with teachers compliant during the intervention period (376). The remaining study described a 6-week post-intervention follow-up but did not report the results for this (394). Only one study used significance testing to assess intervention effects on sex: finding least active girls at baseline to more than double their physical activity during the intervention (372).

Across all assessed physical activity outcomes within these eighteen studies, twenty outcomes were positively associated with physically active lessons, four outcomes showed no difference between intervention groups and no outcomes were negatively associated with physically active lessons.

4.5.10 Health outcomes

Changes to health outcomes with physically active lesson provision were assessed in two of the twenty-eight identified studies (Tables 4-1; 4-3). Both studies assessed BMI and found it to increase overall in both intervention and control groups during the length of their interventions (383, 387). However one found BMI to be effected in a dose-response relationship, with schools running ≥75 minutes of physically active teaching a week showing lower pupil increase in BMI after 3 years (383).

4.5.11 Educational outcomes

Changes to educational outcomes with physically active lesson provision were assessed in twenty of the twenty-eight identified studies (Tables 4-2; 4-3). Ten studies assessed educational outcomes only (325, 375, 378, 381-382, 386, 390, 391, 393, 395) and ten studies assessed educational outcomes alongside PA and health outcomes.

4.5.11.1 Educational outcome measurement and results

Sixteen out of twenty studies found positive effects of physically active lessons on at least one educational outcome. A wide range of educational outcomes and assessment tools were assessed across studies. To allow clearer synthesis of findings outcomes are hereby clustered by relevance, with methods and results reported together.

On-task behaviour

On-task behaviour was assessed in six studies, with four of these being cluster randomised controlled trials and two using a within participants design. All studies used momentary time sampling observations, where trained researchers observed pupil behaviours in-turn for fixed intervals (129, 132, 377, 378, 380, 392). Behaviour was rated as either off-task (e.g. placing head on desk, yawning, talking to others when not part of given task) or on-task. Three studies observed all participating pupils in any given class and three observed only six students in each session (377, 380, 392) with one of these selecting pupils purposively to observe two of low, medium and high Maths ability (377). Pupils were observed for between 5- (129, 378, 380) and 15-seconds at a time (377, 392). Overall observations lasted for 30 minutes, except one study which assessed for 50 minutes (380). All studies used pre-recorded audio files to ensure observer timings were regulated to their set protocols. Two studies assessed on-task behaviour during physically active lessons only (377, 392), two assessed on-task behaviour immediately following the lessons (129, 380) and two assessed for 30 minutes before- and 30 minutes after active lessons (132, 378). Secondary trained observers were described as present in five studies to allow inter-rater reliability to be assessed, in between 39% (132) and 100% of sessions (129, 377). Although some studies recorded behaviour in a more complex way, all studies analysed behaviour in binary on- or off-task format. Five out of six studies found on-task behaviour to improve with physically active lessons compared to typical teaching (132, 377, 378, 381, 392). The remaining study found on-task behaviour to not significantly change following intervention sessions, compared to it decreasing following control sessions (129).

Academic achievement

Academic achievement was measured in five studies. All studies were cluster randomised controlled trials and all used standardised tests of academic achievement. Donnelly (383) used the well-validated 2nd edition Wechsler Individual Achievement Test (WIAT-II-A) (417), taking 30 minutes to complete per pupil. Intervention pupils scored significantly improved test results across maths, reading, spelling and composite areas ($p<0.01$), whereas control pupils only improved in maths (383). Reed (390) used mandatory Palmetto Achievement Challenge Tests (PACT) (418) in maths, language arts, science and social studies. Achievement was only assessed immediately post-intervention, with intervention pupils scoring significantly higher in social studies (*p*=0.004) but no other areas (390). Fedewa (391) used the Measures of Academic Progress standardised testing tool (419), finding intervention pupils to score significantly higher in Maths ($p<0.01$) and Reading achievement ($p<0.01$) compared to controls. Riley (377) used Progressive Achievement Tests in Mathematics (PATMaths) (420) to evaluate achievement in their maths-focused programme, although no details were given on the length and content of this measure. No difference in maths achievement was found between intervention groups. Miller (325) used different achievement measures across participating schools to assess respective feasibility in this pilot study. Pencil-and-paper Progress in English and Maths standardised tests (421, 422) were used in three schools and Computer-adapted inCAS tests (423) were used in two schools. No differences were found between intervention groups with either method. Overall, intervention pupils showed significantly positive increases to academic achievement compared to controls in two studies, with no differences between groups in two studies and one study reporting mixed findings.

Academic skills

Academic skills (abilities facilitating academic achievement) were assessed in five studies, all of which were cluster randomised controlled trials. The research of Kirk (384, 385) assessed early literacy and language skills in preschool pupils using the Early Literacy Individual Growth and Development Indicators (IGDI) for ages 0 to 8 (424). This featured three tasks of picturing naming, rhyming and alliteration (e.g. 'Look at the pictures and find the ones that start with the same sound'). At 6 months of intervention, Kirk (384) found significantly increased alliteration ($p<0.01$) and picture naming skills ($p<0.01$) compared to controls but no difference in rhyming skills. At 8 months of intervention, Kirk (385) found significantly increased rhyming ($p<0.01$) and alliteration ($p<0.01$) compared to controls but no difference in picture naming. Reading comprehension was assessed in one study (386) via grade-level easyCBM (Curriculum Based Measurement) assessments (425). This involved providing a reading passage with twenty multiple-choice questions before and after 'Energizers' sessions. No differences were found between intervention groups.

Mixed findings were found in studies assessing academic skills in cohorts over time. Mullender-Wijnsma (381) assessed maths speed after 22 weeks of intervention with a speed arithmetic test ('Tempo-Test-Rekenen'; Speed Test Arithmetic) (426), finding that although intervention pupils in Grade 3 performed significantly better than controls (p<0.01), intervention pupils in Grade 2 conversely performed significantly worse than controls (p<0.01). The study also assessed reading ability with a read-aloud test ('E´en-Minuut-Test'; 1-Minute Test) (427), finding Grade 3 control pupils to perform significantly better than intervention pupils (p<0.01). Following on from this study, Mullender-Wijnsma (382) re-assessed these skills after 2 years of intervention, finding no difference in reading ability but significantly higher intervention group scores in maths speed (p<0.001). The study also found significantly higher spelling (p<0.001) and maths abilities (p<0.001) in the intervention group compared to control. It appears that longer-term use (2 years) of physically active lessons in this cohort may have clearer benefits for academic skills than shorter term use (22 weeks). However, shorter term use in this study is still far longer than the majority of physically active lesson interventions. Overall, four studies reported mixed academic skill findings comparing intervention pupils to controls and one study reporting negative findings.

Other educational outcomes

Recall of content delivered in physically active and comparative lessons were assessed in three studies. Two of these studies featured a quasi-experimental design (393, 394) and one featured a non-randomised controlled trial (375). Two studies applying physically active teaching in foreign language lessons found significantly greater recall of learned words than typical teaching or seated gesturing conditions (393, 394). Whereas a study assessing physically active Maths teaching found no difference between intervention and control groups (375).

Fluid intelligence studies (the ability to think logically and solve abstract problems) was assessed in two studies (390, 391). Both were cluster randomised controlled trials and used the well-validated Standard Progressive Matrices tests (SPM) Fluid Intelligence Test (428). This features five sets of diagrammatic puzzles where the individual has to identify a missing component. Reed (390) found fluid intelligence to significantly improve in physically active lesson pupils (p<0.05) compared to controls. However, Fedewa (391) found no difference between intervention groups.

Executive functions (cognitive processes needed for complex, goal-oriented behaviour; Section 2.3.4.2) were assessed in one study (379): a cluster randomised controlled trial with a 2-year intervention. This used well-validated tasks of the Golden Stroop Test (429) to measure inhibition, the Digit Span backward and Visual Span backward tasks (430) to measure working memory and the Wisconsin card sorting test (431) to measure cognitive flexibility. The study found no differences between intervention groups in any aspect of executive functions.

Perceived academic motivation was assessed in one study (395), which used an alternating treatments design. It used five out of six factors of the Intrinsic Motivation Inventory (IMI) (432). Interest/enjoyment towards learning (p<0.01), perceived competence (p<0.05) and effort (p<0.05) were found to significantly increase after physically active lessons. No differences were found for the factors of perceived value of the lesson or feelings of pressure. Finally, attitudes towards maths was assessed in one study (377), a cluster randomised controlled trial providing physically active lessons in maths teaching. This was assessed using the Fennema-Sherman mathematics attitude scale (433) but no differences were found between intervention groups.

Across all assessed educational outcomes within these twenty studies, twenty outcomes were positively associated with physically active lessons, twelve outcomes showed no difference between intervention groups and two outcomes were negatively associated with physically active lessons. On-task behaviour was consistently and positively associated with physically active lessons in studies assessing it. Academic achievement and academic skills received mixed findings, with all other educational outcomes being too widely varied to provide tangible conclusions.

4.5.12 Risk of bias assessment

All twenty-eight identified studies were assessed for their potential risk of bias. Six were assessed to have strong- (little risk of bias) (298, 372, 377, 379, 382, 383), twelve to have moderate- (129, 325, 373, 380, 381, 384, 385, 389, 390, 392, 394) and ten to have weak- (large risk of bias) global ratings as assessed by the EPHPP tool (132, 277, 374, 375-376, 378, 386, 387, 391, 393, 395) (Table 4-4).

Selection bias was common, with authors often not reporting the rationale behind their participating schools, or the rate of school or participant study participation (374, 375, 387, 389). The selection processes of classes from larger study cohorts were also absent (129, 373, 379, 382, 383), with a lack of description of recruitment strategies. There were also dubious selection processes such as teacher selection of pupils reported for on-task behaviour observations (377) and sub-group participants (376, 387). Many studies did not report potential demographic confounders or account for them in their analysis (129, 277, 374, 376, 378, 380, 381, 386, 387, 391, 393-394). In all studies, blinding of pupils, teachers and researchers was unclear or unreported. As physically active lessons are being tested as inherently novel experiences, blinding is likely to be difficult or even impossible. Physical activity and educational outcome measures used were shown to be valid and/or reliable in all but three studies (375, 387, 393). Validity and reliability of measures was demonstrated by citing large-scale validation studies or systematic reviews. Many studies provided full numbers and reasons for participant and class attrition, although six studies did not discuss attrition at all (132, 376, 378, 386, 387, 390). Studies identified in the second iteration of this systematic review were notably more likely to report attrition in detail.

Table 4-4. Risk of bias of identified studies

Study	Selection Bias	Study Design	Confounders	Blinding	Data Collection Methods	Withdrawals & Drop-Outs	Overall
de Greef et al. 2016 (379)	Moderate	Strong	Strong	Moderate	Strong	Moderate	Strong
Donnelly et al. 2009 (383)	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Erwin et al. 2011a (376)	Weak	Moderate	Weak	Moderate	Strong	Weak	Weak
Erwin et al. 2011b (389)	Moderate	Strong	Strong	Weak	Strong	Moderate	Moderate
Fedewa et al. 2015 (391)	Moderate	Strong	Weak	Weak	Strong	Moderate	Weak
Goh et al. 2014 (277)	Moderate	Moderate	Weak	Weak	Strong	Strong	Weak
Goh et al. 2016 (378)	Moderate	Moderate	Weak	Weak	Strong	Weak	Weak
Graham et al. 2014 (375)	High	Moderate	Strong	Weak	Weak	Strong	Weak
Grieco et al. 2009 (129)	Moderate	Moderate	Weak	Moderate	Strong	Moderate	Moderate
Helgeson, 2013 (386)	Moderate	Strong	Weak	Weak	Moderate	Weak	Weak
Kirk et al. 2014 (384)	Moderate	Strong	Strong	Weak	Strong	Strong	Moderate
Kirk et al. 2016 (385)	Moderate	Strong	Strong	Weak	Strong	Strong	Moderate
Liu et al. 2008 (387)	Weak	Strong	Weak	Moderate	Weak	Weak	Weak
Mahar et al. 2006 (132)	Moderate	Strong	Weak	Moderate	Strong	Weak	Weak
Martin & Murtagh. 2015 (374)	Weak	Moderate	Weak	Weak	Moderate	Strong	Weak
Mavilidi et al. 2015 (394)	Moderate	Strong	Weak	Moderate	Moderate	Strong	Moderate
Miller et al. 2015 (325)	Moderate	Strong	Strong	Weak	Moderate	Strong	Moderate

Mullender-Wijnsma et al. 2015a (380)	Moderate	Moderate	Weak	Moderate	Moderate	Strong	Moderate
Mullender-Wijnsma et al. 2015b (381)	Moderate	Strong	Weak	Moderate	Strong	Strong	Moderate
Mullender-Wijnsma et al. 2016 (382)	Moderate	Strong	Strong	Moderate	Strong	Moderate	Strong
Oliver et al. 2006 (372)	Moderate	Moderate	Strong	Moderate	Strong	Moderate	Strong
Reed et al. 2010 (390)	Moderate	Strong	Strong	Moderate	Strong	Weak	Moderate
Reznik et al. 2015 (373)	Moderate	Strong	Strong	Weak	Moderate	Strong	Moderate
Riley et al. 2015 (392)	Weak	Strong	Strong	Moderate	Moderate	Strong	Moderate
Riley et al. 2016 (377)	Strong	Strong	Strong	Moderate	Moderate	Strong	Strong
Toumpaniari et al. (2015) (393)	Moderate	Strong	Weak	Weak	Weak	Strong	Weak
Trost et al. 2008 (298)	Strong	Strong	Strong	Moderate	Strong	Strong	Strong
Vazou et al. 2012 (395)	Moderate	Moderate	Strong	Weak	Strong	Moderate	Moderate

Note: Assessed using Effective Public Health Practice Project (EPHPP) tool (370)

4.6 Discussion

4.6.1 Summary of findings

This systematic review addressed Aim 1 and Question 1 of the thesis (Chapter 3). Twenty-eight studies were identified that assessed the effects of physically active lesson interventions compared to typical teaching. Positive effects of physically active lessons on physical activity outcomes were found in fifteen out of eighteen studies, with the remaining three studies finding no significant difference between intervention and control participants. During lesson time and the school day, physical active lessons were found across most studies to increase step counts, overall activity counts and MVPA. These improvements were also shown to be sustained across intervention periods, showing activity does not reduce as session novelty decreases. With positive effects emerging from a diverse range of data collection methods, study designs and populations, this evidence largely supports the potential of physically active lessons in promoting school-based physical activity. However, only one study assessed physical activity outside of school-time (383), providing little evidence on the effects of physically active lessons on leisure or weekend activity levels. A more in-depth critique of this issue and wider problems with research identified in this review is discussed in Section 4.7.2 with recommendations for future VFT work.

BMI was the only health outcome evaluated, with this assessed in only two studies (383, 387). Neither study found BMI levels to reduce in intervention pupils; however one study found BMI increases to be smaller in intervention pupils with more intense delivery of sessions (≥75 minutes a week). As physically active lessons are relatively subtle interventions typically lasting 10 to 15 minutes and largely eliciting bursts of MVPA, it seems unlikely that they alone would lead to BMI reductions. Although this systematic review sought interventions implementing physically active lessons only, the combination of such sessions as part of complex interventions may have different effects on BMI. Complex interventions featuring physically active lessons have found mixed results for BMI. For example, an intervention featuring Take 10! sessions within a 2 year complex, school-wide intervention (n=2,494) found decreases in BMI ($p<0.05$) and weight ($p<0.001$) among girls only in intervention schools compared to controls (434). However, a study assessing a 16-month complex intervention including 15-minutes of physically active lessons per day (n=288) found no significant changes to BMI between intervention groups (128).

Sixteen out of twenty studies found positive effects of physically active lessons on at least one educational outcome. Overall, twenty educational outcomes were positively associated with physically active lessons, twelve outcomes showed no difference between intervention groups and two outcomes were negatively associated with physically active lessons. The majority of research hence supports the notion that integrating physical activity via active lessons is beneficial or at least not detrimental to schools' 'core business' of education (69). Arguably the strongest evidence identified in this review exists for on-task behaviour, with five out of six studies showing beneficial effects. More mixed findings were found for academic achievement (k=5) and academic skills (k=5), with content recall, fluid intelligence, executive function and attitudinal outcomes being assessed in too few studies for tangible conclusions to be made.

Risk of bias was relatively high, with twenty-two out of twenty-eight studies being of weak or moderate study quality. This low study quality has also been identified in wider physical activity intervention research in children and young people (435). A lack of participant and experimenter blinding was common, often not described or impossible due to the inherently novel nature of the physically active lesson intervention. Potential confounding variables were often not reported, or were not addressed in analyses. For example, only eight studies reported ethnicity with predominantly white samples common in these studies. It is important that physically active lessons as relatively novel interventions are tested in diverse samples to provide evidence across populations (436). Also school, class and pupil selection and attrition was often poorly described, providing little guidance on recruitment and retention strategies and their effects.

4.6.2 Review strengths and limitations

The main strength of this systematic review is the use of internationally-adopted PRISMA guidelines (366) to inform its development and conduct. *A priori* decisions on search criteria, inclusion and exclusion criteria and data extraction tables were used to limit potential bias during the review. The well-validated EPHPP tool (370, 371) was used to assess study quality and risk of bias. Assessing physically active lessons on both physical activity and educational outcomes provides a literature appraisal relevant to health and education researchers and professionals.

A limitation of this study is that only English language papers were reviewed due to restrictions of the researcher. However in practice no papers were excluded due to this criterion (Figure 4-1). Secondly, this review may be restricted by wider publication bias in this novel research area, with studies showing positive effects more likely to be submitted and published than null findings (138). This may be especially problematic for educational outcomes as a lack of significant difference between intervention groups is actually positive: showing that physical activity can be integrated into curriculum teaching without detrimental educational effects (128, 129).

4.7 Recommendations for future VFT research: Physically active lessons systematic review

This systematic review revealed various inadequacies in the twenty-eight identified physically active lesson intervention studies. At this Development stage of the PhD (279), it was important to critically evaluate this existing body of evidence in order to better inform the development of future VFT interventions. Limitations of identified studies were hence assessed alongside related literature (Chapter 2) to identify recommendations for subsequent VFT work.

4.7.1 During VFT protocol development

Literature-based recommendation 1: Provide theoretical background

A lack of theoretical basis for interventions was evident in most identified studies. Only two out of twenty-eight studies featured theoretical justifications for their choice of outcomes and two only mentioned theory in passing. This is typical of many interventions, with common-sense development used instead of formal analysis of target behaviours or the mechanisms of action behind them (437). Theory and behaviour change techniques (282, 437) were hence applied in VFT work to ensure a grounded basis for development and to aid replication. Application of theory and behaviour change elements is shown in Section 5.4.1.

Literature-based recommendation 2: Involve teaching staff during VFT development

Only five studies included teachers in the development of physically active lesson interventions. Teachers will need to be included throughout VFT development to ensure content is relevant to the curriculum and teaching environment (438, 439). Without this collaboration, VFTs will not reflect teacher considerations, will be less likely to have the support of teachers and less likely to be introduced at curriculum level (69). Teacher partnership and guidance was sought in qualitative feasibility work (Section 5.3) and in VFT programme development (Section 5.4.2).

4.7.2 During VFT intervention

Literature-based recommendation 3: Use accelerometers to assess activity intensity of VFTs

Many studies assessed physical activity primarily with pedometers. These provide step-count data only and do not detect the sporadic movements typical in children (29) (Section 5.4.4). The use of accelerometers enables assessment of activity intensity, including measures of sedentary, light and MVPA time (440). Although other studies used accelerometers, only two reported results across the full range of activity intensity. It is important to assess the range of activity elicited by physically active lessons such as VFTs to fully ascertain their adequacy. Accelerometers were accordingly used in all subsequent VFT intervention work (Chapters 6-8).

Literature-based recommendation 4: Record pupil physical activity for longer periods

Only one study measured activity during physically active lesson intervention periods inside and outside of school, across weekdays and weekends (383). This is far from the highest reliability of monitoring, identified as 7 days for 10 hours per day (148, 441). The ActivityStat Hypothesis and supporting research has suggested that increased physical exertion in children may be compensated by increased subsequent sedentary time (178, 182) (Section 2.4.5). However the existing body of research identified in this systematic review cannot assess if physically active lessons lead to changes beyond school-time. Adoption of longer-term physical activity assessment in VFT intervention work is applied in Chapters 6 & 7.

Literature-based recommendation 5: Ensure intervention and follow-up periods are as long as possible

Intervention periods ranged greatly across studies from one day to three years. School physical activity interventions of 12 weeks and over have been recommended and systematically assessed in a recent Cochrane review (245). However, only twelve of the twenty-eight identified studies met this intervention duration. The majority of studies had no or a relatively short post-intervention follow-up time, preventing longer term assessment of outcome effects. These aspects may be indicative of the relative infancy of physically active lesson research, with eight out of twenty-eight identified studies describing themselves specifically as pilot or feasibility studies. Feasibility work and VFT intervention development will restrict the time available for intervention testing during this PhD. However, it is important that interventions and follow-up are as long as possible. Intervention phases are reported in the VFT longitudinal study protocol (Section 6.4.1).

Literature-based recommendation 6: Measure and analyse VFT intervention effects by pupil demographics

Risk of bias assessments showed many studies did not report potential demographic confounders or test associated effect modification in their analysis (Section 4.5.12). Only one study assessed the effects of physically active lesson interventions on sex (372). As shown in the literature review (Section 2.3.3), girls are typically less active (52) and may respond less well to activity interventions than boys (245). It is hence important to assess potential effects of physically active VFTs on sex to assess if this is a tangible intervention to benefit girls. Additionally, VFT intervention work should measure BMI as a pupil demographic. Although this review identified only two studies assessing BMI as an outcome with no intervention effects observed, measurement of BMI as a demographic would provide information on intervention effects on respective groups. Reporting and analysis of pupil demographics are shown in longitudinal VFT work (Chapters 7 & 8).

Literature-based recommendation 7: Fully evaluate developed VFT intervention

Identified studies tended to focus solely on outcomes rather than also assessing the processes behind physically active lesson implementation. Although process evaluation measures were reported in sixteen out of twenty-eight studies, the quality and extent of this measurement varied greatly. This often made it difficult to judge the degree of implementation and satisfaction for each intervention (442). The importance of such process evaluations was especially emphasised in the findings of Erwin (389), where step results would have been inaccurate without accounting for compliance data. The proportion of intended material covered in each session, as well as the attendance of pupils should be routinely assessed to allow better appraisal of study output (284, 442). Perceived facilitators and barriers to intervention use should also be assessed to help interpret implementation levels and improve subsequent intervention iterations. These considerations seem especially relevant given the use of novel classroom technology that will be inherent to physically active VFTs. Although only used in one study identified in the systematic review (Section 4.5.4), wider school physical activity research often employs well-validated evaluation tools such as the RE-AIM framework (399, 443) to evaluate the Reach, Efficacy/Effectiveness, Adoption, Implementation and Maintenance of interventions. Further information on the importance of evaluation and adoption of the RE-AIM framework in VFT research can be found in Chapters 5, 6 & 9.

4.7.3 During write-up of VFT results

Literature-based recommendation 8: Ensure VFT intervention is fully described to allow replication

Most studies gave examples of intervention sessions, with two providing full lesson plans. However, even in studies with low risk of bias there were sometimes issues with insufficient intervention or demographic details. For example, although the paper of Oliver (372) was assessed to have low overall risk of bias, the frequency and length of their virtual walk intervention sessions were absent. As with any intervention, full detail of physically active lesson procedures is required to allow replication. The length and frequency of intervention, detailed examples of sessions, information of any additional equipment and classroom layout changes are required to allow research and real-world implementation. Given that physically active lessons are still relatively novel (69, 295); it is vital that a full description of the developed VFT intervention is provided to allow reproduction. Use of randomised controlled trial protocols such as the Consolidation Standards of Reporting Trials (CONSORT) guidelines (444, 445) would help ensure all relevant information is provided. These guidelines feature a checklist of key information to include in each aspect of RCT reporting, such as details on trial design, recruitment and blinding. Full reporting of the longitudinal VFT intervention developed using CONSORT guidelines is accordingly given in Chapter 6.

4.8 Conclusion

This chapter features the work of two iterations of a systematic review into the methods and outcomes of physically active lessons. Twenty-eight papers were identified in Spring 2016 compared to just eleven identified papers in the first iteration of Spring 2014 (3), showing the increasing level of research interest in this area during the course of this PhD. Support for physically active lessons as increasing activity was evident in most studies, however measurement was commonly limited to school-time only. The effects of these intervention sessions on educational outcomes were more varied, with a wider range of outcomes assessed. Most studies were assessed to have weak or moderate study quality, with confounders and participant attrition often unreported and blinding of participants and researchers often difficult or unreported. Taking all identified research and evaluation into account, various recommendations were made for subsequent VFT work in this thesis. These included using theory and clear intervention reporting to increase replicability of studies, assessing physical activity beyond the school day and involving teachers in intervention development. These recommendations were addressed in feasibility work (Chapter 5) and the main VFT intervention (Chapter 6-9).

Chapter 5 Virtual Field Trips Feasibility Work (including Study 1) and resulting changes made

5.1 Introduction

Reviewing recent academic and grey literature (Chapter 2) showed the positive effects of physical activity on child health, educational and wellbeing outcomes. Also clear from both literature and systematic reviews (Chapters 2 & 4) is an increasing interest in integrating physical activity into classroom teaching. Sedentary, largely university-based Virtual Field Trips were identified in the literature review as holding potential for translation into physically active teaching. Following the 'Feasibility/Pilot' stage of the MRC intervention guidelines (279), preliminary work was required to test VFT intervention procedures and recruitment strategies for future work.

Although the terms 'feasibility' and 'pilot' are used somewhat interchangeably in MRC guidelines (446) and health-related journals (447), their meanings are quite different and so will be defined here before related VFT work is presented. According to the National Institute for Health Research (NIHR), feasibility studies aim to answer the question: 'Can this research be done?' (448). They consist of research performed before the main intervention study that inform on important parameters needed to design the latter (448). These parameters include aspects of centre or participant recruitment, intervention adherence or estimations of outcome effects for sample size calculations and intervention compliance (447). By contrast, pilot studies are smaller versions of the large-scale intervention, enabling randomisation and recruitment procedures and outcome measurements to be trialled (448).

In this VFT research, a mixed-methods approach to feasibility work was undertaken. This combined a quantitative pilot study to test the suitability of VFT technology with a qualitative feasibility study to assess perceptions of VFTs in teachers and pupils. Mixed-method and qualitative approaches are increasingly being used within feasibility stages of randomised controlled trials (449). They allow understanding of potential intervention users' experiences of feasibility versions of a given intervention to help identify potential areas for modification (449).

This chapter presents feasibility work informing the main Virtual Field Trips study (Chapters 6-9), divided into three sub-chapters. Chapter 5A briefly summarises recommendations identified from a VFT pilot study previously undertaken for the Masters project of this 1+3 PhD studentship. Chapter 5B presents the findings and recommendations arising from a qualitative feasibility study interviewing teachers and pupils to assess the potential of physically active VFTs. Finally, Chapter 5C charts the revisions made to the VFT intervention prior to the main VFT study.

5.2 Chapter 5A. Masters project VFT pilot study

*This pilot study was run as the Masters dissertation project for this 1+3 PhD studentship (450). The full study can be read in the BMC Public Health published paper (2) (*Appendix 5A*).*

For the Masters project of this 1+3 PhD Studentship (450), a VFT pilot study was run in a small primary school sample. It is briefly summarised here as it provided insight for subsequent recommendations.

5.2.1 Brief study outline

The Masters pilot VFT study provided a one-off, 30-minute Olympic-themed VFT session that was either run with: a) pupils standing and physically active or b) seated throughout. The study primarily aimed to:

1) Identify practical considerations for physically active VFT sessions prior to larger-scale research.

The study also aimed to secondarily and provisionally:

1) Objectively measure children's physical activity during the VFT lesson and the school day
2) Assess pupil's recall of content delivered in VFT session

5.2.2 Recommendations from systematic review addressed in Masters pilot study

The Masters project VFT pilot was conducted prior to the physically active lessons systematic review of Chapter 4. However, some of the recommendations emerging from the review to increase the efficacy of VFT work were already addressed within this pilot study.

Literature-based recommendation 3: Use accelerometers to assess activity intensity of VFTs

Actigraph GT1M accelerometers (CSA, Shalimar, FL) were worn by pupils from 9:00AM to 3:00PM during the study day. Data was analysed using 15-second epochs and child-appropriate cut-points (Section 5.4.4.1).

Literature-based recommendation 6: Measure and analyse VFT intervention effects by pupil demographics

Pupil sex, ethnicity and BMI were assessed in this pilot study. There were no significant differences in demographics between intervention groups and schools, nor in VFT physical activity or content recall outcomes. Future research will continue to record and assess pupil demographics to understand potential differences in outcomes.

Literature-based recommendation 7: Fully evaluate developed VFT intervention

A brief evaluation of the one-off VFT session provided was done in this pilot study. Pupils and teachers were provided with brief questionnaires after the VFT session to assess acceptability. Difficulties in the provision of VFTs and outcome assessment were also noted, with iterative recommendations made (Section 5.4). An extensive evaluation was done for the larger-scale VFT intervention as per RE-AIM guidelines (399, 443) (More detail in Section 5.4.6).

Literature-based recommendation 8: Ensure VFT intervention is fully described to allow replication

The published study of this pilot featured a step-by-step description of how the London 2012 Olympic themed VFT was developed on Google Earth (2). A screenshot of the VFT was also provided, along with descriptions on how the respective sedentary and active versions were delivered and participated in. A detailed description of the subsequent larger-scale VFT intervention programme was also provided (Chapter 6).

5.2.3 Recommendations for future VFT research: From Masters pilot project

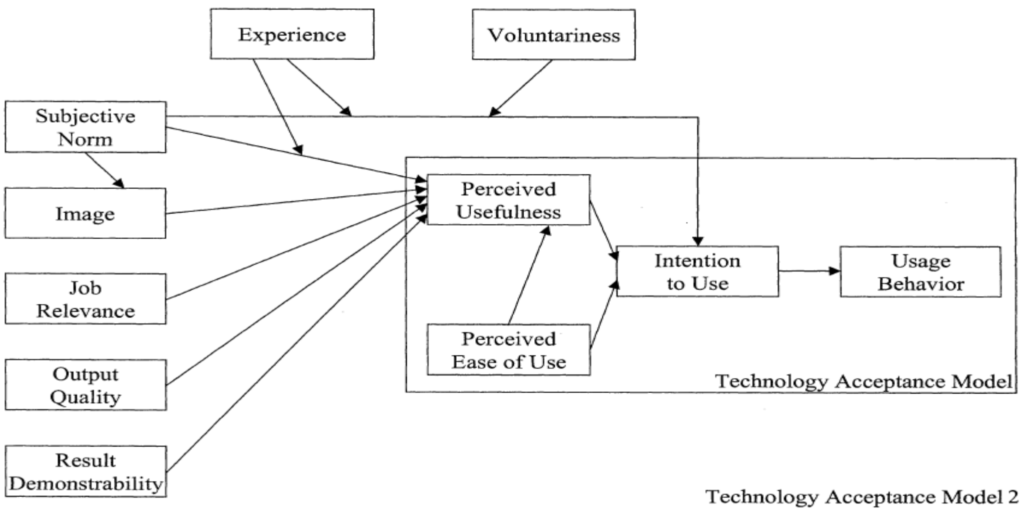
As the first of two feasibility stage studies (279), this pilot VFT intervention allowed identification of practical issues to be addressed prior to future research. In addition to issues identified following the physically active lessons systematic review (Chapter 4; Literature-based recommendations 1-8), recommendations were noted to be addressed prior to longitudinal intervention work.

During VFT development

Pilot study recommendation 1: Use VFT software more compatible with school technology

Google Earth was used to develop and run VFTs in the pilot study. Although use of this software was beneficial as it was already available on school computing systems, there were practical issues. School firewall internet restrictions meant that different images and videos were available on different classroom computers: with edits needed prior to each session to ensure functionality. Such issues with school internet connectivity are commonplace in schools to aid pupil safety but can limit functionality and restrict the content teachers can deliver in sessions (339). Although tolerable in small-scale feasibility research, this issue is not permissible in longitudinal research or real-life implementation. In line with the Technology Acceptance Model (TAM) and its iterations (451, 452); technology that is not perceived as easy to use and useful by service users (teachers) will less likely be used (Figure 5-1). This model is supported by a range of longitudinal research showing perceived usefulness and ease of use to strongly influence intentions to use technology (451, 453). School work employing TAM showed teachers to focus on perceived ease of use and usefulness in continued implementation of new technologies (454, 455). Although found in meta-analysis work to explain only 40% variance in usage behaviour across a variety of contexts (456), TAM does helpfully illustrate the range of influences impacting on school technology use. In VFT intervention work, the low ease of use in this Google Earth format would likely lead to reduced implementation and weak findings. As such, alternative software was trialled prior to future research (Section 5.4.3).

Figure 5-1: Technology Acceptance Model and its second iteration (451)



Pilot study recommendation 2: Use accelerometer cut-points most appropriate for VFT intervention

Cut-points are pre-defined thresholds that allow accelerometer data (counts per given time-point or 'epoch') to be translated into minutes of activity intensity (457). Cut-points are generated from calibration studies where participants perform physical activities of varying intensity whilst wearing an accelerometer and simultaneously having their energy expenditure assessed by a criterion measure such as indirect calorimetry (457) (Section 2.4.1). Various cut-points have been published: calibrated for different populations (various ages and backgrounds), using different devices, settings (laboratory or field-based) and different physical activities (39). This has produced an abundance of published cut-points for researchers to choose from, but little accompanying guidance as to which to use for any given project (457, 458).

Data from the VFT pilot study was originally analysed for the Masters project using Mattocks cut-points (459) (Sedentary: 0-100 counts per minute (CPM), Light: 101-3580 CPM, Moderate: 3581-6129 CPM, Vigorous: ≥6130 CPM). These were calibrated in children from free-living as opposed to treadmill activities: reflecting the natural, sporadic movements typical at this age (29, 460). However, although pupils in the active intervention group were informally observed by the researcher to be standing and visibly active throughout the session: 72% of the active group's VFT activity was still recorded as sedentary.

The standing, on-the-spot activity elicited during this pilot VFT does not comply with officially defined sedentary behaviour**:** energy expenditure ≤ 1.5 metabolic equivalents and a sitting or reclining posture (25, 142). As such, a review of child accelerometer cut-points was done to assess if a more suitable interpretation of VFT accelerometer data existed for larger-scale research (Section 5.4.4). The cut-points identified in this review were used to re-analyse the pilot study data and were reported in the published paper (2).

Pilot study recommendation 3: Assess feasibility of combining accelerometers with other forms of VFT physical activity measurement

It was evident from this pilot study that accelerometers may not be the most suitable tool to measure VFT-induced activity. Activity elicited by the pilot session was mostly recorded on the medio-lateral axis. This reflects the non-ambulatory, on-the-spot movement prompted: as opposed to the more common ambulatory, travelling movements assessed by accelerometers (29). Accelerometer cut-points are also typically derived from ambulatory activities such as walking (39) (Section 2.3.2). A weakness of accelerometers is their weaker sensitivity to non-ambulatory movements, such as cycling and on-the-spot movement in comparison to accelerating, travelling movements (48). As such, it was important to assess if other activity measurement techniques could be used to triangulate accelerometer measurements (29, 32). An assessment of the potential complimentary tools available to the researcher is reported in Section 5.4.5.

Pilot study recommendation 4: Employ strategies to ensure optimal accelerometer wear-time

Adjustable accelerometer belts were made by the researcher to reduce costs compared to pre-made versions. Lengths of the elastic for belts were cut as close to mean waist circumference estimates appropriate for the 9-10 years age of Masters pilot (2) participants of 57.45cm (58.10cm (SD=5.62) for boys and 56.81cm (SD=4.90) for girls (461)), with an additional 20cm added for belt adjustment. However, a small number of pupils in the overall sample (n=2; 2.4%) removed their belts during the day due to size discomfort. The researcher also taped a paper logo on the front of each accelerometer to show pupils which way up to wear their belt (Appendix 5B). Each logo also featured a device number to enable the researcher to log which participant had which device. A contact telephone number was also taped onto the back of each accelerometer to aid return if devices went missing. As future VFT intervention work aimed to assess physical activity over long periods of time and beyond the school environment (Chapter 6), strategies were required to ensure optimal accelerometer comfort and wear-time. The approaches used in longitudinal VFT work are reported in Section 6.4.3.

5.3 Chapter 5B. Study One: Perceptions towards Virtual Field Trips in teachers and pupils

The full study can be read in the published BMC Research Notes paper (4) (Appendix 5C).

Reviewing existing physically active lesson literature (Chapter 4) and the Masters project VFT pilot study (Section 5.2) provided useful insight into past research and areas for methodological improvement. However, this work could not provide specific perceived strengths and weaknesses of physically active VFTs from target users. They also do not provide first-hand accounts of physically active lesson use in UK teachers.

Perceptions were sought into the content and software of the proposed VFT intervention in both teachers and pupils. Given the novel nature of this technology-based intervention, it was essential to highlight potential barriers to VFT use prior to larger-scale intervention work. It has been widely shown that accounting for institutional and individual barriers around school health interventions is essential to maximise intervention implementation (462, 463). Developing the intervention without prior consultation from its recipients would likely lead to reduced acceptability and subsequent reduced fidelity, reach and dosage (449, 464). Additionally, it was also important to identify perceived facilitators of VFT use to highlight to potential participant schools during recruitment phases.

Qualitative methods to identify user perceptions of barriers and facilitators are useful at pre-trial stage to improve effectiveness in subsequent interventions (449). With this PhD adopting an exploratory sequential mixed methods design (449, 463, 464); a qualitative component was hence devised to identify teacher and pupil perceptions prior to larger-scale intervention work.

5.3.1 Research questions

i) To what extent do participants perceive physically active lessons to be present in UK teaching practice?

ii) What are the perceptions of teachers towards VFTs as physically active lessons?

iii) What are the perceptions of pupils towards VFTs as physically active lessons?

5.3.2 Objectives

The objectives of this study were to:

i) Appraise the perceived extent of current physically active lesson use in current UK educational practice

ii) Explore teacher attitudes towards physically active VFTs after a sample session

iii) Explore pupil attitudes of physically active VFTs after a sample session

5.3.3 Incorporation of recommendations from systematic review

Recommendations identified in the systematic review (Chapter 4) were assessed to be incorporated into this qualitative feasibility study.

Literature-based recommendation 2: Involve teaching staff during VFT development

To meet this recommendation, this study sought to explore the views of teachers as well as pupils towards physically active VFTs at the feasibility stage of research. Two teachers interviewed in this study also worked with the researcher to develop the larger-scale VFT programme (Section 6.4.5).

5.3.4 Methods

5.3.4.1 Design

Teacher semi-structured interviews and pupil focus groups were carried out by the author. One-on-one teacher interviews were used to allow extended discussion on respondent's individual opinions and taught experience (465). With children less familiar with one-to-one discussion with an adult (466), focus group methodology was used to obtain the views of multiple pupils in a more relaxed environment. The author held a 'moderator' role in the focus groups to facilitate comfort, ensure all children contribute to a focused discussion and to seek clarification of unclear points (467). The Consolidated criteria for Reporting Qualitative studies (COREQ) checklist was followed (468) to provide explicit and comprehensive reporting of these qualitative findings.

5.3.4.2 Participants

Convenience sampling in Greater London was used for both teacher interviews and pupil focus groups. Teachers were recruited during the 2013/4 school summer holidays via personal contacts and social media. Pupils were recruited during July to October 2014 via direct enquiries to schools. Discussions were held until the author observed saturation of ideas (469).

5.3.4.3 Ethical approval

UCL ethical approval was granted for both components of this qualitative research (Ref: 3500-003). This included allowing photographs to be taken during pupil focus groups. Informed consent forms were provided on the day of scheduled discussions for teacher interviews. For pupil focus groups, the researcher delivered a 5-minute introduction to the research topic a week before the scheduled focus group date. Parent (Appendices 5D & 5E) and pupil (Appendices 5F & 5G) information sheets and informed consent forms were then supplied for children to take home. Pupils with reading difficulties or who used English as a second language received an additional one-to-one description of the study by a class teaching assistant and the researcher. Only pupils with both completed parent and pupil consent forms could participate in a focus group. Teacher interview information and informed consent sheets are shown in Appendices 5H & 5I respectively.

5.3.4.4 Instrumentation

An interview script of open-ended questions was developed to ensure standardised enquiry in both teacher interviews (Appendix 5J) and pupil focus groups (Appendix 5K). This featured opening questions exploring experiences of physically active lessons and questions on the perceived strengths and weaknesses of VFTs. The Olympic-themed VFT from the Masters pilot project was used as a demonstration, presented on Google Tour Builder (47): the second iteration of VFT software development (Section 5.4.3.2). All interviews were audio recorded using an Olympus DM-450 Dictaphone.

5.3.4.5 Procedure

Teacher interviews were held at a time and place convenient to each participant, typically in their home. Pupil focus groups were held at schools in vacant classrooms. To facilitate comfort, focus group seating was arranged in a circle and children were allowed to choose their own seat (466). The researcher acted as a 'moderator' to ensure a focused discussion contributed to by all and to seek clarification of unclear points for accurate analysis (467, 471). To ensure audible recorded comments, an inflatable globe was passed between pupils to denote the person speaking at that time. An additional researcher (Dr Nicola Shelton) observed the first pupil focus group to provide feedback on non-verbal responses from participants and take photographs. The researcher made field notes during teacher interviews and pupil focus groups.

Informed consent forms were signed prior to interview, with parent consent additionally required for pupils. Teacher interviews lasted between 20 to 60 minutes and pupil focus groups lasted between 40 and 60 minutes. Questions first assessed the interviewee's attitudes towards school-based physical activity and then asked them to describe lessons they had experienced integrating physical activity other than PE. A VFT demonstration was then provided. In teacher interviews, this was delivered on a laptop with verbal description of how physical activities are integrated. In pupil focus groups, this was delivered by the researcher on an interactive whiteboard, with pupils taking part in the relevant activities. Questions then assessed the potential benefits and weaknesses of VFTs as physically active lessons.

5.3.4.6 Data analysis

Thematic analysis was used to analyse transcripts, which allows patterns within qualitative data to be identified, analysed and reported (472). Analysis was performed following the six phase method advocated by Braun and Clarke's (2006) seminal paper. Phase 1 involved familiarization with the data via verbatim transcription on the day of the interview using Express Scribe software, before reading and re-reading the data. Initial codes across the entire data set were generated in Phase 2, with data collected according to each code and recorded using Microsoft Excel. Themes were then sought by collating codes into potential themes (Phase 3), with these themes then reviewed against both the coded extracts and entire data set (Phase 4). Six themes from teacher interviews and four themes from pupil focus groups with clear names and definitions were established at Phase 5. These were used to produce the final report of the data in Phase 6 (473). An inductive approach was used to allow themes to emerge directly from the data (473). The number of participants reporting each theme was recorded.

5.3.5 Findings

5.3.5.1 Teacher interviews

Twelve teachers were interviewed, with ten working in primary-schools (ages 4 to 11) and two working in secondary schools (ages 11 to 18). Eleven interviewees were female, one interviewee was a PE co-ordinator, one was a primary school head teacher and two worked primarily with Special Educational Needs (SEN) children. All teachers worked in different Greater London schools. The participants collectively held 62 years' experience working in schools, ranging from one year to twenty years.

5.3.5.1.1 Current physically active lesson teaching practices

Many interviewees (n=8, 66.7%) described physical activity in taught lessons as "*becoming more the norm*" and routinely taught in modern teacher training. Incorporating physical activity was also described as representative of engaging teaching practice by some participants (n=4/12, 33.3%), "*If teachers aren't doing that then they're boring teachers*". There was evident variability in use of physically active lessons, with teachers (n=4, 33.3%) describing their use according to perceived group learning styles: *"I think it just depends on the children".* Physical activity breaks and lessons were mentioned by interviewees (n=8/12, 66.7%) as a de-stressing and focusing technique for children: "*it gives you both a bit of a break as well and it just re-jigs their mind and gets them back on task*".

5.3.5.1.2 Barriers of physically active Virtual Field Trips

1) Time

All interviewees (n=12, 100%) described children as insufficiently active during school hours. Movement was stated as often restricted to break and lunchtimes due to academic pressures. For example, PE classes were mentioned by some (n=4/12, 33.3%) as often removed in favour of other academic lessons: "*PE as well is one of the lessons where if you've got something else planned that you need to do then PE is the one that goes".* There was also evident variability in school resources and attitudes towards physical activity. Whereas some interviewees stated extra-curricular sports and activities as a priority in their school: "*our school is very lucky as we have parents that are willing to pay for that* (extracurricular physical activity) *and we have a company that comes in to work with us*"; others felt their school prioritised academic targets: "*to be fair to the schools I think how much time do you have?*

There's so much pressure on what they're learning and the timetable's so rammed so you can't fit any more in."

Most teachers (n=10/12, 91.7%) reported a need for VFT sessions to be presented as a ready-made package: "*definitely, definitely, definitely have it ready for us or I reckon teachers won't use it."* Again relating to the strong academic pressures, many teachers saw a need for sessions to be fully developed to minimise time costs in preparation: "*There's often not a lot of time for new things. I don't think many people would want to sit and make these."* The following quote clearly illustrates this issue:

"It depends what teacher you get because if you've got someone who's confident in ICT, confident in developing and wants to, the type of person who puts things on Primary Resources or TES (Teaching resource websites) *and is really proud of all their resources, of course they will* (develop their own VFTs)*... and then quite frankly they go and have families and have lives! And then when you get a life, you don't have time to sit on a Sunday evening and start making these… anything like this needs to be easy to implement that can be used straight away"*

Headteacher, 20 years' teaching experience, 1 year head teaching experience

2) Resistance to technology

Various sub-themes in negative or resistant attitudes towards technology by teaching staff and schools were noted. Firstly, (n=7/12, 58.3%) highlighted that VFTs could receive different reactions from teachers depending on their ICT competencies. However no interviewed teachers felt that they themselves would have difficulties using the technology. This was stressed as a vital consideration to keep in mind during school and teacher recruitment. The following quote clearly expresses this issue:

"There's some staff who rely so heavily on technology and their whole lesson features technology in such different and often really creative ways… but there's teachers who are just very old-school who don't even want to use the interactive whiteboards and really shy away from information tech-type lessons… I think the biggest battle will be getting the teachers to not be lazy and have a go at using it."

Secondary School English Teacher, 4 years' experience

Secondly, a minority of teachers (n=3/12, 25%) queried the suitability of using VFT technology to reduce sedentary behaviour: "*You could use electrical tools like this but you don't have to*". They described viewing technology itself as a primary cause of child inactivity, proposing a non-technological alternative as potentially more appropriate. For example, "*we're using technology to solve a problem that technology has caused*", suggests perception of a cyclical relationship between technology and activity in these interviewees. Some teachers (n=2/12, 16.7%) described how outside activity is valued over class-based movement in their schools. For example "*Schools like mine* (would say) *'Take them outside'*".

3) Potential novelty factor

Some interviewees (n=3/12, 25%) identified a potential limited "*novelty*" factor for the interactive maps and media content in VFTs. Although no interviewed teachers had seen the Google Tour Builder programme used before, some were wary it could become stale after a few lessons. For example: "*think the novelty will be there with un-technological children but for those that are used to technology, they'll be like 'OK I get it'*" Additionally, two teachers (n=2/12, 16.7%) reflected that schools find it difficult to keep up with frequent evolutions in technology: "*with technology, nothing impresses them. If anything we're more impressed because we are behind, children are ahead of us*."

5.3.5.1.3 Facilitators of physically active Virtual Field Trips

1) Flexibility of VFTs as teaching tool

All teachers (n=12, 100%) provided a variety of creative ways that VFTs could be used in their teaching. These ranged from "*starters or plenaries",* to *'brain breaks'* to increase children's attention in the morning or after lunch. Teachers also enthusiastically provided a multitude of topics that VFTs could cover. Common areas included geography and history based themes, such as "*With Year 5.. the Victorians, Africa, the Aztecs, water, Geography, Earth Sun and Moon in Science, extreme Earth like tsunamis and lightning…*". Some teachers (n=5/12, 41.7%) also mentioned the potential for '*Maths*' or English-based sessions: "*You could also do a story map of a book*." One teacher (8.3%) also emphasised the potential for VFTs as physical education teaching tools: "*this lends itself beautifully to PE teaching.. give me* *something on there that shows me the correct technique.. we learn together as we practice it in class.*"

Additionally, some (n=5/12, 41.7%) described physically active VFTs as being "*cross-curricular*" in nature by linking physical activity to other topics such as Maths and English: a key feature of the new National Curriculum (364). Two teachers (16.7%) described VFTs as also being useful within ICT for older primary-age pupils: allowing them to develop sessions themselves. Some teachers (n=3/12, 25%) also mentioned the opportunity to add a competitive element to VFTs: encouraging group-based challenges to be more active. For example, "*You could have competition and a leader board that was topic-based like with the fire (Great Fire of London): 'Who could run away from the fire?' or 'Who can escape the plague quickest today?'*"

2) VFTs for inclusive learning

A common theme throughout all teachers' responses was the potential of VFTs as teaching tools to include all pupils in an equal learning environment. The presence of both visual and kinaesthetic elements in active VFTs was appealing to many teachers (n=6/12, 50%) who saw this as "*encouraging all types of learning styles to participate in lesson which is really good".* Some teachers (n=5/12, 41.7%) also described physically active VFTs as useful to manage behaviour in pupils with attention disorders. Examples of conditions included ADHD, autism, or "*those that a general static lesson doesn't necessarily grasp their attention for long enough*". Teachers reflected on their use of physical activity in lessons especially to cater for these populations: "*We do that all the time if any kid with SEN or ADHD, we always have physical activity involved in their lessons and that's mainly for them!"*

VFTs were also described by some as a useful alternative to school trips. Some teachers (n=4/12, 33.3%) described how ever-expanding school populations made organising school trips "*a logistical nightmare"*. This concurs with previous VFT research, where development was inspired by cost, planning and travel restrictions within higher education (342, 347). They were also seen as useful for physically disabled pupils who may be restricted by the actual school trips they can participate in (n=2/12, 16.7%): "W*e had a boy last year in a wheelchair and there was a lot of school trips we couldn't do as they just didn't have the access*."

5.3.5.2 Pupil focus groups

Three focus groups were held, two with Year 4 pupils (n=12; 8 to 9 years old) and one with Year 5 pupils (n=6; 9 to 10 years old). Nine boys and nine girls participated. All focus groups were held in different Greater London schools.

5.3.5.2.1 Experiences of school-based physical activity

All pupils reflected on their enjoyment of school playtime, swimming and extra-curricular physical activity opportunities. They also provided memorable experiences of lessons integrating physical activity: "*I enjoy when we have Maths and sometimes we go outside and we do activities.. have to do charts of the activities*."

5.3.5.2.2 Views on physically active Virtual Field Trips

1) VFTs to share experiences with peers

All students commented on VFTs as an opportunity to have "*fun*" with their peers. As seen in teacher interviews, pupils also suggested the introduction of teams to encourage physical activity competitiveness during the sessions. It was also mentioned that alternation of these teams would allow interaction socialisation with different pupils. For example, "*You could have like a weekly group and you could keep changing it round so you get to socialise with other people… and just like try and also get to know them while learning.*" Three students (16.7%) mentioned how VFTs could be used to explore and share countries from their family heritage, "*I would like to go back to my home country.. I've heard these really cool stories about this really big volcano there and I would like to see it*".

2) VFT novelty

Pupils indicated familiarity with Google Earth software but described liking the novelty of using their bodies during the lesson and to answer questions. *"I liked it.. You could move around and use body movements to get picked (*to answer a question*)."* Pupils also discussed how being active made them feel more immersed in the locations of the VFT: *"you was like moving your arms, legs and your stomach to actually feel like you're actually going to that country".*

3) Exertion of VFT physical activity

Some children commented on feeling tired after the demonstration VFT, such as "*You really get tired as you start to travel somewhere..*" and "*I need water!".* This may be expected given that the physically active session was innately novel compared to the sedentary teaching style they are used to.

5.3.6 Discussion

Previously published qualitative interviews and process evaluation research has uncovered facilitators and barriers effecting the implementation of school-based physical activity interventions (69, 284, 293). This study aimed to identify potential facilitators and barriers of VFT use in teachers and pupils, prior to longitudinal intervention research.

5.3.6.1 Facilitators of VFT use

Teachers explicitly described factors facilitating VFT use. VFTs were praised as inclusive learning tools due to their innate combination of kinaesthetic, audio and visual elements. They also provided a broad range of suggestions for potential VFT sessions, showing scope for integration across the curriculum. Both teachers and pupils identified a potential for active VFTs to enable challenges between classmates: encouraging pupils to compete and be more active in sessions. Interestingly, this desire for competitiveness in VFT sessions contradicts previous research, finding increased overall PA enjoyment when rivalry is not involved (474). Ideas for adding competition within VFT classes were subsequently included in teacher training (Section 6.4.6).

Another discreet facilitator can also be derived from teacher interviews. Despite the systematic review identifying little empirical evidence for physically active lessons in the UK (Section 4.5), teachers reported common use of these sessions in their own practice. Activity integration was reported as indicative of good teaching practice and embedded into modern teacher training. If this observed familiarity with physical activity integration is also found within the wider primary teaching population, it may serve as a facilitator in future intervention work. Teachers may be more used to developing lessons with physically active elements and may be more inclined to adopt VFTs into their regular teaching.

5.3.6.1.1 Barriers to VFT use

Various important barriers were identified. Firstly, lack of time was seen as an important potential barrier for VFT use. This was also identified as the most consistent barrier in a recent systematic review of implementation issues in school-based physical activity interventions (284). Multiple demands for academic, physical and social outcomes are present in schools (222), often making it challenging for teachers to integrate physical activity into their busy curriculum (475). To maximise recruitment and fidelity in future research, school recruitment and teacher training stages must highlight research showing increased PA in schools to not compromise academic achievement (128) and classroom behaviour (132). It is essential that the VFT intervention must be acceptable to multiple stakeholders such as the head-teacher, teachers, parents and governors (222) to maximise uptake and minimise attrition.

Secondly, although VFTs were described by the researcher as ready-made sessions, some teachers warned of potential resistance from peers less confident in using technology. This may produce a biased sample in future intervention work. Teachers with lower technology proficiency may be less likely to participate in VFT interventions, or less likely to complete them as intended. Full training will be provided but this may still be insufficient to encourage some teachers of the merits of active VFTs. These considerations of VFT use replicate the Technology Acceptance Model (TAM) (453, 476), also seen as relevant in the Masters pilot project (Section 5.2.3). As found in other school-based TAM research (454, 455), teachers who perceive VFT technology as useful and easy to use should be more likely to use it. It will hence be necessary in future work to improve software functionality as much as possible (Section 5.4.3) and emphasise benefits to teachers during VFT recruitment and training (Section 6.4.6).

Teachers predicted a potentially small degree of novelty for VFTs. Pupils also showed familiarity with the Google Earth-based software used and enjoyed the novel addition of activity to travel to and explore locations. By integrating a variety of media, locations and movements into future VFT programmes, it is hoped that pupil's perceived enjoyment and novelty will persist. Longitudinal VFT study will assess if these perceptions of novelty remain during regular sessions and whether children become more attuned to being active during VFT sessions.

Finally, children reported high levels of physical exertion during VFT sessions. This seems to support accelerometer findings from the Masters project showing VFTs to instigate MVPA (2). Although the VFT used in this study featured breaks between each activity; it is important to be aware that children may feel over-exerted during this novel active teaching method. Measurement of exertion during VFTs in longitudinal study will show if this is related to actual physical activity levels and enjoyment of sessions. Interestingly, other barriers commonly cited in school physical activity research of lack of space and safety concerns (84, 288) were not cited in this sample.

5.3.6.1.2 Study strengths and limitations

This study was evaluated against the qualitative research trustworthiness criteria advocated by educational researcher, Andrew Shenton (477). Other methods of assessing quality in qualitative research are available (478), however Shenton's criteria were chosen for their clear description and comprehensive inclusion of validity and reliability considerations. Study One was evaluated against four overarching criteria of credibility, transferability, dependability and confirmability (477). Firstly, credibility was assessed in terms of internal validity: evaluating if this study measured what was actually intended. Triangulation of different methods ensured that settings were best suited to capture the opinions of respective audiences (479), providing a familiar peer environment in pupil focus groups (480) and time for extended answers in teacher interviews (465). The adoption of well-established research analysis was evident in the use of semi-structured interview scripts and Thematic Analysis techniques (473) to analyse data. Additionally procedures followed within both teacher interviews and pupil focus groups such as the use of prompts, pupil seating arrangements and group size adhered to previous published educational and health-based qualitative work (466). However, convenience sampling was used to recruit a small sample of teachers, with pre-existing relationships between interviewer and interviewee present in some interviews. This personal connection may have led participants to withhold their true negative feelings about the subject matter (481). Conversely, it could be seen that this familiarity may have encouraged respondents to be more honest in their VFT evaluations to ensure accurate results for the researcher (481). Although two teachers continued their engagement with the project by providing subsequent support for full intervention development (Section 6.4.5), there was generally a lack of prolonged engagement between the investigator and teachers and pupils. This may have limited trust between parties and prevented true understanding of respondents' respective school environments (479). There is mixed evidence for holding child focus groups in school settings and using existing class relationships. Pupils may have been positively prompted to answer to the best of their ability as with typical teaching, or may have conversely felt distracted by existing peer relationships or repressed by school expectations of adult-child hierarchies (480, 482). Negative case analyses (cases contradicting the status quo) were reported wherever evident to include all considerations potentially of use in this feasibility stage of VFT work (477). Perceived facilitators and barriers of potential physically active VFT use such as time needed to deliver and prepare sessions, were largely aligned with wider qualitative work in this area (284).

Secondly, transferability was assessed in terms of external validity: evaluating how generalizable this study's findings are to wider educational populations (477). Although qualitative research is somewhat bound to the populations, geographical location and organisations in which fieldwork is performed, it is important to recognise the boundaries of this study's conclusions (477). Participants across both methods were drawn from different Greater London schools, which may limit applicability of findings to other geographical locations. Participating teachers had a broad range of teaching experience across mainstream and SEN education. This may mean findings would not be replicated in other samples with different levels and ranges of experience (477). Teacher interviews were held in a variety of locations during the school holidays to maximise recruitment, which may limit replicability compared to solely school-based settings (483).

Thirdly, dependability was assessed in terms of reliability: evaluating if the same results would be obtained using the same participants, contexts and methods (477). The possibility for replication is generally limited in qualitative research as responses are tied to the exact context of original data collection (484). As these participants have now already been exposed to novel VFTs, responses would likely differ when questioned about them on a second occasion. However, methods and analysis techniques were reported as best as possible to allow replication in other contexts. Finally, confirmability was assessed in terms of relative objectivity: how much the observed findings were the result of ideas and experiences of participants, rather than characteristics and expectations of the researcher (477). As the researcher was due to perform the subsequent VFT intervention herself, it may have been that respondents felt obliged to respond overly positively to the sample session (484). Different responses may have been observed if an alternative interviewer who was not connected to ongoing VFT research ran these investigations instead. However, this would not meet the requirements for work as part of a PhD thesis.

5.3.7 Conclusion

This study provides valuable insight into UK teachers' and pupils' perceptions of VFTs as active lessons. The potential for VFTs as an inclusive and flexible teaching tool was highlighted. Potential issues were identified to be addressed before further intervention work. Firstly, teachers warned that the use of novel technology could limit teacher appeal, which may in turn bias the recruited intervention sample. Secondly, teachers stressed that VFT sessions must be ready-made and curriculum-focused to maximise uptake. Teachers also thought that pupil enjoyment of VFTs may lessen over time due to a reduced novelty factor. Finally pupils demonstrated physical exertion during VFTs, which may manifest in negative views of these sessions in children.

5.3.8 Recommendations for future VFT research: Study One

This second, qualitative VFT feasibility study provided provisional information on the suitability and effects of physically active VFTs in primary schools. Recommendations arising from teacher interviews and pupil focus groups were identified to be addressed prior to larger-scale VFT intervention work.

5.3.8.1 During VFT development

Study One recommendation 1: Ensure VFT programme relates to specific curriculum content

As with other studies (222, 284, 475); teachers stressed a lack of teaching time as a barrier to using physically active lessons. These findings have been recently replicated by Department for Education research (292), showing multiple responsibilities and targets as distressing to teachers (n=1,685). The full VFT intervention was comprised of ready-made sessions and tailored to year-specific National Curriculum content (364). This enabled VFTs to be integrated into existing class subject timetabling and helped facilitate optimal uptake. Unlike most of the physically active lesson interventions identified in the systematic review; the VFT programme was developed with teachers of target year-groups to ensure the programme is relevant. Development of the curriculum-relevant content is described in Section 6.4.5.

Study One recommendation 2: Develop and provide VFT teacher training

Evident in this study was a need for VFTs to be presented as a ready-made package with clear instructions. Hence to further maximise uptake of this novel intervention, full teacher training is required. This will firstly need to highlight the evidence-based benefits of physical activity for children's health, wellbeing, academic achievement and classroom behaviour. It will also need to provide one-to-one teacher use of the VFT intervention and a full introduction to the programme. The provision of an accompanying step-by-step manual will also aid ease of use. Full details of VFT teacher training is provided in Section 6.4.7.

Study One recommendation 3: Assess pupil exertion during VFTs

Some pupils in this study reported perceived exertion during the VFT session: recognised to represent subjective symptoms of physical strain (485). Perceived exertion has not been measured in previous physically active lesson interventions (Chapter 4). However it has been assessed in Active Video Game (AVG) interventions for children: where perceived AVG exertion ratings were equivalent (486) or greater than walking (487). It has also been assessed in after-school physical activity intervention as a form of process evaluation (488). Assessing ratings of perceived exertion in future longitudinal intervention work will help assess potential associations with physical activity and VFT enjoyment (Section 5.4.5.4).

5.4 Chapter 5C. Changes made after feasibility work

The recommendations identified in systematic review and feasibility work are now addressed. This allows intervention and measurement improvements to be made prior to the longitudinal VFT intervention. A summary of the changes made and where they are addressed in the thesis can be found in Table 5-1.

5.4.1 Provide theoretical background

Literature-based recommendation 1: Provide theoretical background

The systematic review showed a lack of theoretical background in past physically active lesson research (Section 4.5.4). Theory is important for interventions as it allows researchers to understand the 'active ingredients' influencing behaviour change in participants (489). Physically active lesson interventions and child health interventions more generally seem to focus on answering the questions: 'How well does it (the intervention) work?', using effect sizes and sample sizes, or 'Does it work?' using process evaluation tools (490). Instead, Professor Susan Michie's key work into the standardisation of behaviour change interventions argues that the core question asked of interventions should be 'How does it work?'. By using a supported theoretical basis in intervention development and providing clear, detailed descriptions of the techniques embedded within interventions, successful programmes can be replicated (282, 490, 491). This is especially important for school-based interventions such as physically active lessons, where the ultimate aim of research should be for translation into educational practice.

Although theories provide insight into how behaviour may change, they often do not provide advice on how to actually develop associated interventions (491, 492). This is evident in the aforementioned Social Ecological Model outlined in Section 2.5.4. This shows the range of influences health behaviours from intrapersonal behavioural factors to interactions between individuals and wider social, physical and policy environments (211, 493). However, it provides no advice on how these relationships can be targeted and addressed via interventions. As such, Michie and colleagues have developed a range of flexible tools to enable behaviour change theory and techniques to be implemented across disciplines and behavioural outcomes (494). By ensuring VFT components are embedded in theory as much as possible and by describing the intervention in terms of comparable behaviour change techniques, the VFT intervention will be more replicable (437, 494).

Table 5-1: Recommendations made from systematic review and feasibility work to apply in remainder of PhD

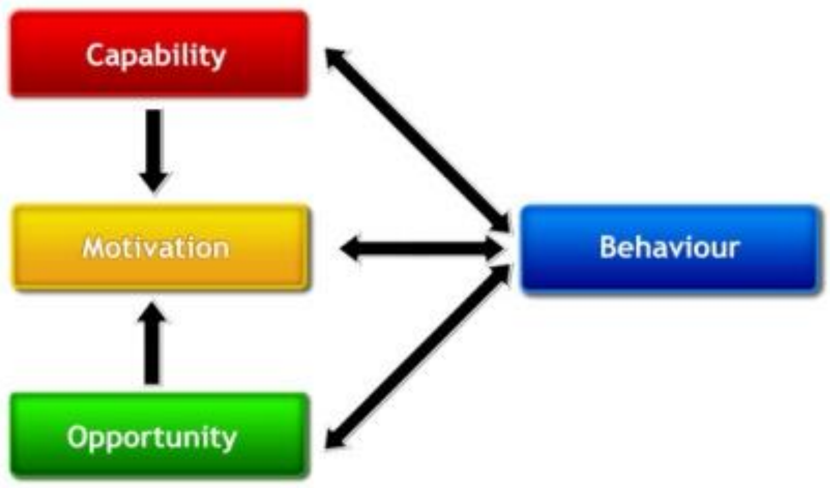
Recommendation	How issue addressed	Where issue addressed
Literature-based recommendation 1: Provide theoretical background	Capability, Opportunity, Motivation (COM-B) model applied to Virtual Field Trip (VFT) context	Section 5.4.1 (1)
Literature-based recommendation 2: Involve teaching staff during VFT development	1) Teachers consulted in qualitative interviews during feasibility work 2) Teaching staff helped to design longitudinal VFT intervention around curriculum	1) Section 5.3 (4) 2) Section 6.4.5 (1)
Literature-based recommendation 3: Use accelerometers to assess activity intensity of VFTs	Accelerometers used as primary physical activity measure	1) Section 5.2 (2) 2) Section 6.4.9.2 (1)
Literature-based recommendation 4: Record pupil physical activity for longer periods	Accelerometers assessed physical activity during four whole days at each data collection point	Section 6.4.9.2 (1)
Literature-based recommendation 5: Ensure intervention and follow-up periods are as long as possible	6-week intervention period and 3-month follow-up for longitudinal VFT intervention: the longest possible with available PhD resources	Section 6.4.1 (1)
Literature-based recommendation 6: Measure and analyse VFT intervention effects by pupil demographics	Analyses run accounting for demographics	1) Section 5.2 (2) 2) Chapter 7 3) Chapter 8
Literature-based recommendation 7: Fully evaluate developed VFT intervention	Longitudinal intervention evaluated according to RE-AIM framework	1) Section 6.4.9.5 (1) 2) Chapter 9
Literature-based recommendation 8:	Full intervention description with Behaviour Change Techniques	Section 6.4.6 (1)

Ensure VFT intervention is fully described to allow replication		
Pilot study recommendation 1: Use VFT software more compatible with school technology	1) Google Tour Builder browser plug-in used 2) PowerPoint with embedded Google Earth pictures and videos used	1) Section 5.4.3.2 (4) 2) Section 5.4.3.3 (1)
Pilot study recommendation 2: Use accelerometer cut-points most appropriate for VFT intervention	Review of accelerometer cut-points literature ensured most appropriate used	1) Section 5.4.4.1 2) Section 6.4.9.2
Pilot study recommendation 3: Assess feasibility of combining accelerometers with other forms of VFT physical activity measurement	1) Feasibility of Heart Rate monitoring and observational physical activity assessed 2) Observational measures used in longitudinal VFT study	1) Section 5.4.5 2) Section 6.4.8.3 (1)
Pilot study recommendation 4: Employ strategies to ensure optimal accelerometer wear-time	Pupil competition based on accelerometer-wear time in longitudinal VFT study	1) Section 6.4.3 (1) 2) Section 7.3.1
Study One recommendation 1: Ensure VFT programme relates to curriculum content	Teaching staff helped to design longitudinal VFT intervention around curriculum	Section 6.4.5 (1)
Study One recommendation 2: Develop and provide VFT teacher training	Teaching training provided prior to longitudinal VFT intervention	Section 6.4.7 (1)
Study One recommendation 3: Assess pupil exertion during VFTs	Pupil exertion assessed by questionnaire in longitudinal VFT intervention	1) Section 6.4.9.5.3 (1) 2) Section 9.3.2.2

5.4.1.1 The Capability, Opportunity, Motivation – Behaviour (COM-B) model

The Capability, Opportunity, Motivation (COM-B) model has been recently introduced by Michie and colleagues as a framework for understanding behaviour change across interventions (282). It proposes behaviour as understood in the context of the individual's existing Capability: the individual's physical and psychological capacity to engage in behaviour, Opportunity: the social and physical factors outside the individual that make behaviour possible and Motivation: cognitions that automatically and reflectively facilitate and empower behaviour (282, 494) (Figure 5-2). The directional arrows represent potential influence between components in the model. For example, capability and opportunity can influence motivation; with a reciprocal influence indicated between behaviour and all three cognitions (282). The COM-B model can be applied to intervention design by considering what the behavioural outcome target is, and what cognitions are required to change to facilitate improvements in this outcome (282).

Figure 5-2: The COM-B model as a framework for understanding behaviour (282)



Numerous other theories of behaviour change exist, emerging from a range of psychological, economic and sociological backgrounds (492). As previously discussed (Section 2.5), these theories generally have a narrow focus of potential determinants of behaviour change depending on their disciplinary background (212). In contrast, the COM-B model provides a simple framework for incorporating a broad range of physical, psychological and social aspects. A critique of this approach can be found in Section 5.4.1.3.

5.4.1.2 Behaviour Change Technique Taxonomy version 1 (BCTTv1)

Another integral tool in Michie's work towards standardising behaviour change interventions is the Behaviour Change Technique Taxonomy version 1 (BCTTv1: hereby referred to as BCTT) (495). As found in the systematic review, the content of physically active lesson interventions is poorly described. This limited intervention reporting seems to be typical across disciplines and presents a major barrier to scientific and real-world implementation (437, 491, 496). Although intervention descriptions are required in CONSORT guidelines for randomised controlled trials (497), Michie identified that there was little guidance on how to actually report such details (437). The BCTT was hence designed to act as a rigorous method of specifying the effective 'active ingredients' (489) or 'Behaviour Change Techniques' (BCTs) within interventions (495). By reporting the exact nature and content of interventions in a standardised way, studies can be more accurately compared and replicated (437, 496, 498).

The BCTT provides specific description of 93 techniques clustered into 16 groups that can be used within interventions to increase the likelihood of behaviour change (495) (Figure 5-3). These techniques were identified in a Delphi-type exercise, where 14 experts rated labels and definitions of 124 BCTs identified from an extensive literature review (495). Under this taxonomy, BCTs are described as applicable to a range of health behaviours and can be used alone or in combination with each other (495). BCTs are clearly and concisely described to allow maximal understanding across disciplines and user backgrounds (495). The BCTT presents the large number of BCTs in a hierarchical structure according to groupings of similar themes (495): replicating taxonomies common in the natural and social sciences (499).

Figure 5-3: Behaviour Change Technique Taxonomy version 1 (BCTTv1) (495)

Grouping and BCTs	Grouping and BCTs	Grouping and BCTs

1. Goals and planning 1.1 Goal setting (behaviour) 1.2 Problem solving 1.3 Goal setting (outcome) 1.4 Action planning 1.5 Review behaviour goal(s) 1.6 Discrepancy between current behaviour and goals 1.7 Review outcome goal(s) 1.8 Behavioural contract 1.9 Commitment **2. Feedback and monitoring** 2.1 Monitoring of behaviour by others without feedback 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome(s) of behaviour 2.5 Monitoring of outcome(s) of behaviour without feedback 2.6 Biofeedback 2.7 Feedback on outcome(s) of behaviour **3. Social support** 3.1 Social support (unspecified)	**5. Natural consequences** 5.1 Information about health consequences 5.2 Salience of consequences 5.3 Information about social and environmental consequences 5.4 Monitoring of emotional consequences 5.5 Anticipated regret 5.6 Information about emotional consequences **6. Comparison of behaviour** 6.1 Demonstration of behaviour 6.2 Social comparison 6.3 Information about others' approval **7. Associations** 7.1 Prompts/cues 7.2 Cue signalling reward 7.3 Reduce prompts/cues 7.4 Remove access to reward 7.5 Remove aversive stimulus 7.6 Satiation 7.7 Exposure 7.8 Associative learning **8. Repetition and substitution** 8.1 Behavioural practice/rehearsal 8.2 Behaviour substitution 8.3 Habit formation 8.4 Habit reversal 8.5 Overcorrection 8.6 Generalisation of behaviour 8.7 Graded tasks **9. Comparison of outcomes** 9.1 Credible source 9.2 Pros and cons 9.3 Comparative imagining of future outcomes **10. Reward and threat** 10.1 Material incentive	**11. Regulation** 11.1 Pharmacological support 11.2 Reduce negative emotions 11.3 Conserving mental resources 11.4 Paradoxical instructions **12. Antecedents** 12.1 Restructuring the physical environment 12.2 Restructuring the social environment 12.3 Avoidance/reducing exposure to cues for the behaviour 12.4 Distraction 12.5 Adding objects to the environment 12.6 Body changes **13. Identity** 13.1 Identification of self as role model 13.2 Framing/reframing 13.3 Incompatible beliefs 13.4 Valued self-identity 13.5 Identity associated with changed behaviour **14. Scheduled consequences** 14.1 Behaviour cost 14.2 Punishment 14.3 Remove reward 14.4 Reward approximation 14.5 Rewarding completion 14.6 Situation-specific reward 14.7 Reward incompatible behaviour 14.8 Reward alternative behaviour 14.9 Reduce reward frequency 14.10 Remove punishment **15. Self-belief** 15.1 Verbal persuasion about capability

3.2 Social support (practical) 3.3 Social support (emotional) **4. Shaping knowledge** 4.1 Instruction on how to perform the behaviour 4.2 Information on antecedents 4.3 Re-attribution 4.4 Behavioural experiments	10.2 Material reward 10.3 Non-specific reward 10.4 Social reward 10.5 Social incentive 10.6 Non-specific incentive 10.7 Self-incentive 10.8 Incentive (outcome) 10.9 Self-reward 10.10 Reward (outcome) 10.11 Future punishment	15.2 Mental rehearsal of successful performance 15.3 Focus on past success 15.4 Self-talk **16. Covert learning** 16.1 Imaginary punishment 16.2 Imaginary reward 16.3 Vicarious consequences

Since its inception, the BCTT has been applied within interventions to identify specific BCTs used with the taxonomy's coding system. As identified in the systematic review (Section 4.5.4), the COM-B model and BCTT have been partially applied within a physically active lesson intervention in the 'Active Classrooms' project of Martin and Murtagh (374, 500). BCTs were reported in the paper reporting preliminary findings (374) but not using the taxonomy's numerical coding. These tools are not yet routinely applied to physically active lesson research but provide potential for standardising the reporting of included techniques. This will benefit replication in both research and educational settings (494).

Systematic reviews are now scrutinising interventions across health issues according to their identification of specific BCTs. For example, a recent review of sedentary behaviour interventions for young people identified that BCTs are still often insufficiently described or not in the same terms adopted in the BCTT (501). The transition of this taxonomy in widespread practice will of course take time. However its' potential to allow comparability of intervention techniques and assist replicability has great promise.

5.4.1.3 Critique of COM-B and BCTT approach

The ambitious intentions of Michie's work to radically reform behaviour change theory and interventions have been strongly critiqued. The COM-B model has been criticized as being overly inclusive in its broad coverage of psychological, physical, social and environmental factors (502). The simple, pictoral nature of the model is clearly designed to be of appeal to a wide audience (494). However this simplicity cannot capture all the potential influences on complex human behaviours (503), such as physical activity in the context of this thesis. An inclusive model such as the COM-B evidently seeks to miss nothing but this nature makes it inherently hard to test (504). Some have described the approach of the BCTT to be 'over-systematizing', promoting standardized reporting according to set criteria rather than novel and scientific thinking (503, 505). It can be seen that the development of behaviour change interventions in this way may become restricted to pre-defined aspects, rather than a creative process truly incorporating the problem and context at-hand (505). As seen for the COM-B model, the all-inclusive nature of the BCTT arguably makes it difficult to test (506). It is still unclear what combinations of BCTT techniques work, in which situations and for which behaviours (506).

Despite this clear critique, the rate of COM-B and BCTT uptake in research has been astonishing since their inception. The work has collectively been cited over 7500 times (507) since its publication in 2013 (495), a large number for the field of behavioural medicine, or any field. Despite their weaknesses, the COM-B and BCTT do describe broad aspects of behaviour change influences simply. This makes them suitable for translation beyond academia and gives them broad appeal (504). With this thesis aiming to develop an intervention with real-world adoption by teachers in educational settings, the adoption of COM-B and BCTT to aid intervention description and development seemed relevant.

5.4.1.4 Application to VFT research

To increase children's physical activity in lessons, the COM-B model suggests that we must address three core cognitions influencing behaviour. As the provision of physically active lessons is ultimately the decision of the teacher, their cognitions are primarily important to the behaviour rather than those of the pupils. Firstly, the COM-B model suggests the need to increase individual teachers' physical and psychological capability to integrate activity into teaching, possible via training provision. Secondly, teachers' opportunity to teach physically active lessons must be increased. This should be done physically by supplying relevant, ready-made teaching resources and by ensuring activities are suitable given class space restrictions and socially by showing the perceived value of physically active lessons in training. Teacher's motivation to teach physically active lessons will increase if sessions are quick to run and produce visible activity and educational benefits to pupils. In addressing these three core cognitions, the COM-B model posits that the likelihood of actual physically active lesson teaching behaviour will increase (282). The suggestions of this framework on the cognitions important to physically active lesson behaviour in teachers are supported by findings of Study One (Section 5.3) and previous studies of teacher experiences (69, 284). The reporting of VFT intervention components according to the standardized and increasingly publicised BCTT (495) should ensure better understanding across academics, policy makers and educational professionals.

5.4.2 Involve teachers in VFT development

Literature-based recommendation 2: Involve teaching staff during VFT development

A lack of teacher inclusion in the development of previous physically active lesson studies was clear from the systematic review (Section 4.5.4). To ensure relevance of the VFT intervention to National Curriculum objectives (364), it was vital that teachers were involved in its development. Two teachers interviewed in Study One aided in the development of the main VFT intervention. Both teachers had recent or current experience of teaching Year 4 and were aware of its curriculum content. As such, Year 4 (8-9 years old) was chosen as the target year-group for the VFT intervention: as opposed to Year 5 pupils in the Masters pilot project. The researcher met with each teacher separately to discuss how the National Curriculum could be applied across each VFT session.

Study One recommendation 1: Ensure VFT programme relates to curriculum content

The systematic review identified that most physically active lesson interventions are delivered during Maths and English teaching (Section 4.5.4). There are no statutory requirements as to how often Maths and English or any subject is taught at Key Stage 2 (364). However, guidance from the Qualifications and Curriculum Authority recommends that to meet National Curriculum objectives; English should be taught for 5 - 7 ½ hours a week and Maths for 4 ¼ - 5 hours a week at Key Stage 2 (508). As these subjects represent the majority of teaching time at between 39-53% (508); English and Maths were decided as the basis for the VFT programme.

The researcher worked with the two Year 4 teachers to ensure VFT sessions related to year-specific statutory curriculum requirements (Section 6.4.5). For example in English, Year 4 pupils are required to explore non-fiction texts such as explanation texts (pg. 36; (364)) and so an 'Explanation Texts' VFT session was developed. This involved pupils using movement to travel to locations of diaries across the world, including Amsterdam to explore the home and diary of Anne Frank. For example in Maths, pupils are required to convert between different units of measure, such as from kilometre to metre (pg 127; (364)) and so a 'Metric Movements' VFT session was developed. This involved pupils using movement to indicate answers e.g 'Hop the answer: '500cl equals ? litres'', with pupils having to hop five times for the correct answer. The full programme of VFT sessions is shown in Section 6.4.5 and on the attached CD.

5.4.3 Revise VFT software

Pilot study recommendation 1: Use VFT software more compatible with school technology

5.4.3.1 Issues with first iteration: Google Earth

The Masters project pilot identified room for improvement with the Google Earth VFT software used (450) (Figure 5-4). Although Google Earth was beneficial in being already available on school computing systems, there were practical issues. School internet restrictions meant that different images and videos were available on different classroom computers within the same school. This required the researcher to make edits prior to each session to ensure functionality. Although tolerable in small-scale feasibility research, this issue is not permissible in larger-scale research or real-life implementation. In line with the Technology Acceptance Model (451, 453, 476) (Section 5.2.3); flawed technology that is difficult to use will less likely be adopted by service users (teachers), leading to reduced implementation and weak findings.

5.4.3.2 Second iteration: Google Tour Builder

Alternatives to Google Earth were sought during PhD work following the Masters pilot study. It was decided that a Google Earth-related interface was still preferred, given its innate geographical focus, 3D-model detail and familiarity to teachers. Google Tour Builder (470) was identified as a viable alternative to typical Google Earth software. It was originally developed to allow veterans to record their journeys of military service and share these easily with family (470). The targeted development of Google Tour Builder for plotting journeys and adding multimedia information gives a more professional appearance (Figure 5-4). As with Google Earth, Google Tour Builder is free-to-use and features user-developed 3D maps of major global destinations. Google Tour Builder requires no programming knowledge, unlike Google Earth where basic HTML coding is needed. It also only requires a Google Earth web browser plug-in, which is quick and easy to download. The browser- based nature of Google Tour Builder was useful as it meant that VFT data would be consistently presented across different computers and school systems: removing the problem of missing media experienced during the Masters pilot. The Masters project London Olympic-themed VFT was replicated using Google Tour Builder software (Figure 5-4) and successfully tested during Study One.

The researcher had very positive experiences of providing this second VFT iteration using school computers during Study One. There were no issues with multimedia availability changing between classes and sessions were also quick to download using school internet. With teacher support (Section 6.4.5), development of the full VFT programme for longitudinal intervention work began using this software. A study website was developed (www.virtualtravellerstudy.wordpress.com) using the free Wordpress website. This was designed to provide links to Google Tour Builder VFT sessions for participating teachers via an exclusive log-in section, as well as provide information for potential participants.

However, as the sessions were nearing full development, a major unavoidable issue appeared. The 3D images of global locations were removed by Google, with no information made available on when or if these would be reinstated (Figure 5-5). As Google Tour Builder is described as ‘A Google Earth experiment’ or beta project (470), this means it can be adjusted by the programmers without prior notice. This change was later described by Google as the result of many major web browsers (including Google’s own Chrome browser) removing or reducing support for web plugins (509). Unfortunately as 3D images added integral interest to VFTs and there was no guarantee that 3D functionality would be re-added, it was decided that another software alternative was needed.

Figure 5-4: Screenshots of Masters project Google Earth (left) and Study One Google Tour Builder (right) versions of Olympic VFT

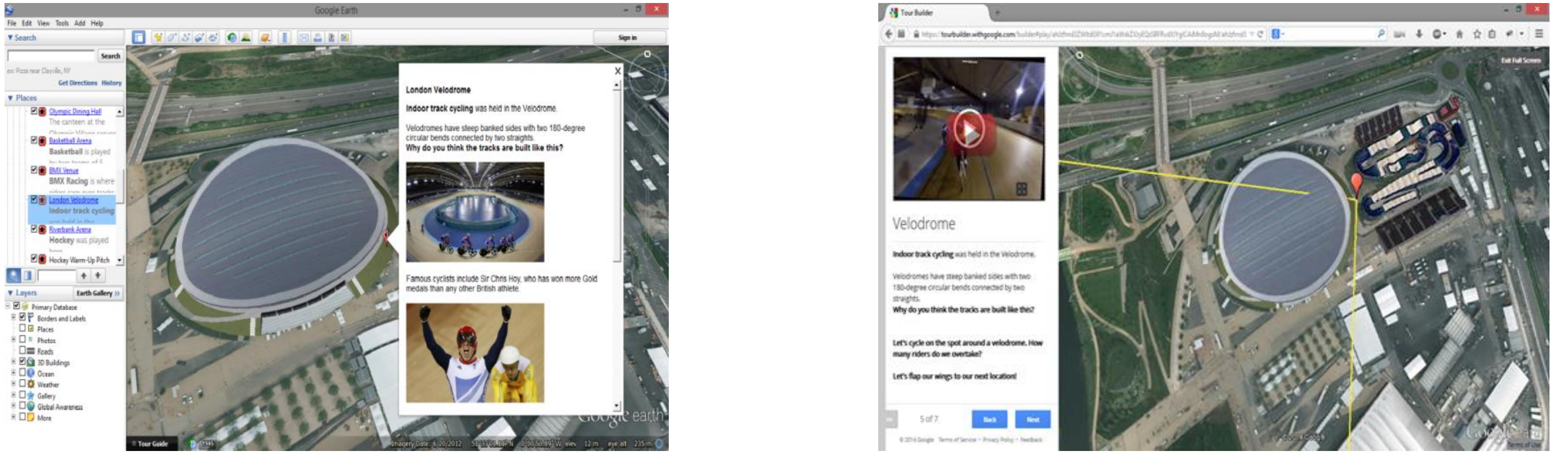


Figure 5-5: Screenshot of Google Tour Builder after 3D functionality lost

5.4.3.3 Third iteration: Google Earth pictures and videos embedded into PowerPoint presentations

Some teachers interviewed in Study One expressed concern that teaching colleagues may have low confidence in using Google Tour Builder VFT technology and may be less likely to participate in research (Section 5.3.5.1). Hence, the unavoidable need to find a replacement for this software provided an opportunity to find an easy-to-use, familiar alternative to appeal to a wide range of teachers. As was the aim with identifying Google Tour Builder as the second software issue; it was important to select reliable, functional software to minimise disruption for teachers and pupils. Use of PowerPoint was frequently observed in Study One's teacher interviews and during school visits. All teachers with interactive whiteboards were seen to use ready-made PowerPoint classes from online resources such as the Times Educational Supplement (TES) Resources (510) and Twinkl educational publishing websites (511), or creating their own.

5.4.3.4 Use of PowerPoint in education

It was important to critically appraise the literature of PowerPoint usage in schools before using them in longitudinal VFT work. PowerPoint is highly pervasive in modern classrooms and interactive whiteboards, and is highly familiar to teachers and pupils (512). Ethnographic work of 100 hours observed in one UK primary school found 43% of teaching to be run using PowerPoint, with teachers reporting it as the 'default' method of session delivery (512). However, there is huge debate over the suitability of PowerPoint for effective learning across education. Yale Graphic Design Professor Edward Tufte has infamously argued against their use (513), describing PowerPoint as fundamentally at odds to effective learning. By providing unrealistic bullet point-based hierarchies and chunking information by slide, Tufte describes most PowerPoint as serving more as a reminder tool for the teacher or presenter rather than an aid for students (513). Proponents of PowerPoint have argued that it is often inadequate knowledge on behalf of the presenter or teacher themselves that leads to ineffective sessions (514, 515). Effective examples of PowerPoint are described to be stand-alone and visual (514).

To the author's knowledge, no research has investigated the comparative effects of PowerPoint versus traditional methods of teaching in primary school samples. Mixed findings have been found in university settings (515), with PowerPoint found to have no effect (516, 517) or a negative impact on information retention (518, 519) versus traditional teaching. No effect on attendance (516, 517) has been found but PowerPoint is commonly preferred by students compared to traditional lectures (515, 517, 518). The majority of this university-based research must be critiqued for having small, non-randomised samples and incomparable conditions: with varying additional materials such as handouts supplied within studies (515, 518). It is questionable how likely this university-based research would relate to primary school teaching given the voluntary attendance of university students and the age difference.

5.4.3.5 Appraising PowerPoint use for VFTs

There are potential strengths and limitations of using PowerPoint for VFT sessions. A limitation is that using PowerPoint may reduce the novelty factor described by teachers in Study One. As PowerPoint will likely be used by classes on a daily basis; the addition of Google Earth-captured pictures and videos with added physical activity may not be sufficiently different from their typical taught lessons to maintain pupils' interest. A variety of movements and activities was integrated into the VFT programme to ensure optimal interest throughout the six week programme (Section 6.4.5).

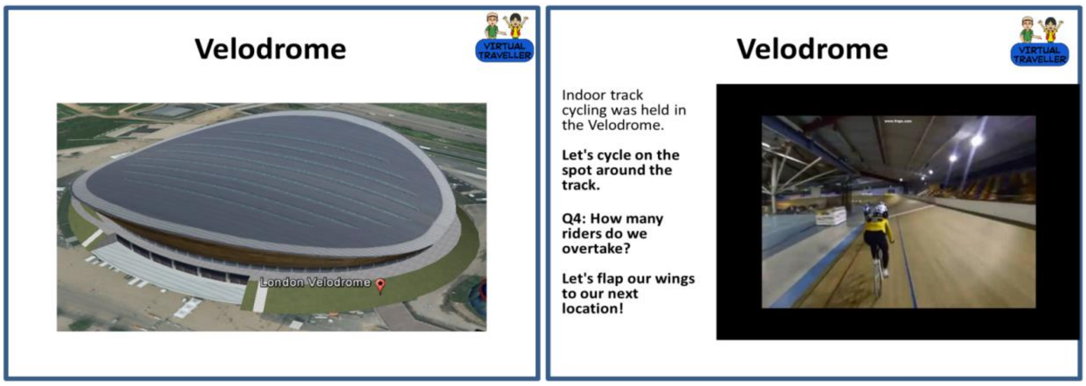
The major strength of using this familiar technology is the increased simplicity of the intervention. Study One found that teachers desired simple software with minimal set-up time. By using PowerPoint software in a novel, active way, the burden on teachers can be reduced. There is no need to be trained to learn new software, as would be required with previous Google Earth and Google Tour Builder iterations. Training and set-up time could be minimised by providing teachers with PowerPoint VFT sessions on a USB stick, as opposed to via logging in to the developed website. This software familiarity was also advertised during recruitment of participating teachers (Section 6.4.7). This increased ease of use should result in increased session implementation, according to the Technology Acceptance Model (451, 476). Optimal implementation of the VFT intervention would lead to more accurate assessment of its effects.

5.4.3.6 Development of PowerPoint VFTs

Given the largely positive appraisal and the need to develop and test the VFT intervention within PhD time restrictions; it was decided to develop the larger-scale programme using PowerPoint software. Sessions developed using Google Tour Builder software were converted into PowerPoint sessions.

Firstly, questions and activity instructions related to each session were added to PowerPoint slides. Secondly, screenshots of 3D images within Google Earth were captured and pasted into relevant PowerPoint sections. Videos of journeys between locations in Google Earth were then developed. Path journeys were recorded using Fraps: a free video capture programme (520). Free sound effects relevant to session locations and themes were then downloaded using the SoundBible website (521) and added to videos using Windows Live Movie Maker. The final videos were embedded within VFT PowerPoints slides (Figure 5-6). Relevant Youtube videos were also downloaded using the Youtube Enhancer Plus Firefox Add-On (522) and edited using Windows Live Movie Maker before being embedded into the PowerPoint sessions. Intervention branding was included throughout PowerPoint sessions (see Chapter 6 for full intervention details and protocol).

Figure 5-6: Screenshots of PowerPoint Olympic VFT with Google Earth screenshots (left) and embedded video (right)



5.4.4 Assess suitability of physical activity measurement

5.4.4.1 Review of suitable accelerometer cut-points

Pilot study recommendation 2: Use accelerometer cut-points most appropriate for VFT intervention

Cut-points allow the transformation of raw accelerometer data to estimate minutes of activity intensity (Section 5.2.3). Data from the pilot study (450) was originally analysed for the Masters project using Mattocks cut-points (459), which found the majority of VFT session time as sedentary in both sedentary and active VFT conditions. Although pupils were observed as moving throughout the active VFT, Mattocks cut-points still reported 72% of this time as sedentary. This suggests that standing and moving time evident in active VFT pupils may not be captured by Mattocks cut-points. During the early phases of the PhD, reasons for this over-estimation of sedentary behaviour and alternative measurement techniques were investigated.

There are some plausible explanations as to why observed movement was not correctly detected as active in this VFT pilot. Firstly, activity elicited by this interactive whiteboard-based session was mostly recorded on the X or anteroposterior axis. This reflects the non-ambulatory, on-the-spot movement prompted by VFTs due to space restrictions, as seen in Active Video Games (523). A weakness of accelerometers is their weaker sensitivity to non-ambulatory movements, such as cycling and on-the-spot movement in comparison to accelerating, travelling movements (48). The Mattocks sedentary cut-point used (≤100 CPM) may hence be too high considering the non-ambulatory movement elicited during VFTs.

Secondly, the Mattocks cut-points were used as set by the Actigraph data analysis software ActiLife: (SB (sedentary): 0-100 Counts per Minute (CPM), light (LPA): 101-3580 CPM, moderate (MPA): 3581-6129 CPM and vigorous (VPA): ≥6130 CPM). However, only MPA and VPA cut-points are actually calculated from 'calibration' of accelerometers in the original Mattocks paper (459), making the range given by ActiLife software unofficial. Although various subsequent papers cite this Mattocks paper and use a full range cut-points from SB to MVPA (524, 525), SB and LPA cut-points are not actually calibrated in this paper and so should hence not be cited as such. Cut-points can vary greatly according to the 'calibration' methods used to general them. Calibration studies use accelerometer output to convert CPM into meaningful concepts of physical activity intensity and sedentary behaviour (148). Such studies often involve children wearing accelerometers during structured activities such as treadmill running or free play for fixed intervals of time (39, 148).

To assess if alternative, suitable child Actigraph cut-points existed, a literature review was carried out. This aimed to:

i) Identify all calibration papers of child Actigraph cut-points against VFT-relevant inclusion and exclusion criteria

ii) Analyse the suitability of all identified cut-points

iii) Select one set of calibrated cut-points for future VFT activity measurement

5.4.4.1.1 Methods

Inclusion and exclusion criteria

To ensure identified cut-points were suitable for VFT use, the following inclusion and exclusion criteria were applied:

1) Sample: Only studies featuring participants aged 3-10 years were included. This is because average activity intensity counts have been found to be similar among this age range (148) and these ages include the target age for longitudinal VFT work (age 8-9; Section 6.4.2). Studies were included regardless of participant sex distribution or country of origin. Studies using disabled or exclusively overweight or obese children were excluded.

2) Accelerometer model: The Actigraph GT1M was used in the Masters project pilot study and was to be used in future VFT work. As great variability is typically found between accelerometer brands (440), the review was hence restricted to cut-points developed with Actigraph accelerometer models only. As there is inconclusive evidence of the comparability of data across Actigraph models (526, 527); all cut-points are reported regardless of Actigraph model.

3) Accelerometer placement: Hip-based accelerometer measurement has been found to outperform wrist-based measurement and has also been found to be more acceptable to

children (40, 41). Given the large body of evidence for right-hip accelerometer placement (39, 148); only hip-mounted calibration studies will be included in this review.

4) Epoch length: Collecting data using small epoch lengths (≤5 seconds) are preferable to reflect the sporadic movements of children (39, 528). 5 second epochs were used in the Masters pilot study (450) and will continue to be used in the remainder of PhD work (Section 6.4.9.2). Previous research has found that reintegrating smaller epochs into a larger epoch may produce differences in MVPA estimates obtained from a single larger epoch (529, 530). However, as Actigraph software allows reintegration of data collected into cut-points of any derivation (531) and limited cut-points were thought to be available, all epoch lengths were included.

5) Classify activities according to established MET standards: To ensure quality of included studies, cut-points were only included if they classified calibration activities related to established MET guidelines (25, 532) (Section 2.3.1). For example, Krishnaveni cut-points (533) were excluded as they incorrectly defined 'active' sitting during writing or drawing as light activity not sedentary, whilst walking was defined as moderate activity, not light.

6) Cut-point types: Only cut-points published following described calibration were included. Cut-points derived from equations or self-derived without calibration were excluded. Papers comparing established cut-points were also excluded. Such papers are often incorrectly cited as establishing cut-points in accelerometer literature and analysis software (e.g (534) in ActiLife software) but were excluded here for not containing calibration. Only cut-points featuring a full range of activity intensity from SB to MVPA were included.

7) Activity used for calibration: Sporadic movements were seen in the Masters pilot project as initiated by VFT sessions and are also recognised as typical generally in children (29, 148). As such, calibration studies featuring treadmill-paced movement which is repetitive and biomechanically different (534) were excluded. This criterion also involved the exclusion of the commonly used Evenson cut-point for children (415). As this is the most commonly-used cut-point in the literature, this has been included for comparison in the results table (Table 5-2).

8) Validation: All otherwise relevant cut-points were included regardless of the presence of accompanying validation work in the paper.

Search strategy

Calibration studies were identified by analysis of existing recent systematic reviews of child accelerometry cut-points (39, 457, 535). Additional searches were carried out on PubMED, Web of Science, MEDLINE and SPORTDiscus to identify any more recently published thresholds. Search terms used were acceleromet*, Actigraph AND cut-point*, cut point* AND calibrat* AND child*, young*, youth.

5.4.4.1.2 Results

A total of six articles meeting the given inclusion criteria were identified (summaries of identified studies and previously used Mattocks cut-points provided in Table 5-2). No cut-points in the literature were calibrated with on-the-spot movements specifically, such as via Active Video Gaming. As such, the most otherwise-relevant cut-points will be used for the remainder of this PhD.

Previously used Mattocks cut-points identified the majority of active VFT activity as sedentary, despite pupils observed as standing and active throughout. As such, it would be beneficial to use a sedentary cut-point lower than Mattocks (0-100 CPM). Of the six identified studies, only Pulsford cut-points met this criteria at SB: <100CPM, LPA: ≤2240 CPM, MPA: ≤3840 CPM and VPA: ≥3841 CPM (536). These were calibrated using the same GT1M Actigraph model and a similar age range (7-8 years old versus 8-9 years old; Section 6.4.2) to planned VFT work. Although the Pulsford paper does not feature a validation study; it has been used by the authors to assess data collected as part of the large Millennium Cohort Study (52, 537). No cut-points exist that are specifically calibrated for on-the-spot movement. Additionally, no other identified cut-points provide the opportunity to capture more non-sedentary activity compared to previously used Mattocks cut-points.

Table 5-2: Identified cut-point calibration studies

Author	Sample	Actigraph used	Activities	Epoch used	Cut-points reported	
Butte et al. 2013 (538)	Calibration: n=69 Validation: n=50 3-5 years Sex=N/A USA	GT3X+	7 days free living	15s	SB/LPA (X-axis) LPA/ MPA MVPA	≤240 CPM 241-2120 CPM 2121-4450 CPM
Costa et al. 2013 (539)	Calibration: n=18 10 girls Validation: n=20 2-3 years 12 girls UK	GT3X+	Sit, listen to stories, walk, roll, dance, run, jump Validation: free play	5s	SB (X-axis) MVPA	≤5 $5s^{-1}$ ≥165 $5s^{-1}$
Evenson et al. (415) (commonly used but excluded as used treadmill)	n=33 5-8 years 21 girls USA	Actigraph model not given	sitting, colouring, basketball, walk and run on treadmill	15s	SB LPA MPA VPA	0-100 101-2295 2296-4011 ≥4012
Mackintosh et al. 2012 (540)	n=28 10-11 years 13 girls UK	GT1M	Drawing, TV, walk, jog, games	5s	SB MPA VPA	≤372 CPM 2160-4806 CPM >4806 CPM
Mattocks et al. 2007 (used in Masters pilot project) (459)	Calibration: n=163 90 girls Validation: n=83 46 girls 12 years UK	7164	Lying, sitting, slow walking, brisk walking, jogging, hopscotch	10s	MPA VPA	3581-6129 CPM ≥6130 CPM
		GT1M	TV, gaming, walking,	15s	SB LPA	<100 CPM ≤2240 CPM

Pulsford et al. 2011 (536)	n=53 7-8 years 29 boys UK		jogging, hopscotch, basketball		MPA VPA	≤3840 CPM ≥3841 CPM
Sirad et al. 2005 (416)	Calibration: n=16 11 boys Validation: n=269 3-5 years 125 boys USA	Actigraph model not given	Sit, play, walk, jog Validation: up to 10 days free living	15s	Age 3: SB LPA MPA VPA Age 4: SB LPA VPA MPA Age 5: SB LPA MPA VPA	 0-301 $15s^{-1}$ 302-614 $15s^{-1}$ 615-1230 $15s^{-1}$ ≥1231 $15s^{-1}$ 0-363 $15s^{-1}$ 364-811 $15s^{-1}$ 812-1234 $15s^{-1}$ ≥1235 $15s^{-1}$ 0-398 $15s^{-1}$ 399-890 $15s^{-1}$ 891-1254 $15s^{-1}$ ≥1255 $15s^{-1}$
Vanhelst et al. 2011 (541)	Calibration: n=40, 20 boys Validation: n=20, 10 boys 10-16 years France	GT1M	Gaming, reading, football, walk, jog, run	1min	SB LPA MPA VPA	0-400 CPM 401-1900 CPM 1901-3918 CPM ≥3919 CPM

As such, Pulsford cut-points will be applied to pilot VFT data to assess potential use in future VFT research.

5.4.4.2 Comparing previously-used Mattocks and newly identified Pulsford cut-points

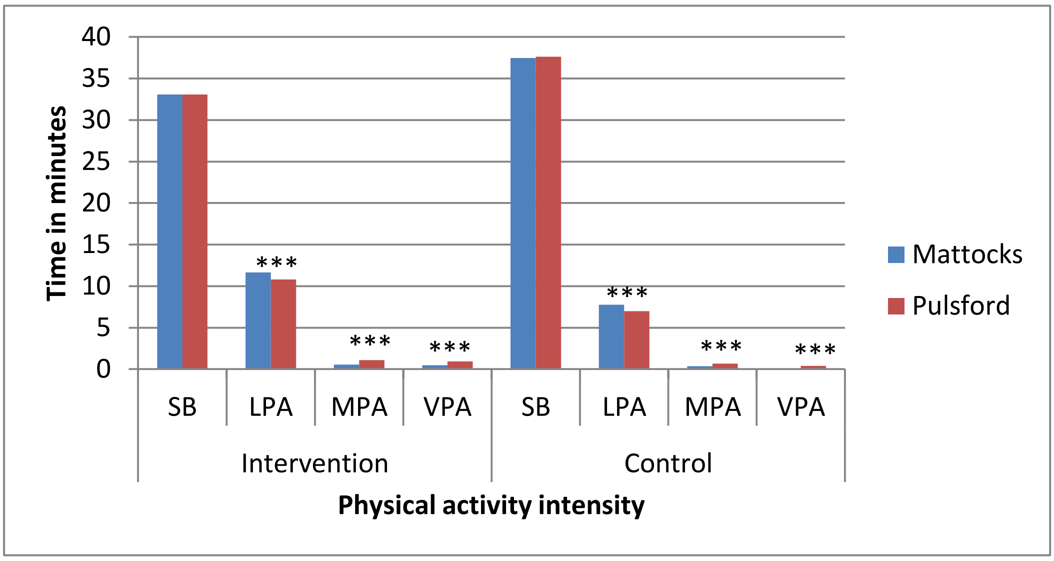
To assess comparability with previously-used Mattocks cut-points; Pulsford cut-points were applied to the existing Masters project pilot VFT data using ActiLife software. Pearson *r* correlations found significant correlations between Pulsford and Mattocks cut-points for all activity intensities (Table 5-3). Unlike with Mattocks cut-points, significant moderate VFT activity between intervention groups was identified using the newly-identified Pulsford thresholds ($F(1,82)=9.94$, $p=0.002$. However, there was no difference in recording of sedentary, light or vigorous VFT time using the two cut-points. Differences between cut-points in the intervention group were examined to assess potential improvements to VFT activity assessment. There was no significant difference between the cut-points in recorded SB. Significantly less LPA ($t(37)=-5.93$, $p<0.001$) and greater moderate ($t(36)=7.19$, $p<0.001$) and vigorous activity ($t(37)=7.05$, $p<0.001$) was recorded using Pulsford cut-points (Figure 5-7). These same associations were also seen for control group activity.

Table 5-3: Comparison of pilot VFT activity intensity using newly-identified Pulsford and previously-used Mattocks cut-points

Activity intensity	VFT Condition	Pulsford (mins)	Mattocks (mins)	*r*
Sedentary	Active	33.06	33.06	
	Sedentary	37.62	37.62	
	All	35.53	35.53	1.00**
Light	Active	10.79	11.65	
	Sedentary	7.00	7.6	
	All	8.73	9.45	0.99**
Moderate	Active	1.08	0.56	
	Sedentary	0.68	0.35	
	All	0.86*	0.44	0.72**
Vigorous	Active	0.93	0.48	
	Sedentary	0.38	0.10	
	All	0.63	0.27	0.91**

Notes: Pulsford cut-points: Sedentary: <100 counts per minute (CPM), Light: 100-2240 CPM, Moderate: 2241-3840, Vigorous: ≥3841 CPM; Mattocks cut-points: Sedentary: ≤100 CPM, Light: 101-3580 CPM, Moderate: 3581-6129 CPM, Vigorous: ≥6130 CPM; **=$p<0.01$

Figure 5-7: Activity intensity of VFT session activity as assessed by Mattocks and Pulsford cut-points



Note. *p*<0.001

5.4.4.3 Discussion

This review has identified that no accelerometer cut-points calibrated to on-the-spot activity exist in the literature. Although the popularity and availability of on-the-spot movement activities such as Active Video Games is increasing (256, 328), there are no cut-points calibrated to accurately record the non-ambulatory movement these elicit in children. The time and cost of a calibration study to generate new cut-points elicited by VFT-elicited activities is far beyond the time-frame and resources available for this PhD research. This lack of suitable existing cut-points may prove problematic for VFT research, where generated activity is primarily on-the-spot. Pulsford cut-points (536) were hence used in ongoing VFT research for their lower minimum cut offs across SB, MPA and VPA intensities (Chapter 6-7). The use of Pulsford as a lesser-used accelerometer cut-point may limit the comparison of findings in subsequent work compared to the large number of studies more commonly using Evenson (415) and Mattocks (459) cut-points. However, this review has ensured the most suitable cut-point is used given the on-the-spot activities inherent to VFTs.

5.4.5 Exploring potential additional activity measurement

Pilot study recommendation 3: Assess feasibility of combining accelerometers with other forms of VFT physical activity measurement

Masters project pilot work (450) identified that bi-axial Actigraph GT1M accelerometers assessed a high proportion of active VFT time to be sedentary (Section 5.2.3). This was despite pupils being observed as active by the researcher throughout the session. Combining two methods of assessment has been shown to provide better estimates of physical activity energy expenditure than one method alone (542). As such, the feasibility of alternative physical activity assessment methods was assessed to potentially improve the validity of the main VFT intervention results.

5.4.5.1 Inclinometers

The use of ActivPal inclinometers (PAL Technologies Ltd: Glasgow, UK) was firstly considered. These are uni-axial accelerometers that are specifically developed to measure postural changes, sedentary time and lower intensity activity (152, 153) (Section 2.4.2). Although not yet tested in physically active lesson contexts (Section 4.5.9.1), they may be more likely to capture on-the-spot movement and transitions from sitting-to-standing elicited by VFTs due to their thigh placement (153). They may hence provide greater detail into the levels of sedentary behaviour and lower intensity activity in VFT sessions, complementing the greater intensity activity detected with typical accelerometers. Unfortunately, these devices were not available and no research budget was available to purchase these; hence they could not be used during this research.

5.4.5.2 Heart rate monitors

The feasibility of heart rate (HR) monitors was then assessed. As discussed in Chapter 2 (Section 2.3.2), heart rate is not a direct measure of physical activity but it does indicate relative cardiovascular stress induced by activity (36, 37). HR monitors make assumptions on the linear relationship between heart rate and oxygen consumption (VO_2) to provide an indirect estimate of physical activity (35). A very limited number of Actiheart (CamNtech, Cambridge, UK) monitors were available to the researcher. These combine heart rate recordings with an integrated omnidirectional accelerometer and are attached with small adhesive electrodes to children's chests (37). In previous treadmill based research with 12-13 year olds, the combined HR and activity count measures of Actiheart had the strongest relationship with PAEE compared with single-measures and had less error (543). HR monitoring has previously been used in physically active lesson research (381) and to compliment accelerometry measures in Active Video Game research with children (486, 544, 545): suggesting potential suitability for VFT research.

However, HR monitoring was found to be unsuitable for a range of reasons. Firstly, the primary outcomes and hypotheses of the main VFT study encompassed all activity intensities including sedentary behaviour (Sections 6.2 & 6.3). Heart rate can be affected by factors other than body movement during sedentary and light intensity activity, such as environmental stress and body position (33, 35, 546). HR monitors were hence not appropriate as they have poor accuracy at lower activity intensities (37, 547) and may overestimate physical activity levels within the VFT intervention.

Secondly, different activity intensities produce large inter-individual variation in HR (35). Research has hence indicated the need for participant-specific calibration of HR monitors across a range of activity intensities for reliable use in children (29, 35). Such calibration methods include indirect calorimetry (Section 2.4.1) (42) and doubly labelled water method: where participants ingest 'heavy water' with uncommon hydrogen and oxygen isotopes to direct measure carbon dioxide production and total energy expenditure (33, 548, 549). All calibration methods have high time and financial costs, making them beyond the scope of this PhD research. Thirdly, heart rate responses lag behind the sporadic changes in actual physical activity common in children (35, 37) and likely to be elicited by VFTs. The use of HR monitors may hence affect the assessment of these intermittent patterns of activity (29).

Finally, the necessity for skin contact to apply HR monitors is problematic in child samples (29). There are great issues with informed consent, as the close contact of researchers or teaching staff required is likely to be uncomfortable for children. Poor acceptability of HR monitors and their electrode pads to skin have been found in past research in children (550). Informal discussion of potential HR monitoring with two teachers during VFT intervention development identified that this may be especially problematic in ethnically diverse populations within the target research area of Greater London. Teachers warned that children and parents of some cultures and religions would be unhappy with such close personal contact, which may lead to reduced participation. Taking all of these considerations into account, it was decided that HR monitoring would not be adopted during further VFT research in this PhD.

5.4.5.3 Observational physical activity measures

Finally, observational measures of children's physical activity were considered. Aforementioned inclinometers and heart rate monitors as objective measures provide information on duration and intensity of physical activity (Section 2.3.2). However, they do not provide information on the type of activity performed (29, 32). Subjective measures are recognised to validate and interpret activity data collected by more objective methods (29, 146, 551). Direct observational tools have been strongly recommended to provide information on the context and environment factors associated with objectively measured physical activity (551, 552). They have also been used to validate objective measurement methods in settings where the usefulness of existing objective tools is unclear. For example, a recent study compared the ability of Actigraph and ActivPAL devices to accurately capture seated and standing time in typical classroom setting (553). These objective measures were compared against the well-validated System for Observing Fitness Instruction Time (SOFIT) (414) observation tool, assessed by multiple researchers coding the activity of recorded classroom behaviour in the corresponding pupils (553). Observation tools involve trained observers classifying children's free-living physical activity by objectively recording behaviour against set criteria for a predetermined length of time (554). By observing activity elicited by VFTs in a structured and standardised way; more detail on activity intensity can be added to the suboptimal measurements obtained by accelerometers.

A range of child physical activity observation tools exist, as outlined fully in various review papers (33, 146, 551). Measures vary by sampling methods (which participant to watch, when and for how long), classification of physical activity types, observation pacing (using stopwatch, timing via earphones) and length of required observer training (551). The commonly-used Children's Activity Rating Scale (CARS) (31) was selected as a physical activity observational measure for the remainder of VFT work in this PhD. This rates children's activity intensity from sedentary to vigorous: ranging from 1: stationary, stationary with limb or trunk movements, slow movement, moderate movement to 5: fast movement (31). CARS was chosen firstly for its physical activity focus, unlike tools combined with eating behaviour assessment such as the Behaviours of Eating and Activity*:* Child Health Evaluation System (BEACHES) (555). It was also chosen for its development as a tool to assess activity in general situations (31), unlike tools developed specifically for PE use such as the SOFIT (414, 556). CARS also has a relatively high sample basis compared to other observational tools, with n=25 during calibration phase and n=192 during validity testing (33). Pupils are unlikely to be more active during CARS observations to satisfy the researcher (33), as indicated by a low observer bias of 16.6% (31). Finally, CARS has acceptable high inter-observer reliability at 84 ±10% in simultaneous observations of the same child (31). Potential limitations of direct observation in VFT work are the high researcher burden (33, 552), especially in PhD work where the researcher runs the day-to-day project alone. Inter-rater observations were made possible with support from a Masters student (Section 6.4.9.3).

5.4.5.4 Self-reported pupil physical exertion

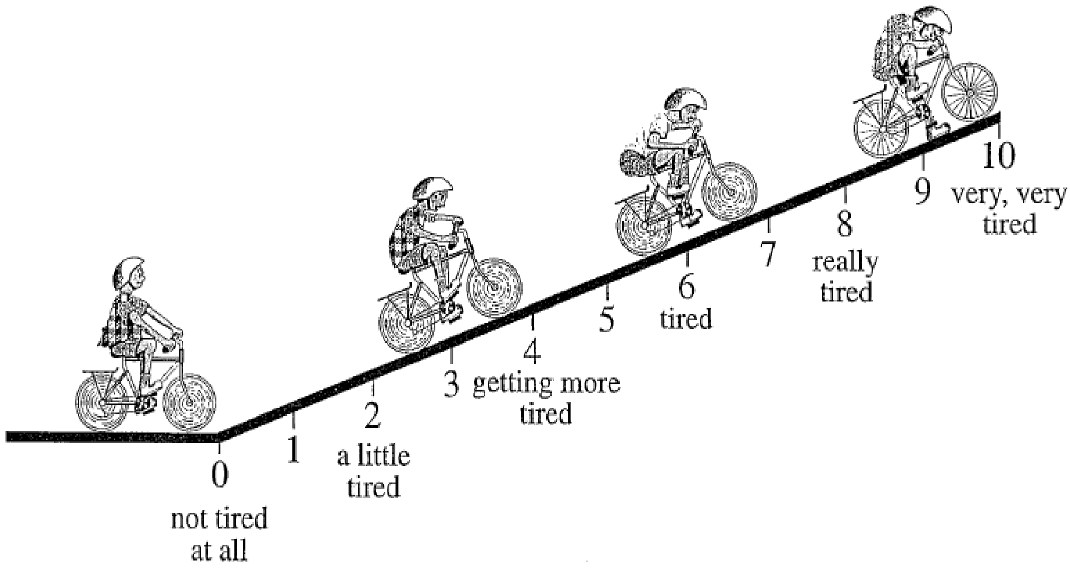
Study One recommendation 3: Assess pupil exertion during VFTs

Some pupils in Study One reported perceived exertion immediately after the VFT session (Section 5.3.5). Perceived exertion has not been assessed in previous physically active lesson interventions (Chapter 4). However, Active Video Game (AVG) interventions have assessed perceived exertion to show equivalent (486) or greater exertion in children than walking (487). Perceived exertion has also been assessed as a form of process evaluation in other school-based physical activity work (488). It was important for perceived exertion to be assessed in longitudinal VFT research to assess if it changed throughout the intervention and to assess any potential associations with other outcomes.

Perceived exertion is an important subjective symptom of physical strain (485), and is the result of a range of sensory, experiential, mood and physical inputs (557). In exhaustion studies with healthy adults, perceived exhaustion has been found to strongly limit exercise tolerance over muscle fatigue (558). Ratings of perceived exertion (RPE) are self-report measures of individuals' perceived effort during physical activity (559). It is recommended that measures of RPE are relevant to the population at hand, as exertion perceptions can vary greatly (485). Adult formatted RPE scales such as the Borg RPE scale, where users rank their perceived exertion from 6 (very, very light) to 20 (maximum exertion) (560) have been deemed unsuitable for use in children. Firstly, children have been found to experience greater cardiorespiratory and muscular exertion during cycle exercise compared to adults (561). Also, adult RPE measures require fairly complex, subjective assignment of words or phrases to describe exercise-related feelings (559). As such, various measures to assess child perceived exertion have been developed and used within physical activity interventions.

A popular example of such a measure is the Children's OMNI scale of perceived exertion (562) (Figure 5-8). This scale features both pictorial and verbal descriptors to be suitable across age-groups and reading levels (562). It requires children to rate how tired they are on an eleven-point scale from 0: 'not tired at all' to 10: 'very, very tired' alongside a corresponding character cycling at increasing steepness. The scale was validated against oxygen uptake and HR monitoring measures in n=80 8-12 year olds using a cycle ergometer at varying levels of activity intensity (562). Using similar methods to the original validation paper; studies have successfully validated the OMNI scale in children aged between 6 and 15 (563) and in disabled children to help them regulate their activity levels (564, 565). Given the evident suitability of OMNI in a wide range of children, it was used to assess perceived exertion in VFT sessions during the remainder of this PhD research.

Figure 5-8: Children's OMNI scale of perceived exertion (562)



5.4.6 Ensuring full process evaluation of longitudinal intervention

Literature-based recommendation 7: Fully evaluate developed VFT intervention

As identified in the physically active lessons systematic review (Section 4.5.6), the majority of previous related interventions focus on PA and educational outcomes, rather than assessing the processes behind the intervention itself (566). It is important to assess the factors underlying an interventions' results to better interpret findings and make any required adjustments to future intervention iterations (567). The MRC describe such evaluation as one of four key elements to the iterative development of all successful health interventions (279) (Section 2.7.2), allowing insight into why an intervention fails or has unanticipated consequences, or why it is successful. To assess the overall feasibility of the longitudinal VFT intervention and its implementation, a thorough process evaluation strategy was developed.

A framework was required to guide the VFT evaluation process and ensure that all aspects of relevant assessment were considered. A range of frameworks exist to evaluate intervention implementation. For example, the Multiphase Optimization Strategy (MOST) developed by Penn State University Methodology Centre is an engineering-inspired framework to evaluate multicomponent behavioural interventions (568). It proposes three main phases of evaluation of screening, refining and confirming phases (568) in a similar style to the MRC complex intervention guidance (279). Although MOST provides a basic structure to intervention evaluation, it does not provide any firm criteria or checklist to base evaluations on.

The RE-AIM framework (399) was selected as the basis for process evaluation in this thesis. This is due to its adoption across myriad intervention settings and its comprehensive and robust criteria (569). The framework describes the public health impact of interventions as a function of five factors: Reach, Effectiveness, Adoption, Implementation and Maintenance. Reach assesses the individual-level of participation (e.g. pupil or patient) and whether the sample is representative of the target population. It is primarily assessed by comparing characteristics of participants and non-participants to evaluate the adequacy of the sample (399). Effectiveness assesses the positive or negative effects of the given intervention on outcome measures, representing the classical assessment of intervention success (399, 570). Adoption assesses the representativeness of settings included in the intervention at an organisational level, including the location, staff involved in delivery and start-up costs (399, 443). Implementation assesses the extent to which a given intervention is delivered as intended (399), such as teacher adherence to an intervention's protocol in this instance. Finally, Maintenance measures the extent to which any behaviour change generated by the intervention is continued over time (571). Maintenance can be assessed in terms of individual-level sustained behaviour change in each participant, as well as in organizational-level prolonged use of a given intervention (399). Unlike other process evaluation frameworks such as MOST, the RE-AIM framework criterion can be broadly seen to assess two domains of intervention validity. It assesses internal validity by assessing the effectiveness of the intervention in question and also external validity by assessing the generalisability and transferability of results to real-world implications (443, 570).

The RE-AIM framework has been used to evaluate many other child physical activity (572) and obesity interventions (573). A recent systematic review of 78 studies evaluated the adoption of the RE-AIM framework in children's physical activity interventions (443). It found that studies reported 52.6% of the RE-AIM components on average. Most studies tended to focus on evaluating measures of internal validity, such as sample size (Reach), participant characteristics (Reach), reporting of results (Effectiveness) and intervention type and frequency (Adoption). This is opposed to more uncommon reporting of external validity measures, such as participant representativeness (Reach), intervention costs (Adoption) or protocol fidelity (Implementation) (443). This is highly problematic for a number of reasons. A focus on internal processes of sample adequacy makes such evaluation only relevant to the specific study at hand. It provides no indication as to the suitability or feasibility of real-world implementation of the intervention. Interestingly, the likelihood of studies reporting ≥65% of RE-AIM components was greater in those with a recent publication date of 2013 or later (443). This suggests that the need for RE-AIM components to be collectively assessed is becomingly increasing recognised by both authors and journals. A lack of comprehensive assessment of RE-AIM framework in papers has also been highlighted in wider health intervention literature, with only 10% of 86 identified grant proposals indicating employment of all aspects (570). Implementation of RE-AIM criteria in the main VFT study is shown in Section 6.4.9.5.

5.5 Discussion

This chapter reported mixed-methods feasibility testing and resulting revisions of physically active VFTs, addressing thesis Aim 2 and Question 2 (Chapter 3). Recommendations from a quantitative Masters VFT pilot study (2, 450) (Chapter 5A) were first presented, before the results of a qualitative feasibility study (4) (Chapter 5B; Study One) and resulting recommendations were discussed (Chapter 5C). Finally, revisions according to recommendations from the physically active lessons systematic review (Chapter 4) (3), Masters VFT pilot and Study One were presented.

Study One explored teacher and pupil perceptions of a sample physically active VFT. Despite there being little empirical evidence in the UK (Section 4.5), teachers reported common use of physically active lessons in their own practice. A range of factors facilitating VFT use were identified, including teachers' perceptions of VFTs as holding potential across a wide variety of curriculum topics and pupils' enjoyment of the sample session. Various important barriers were also identified to be addressed prior to larger-scale study. Firstly, as with previous school-based PA intervention research (284, 289); teachers saw a lack of teaching time as a potential barrier for VFT use. To maximise recruitment and implementation in future research, it was evident that sessions must be quick to set-up and deliver. It was also clear that teacher training must share research showing the myriad of health and educational benefits of PA in children: highlighting the range of potential benefits with the VFT intervention.

Secondly, some teachers warned of potential resistance in colleagues who may be less confident in using technology. This may produce a biased sample as such teachers may be less likely to participate in VFT interventions or less likely to complete them as intended. It was hence important following this feasibility work to provide VFT software that was as simple and familiar as possible to maximise teacher implementation (Section 5.4.3). Some teachers also queried the use of technology to improve sedentary behaviour, as they described increased sitting to be largely as a result of children's increasingly technological lives. It seems a cyclical relationship between technology and activity was observed by these interviewees, with such perceptions in full-scale intervention teachers potentially limiting VFT implementation. These considerations of VFT use replicate the Technology Acceptance Model (453, 476) (Section 5.2.3). Under this model, teachers that perceive VFT technology as useful and easy to use will be more likely to use it. It will hence be necessary in future work to maximise these perceptions in teachers by stressing the practical benefits of VFT technology during teacher training, such as its quick set-up time and simple functionality (Section 6.4.7). Finally, teachers predicted a potentially short novelty factor of VFTs for pupils. Today's children are arguably 'digital natives': immersed in a world of technological ubiquity from birth (574, 575). As such, they are likely to be accustomed to technology such as interactive whiteboards and PowerPoint sessions, which may limit their interest.

Various revisions were made in this chapter that aimed to increase the quality of the final VFT intervention and evaluation. Firstly, the inclusion of COM-B theory (282) provided guidance on how to potentially improve intervention uptake in the final VFT intervention, by addressing the capability, opportunity and motivation of teachers and pupils to be physically active in-class. Recognition that the final VFT intervention should be fully described according to established behaviour change techniques (495) will enable clarity in method reporting and aid replication. Full description of how BCTs were embedded in the final intervention can be found in the VFT intervention protocol (Section 6.4.6). Secondly, the involvement of teachers during development of the final VFT intervention will ensure sessions are optimally tailored to year-group specific National Curriculum objectives (Section 6.4.5).

Thirdly, the refinement of VFT technology towards familiar PowerPoint-based software aims to increase ease-of-use and uptake in teachers. However, the potential costs of this software familiarity on pupil perceptions and outcomes will need to be assessed. Will the use of familiar PowerPoints with embedded Google Earth videos be appealing to pupils throughout the intervention? Process evaluation will assess if this software familiarity leads to high implementation of the full VFT intervention and whether pupil perceptions of VFTs change during the course of the full intervention (Section 6.4.9.5). Finally, physical activity outcomes were addressed in detail to improve sub-par activity measurements identified in the Masters pilot study (2, 450). Reviewing the child accelerometer cut-point literature helped to ensure the most appropriate cut-points are used during the main VFT study (536). The inclusion of a broader range of physical activity measures will far extend previous pilot study assessment (2, 450). Triangulation of accelerometer cut-points maximally suited to VFT activity (536) with direct observations (31) and subjective measures of pupil exertion (562) will provide a more detailed impression of VFT activity in the main study (Section 6.4.9.5).

The combination of an exploratory physically active lesson systematic review (Chapter 4) and two mixed-methods feasibility studies has provided a range of recommendations for subsequent VFT intervention work as described in this chapter. This detailed analysis of issues within both the wider literature and VFT methodology itself enabled a detailed protocol to be developed for the main VFT intervention (Chapter 6).

Chapter 6 Preface to Chapters 7, 8 and 9 – Protocol of Study Two: A pilot, longitudinal Virtual Field Trip Cluster-Randomised Controlled trial intervention

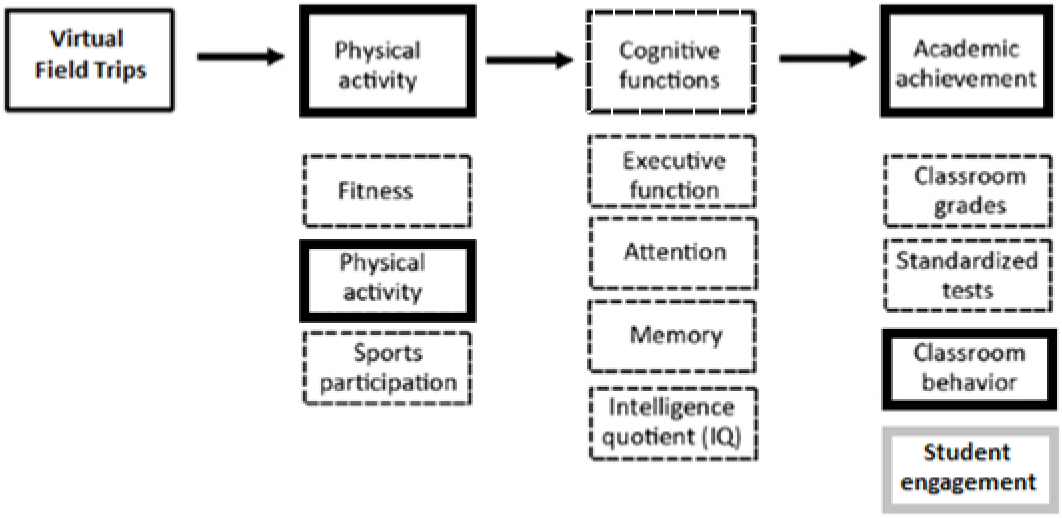
This protocol was published in BMJ Open (1) (Appendix 6A).

6.1 Introduction

To assess the effects of physically active VFTs as real-world teaching tools, a controlled study of sessions over time was required. Following on from feasibility work (Chapter 5), the remainder of this PhD involved the development, provision and analysis of a pilot longitudinal, randomised VFT intervention. The intervention was called 'Virtual Traveller' and was run for six weeks in Year 4 classes. This chapter outlines the research questions and protocol of the main VFT study.

Outcomes for assessment during the Virtual Traveller intervention were selected to best address the remaining thesis aims and questions (Chapter 3; Aims 3-7, Questions 3-7). Howie & Pate's (123) model of the relationship between PA, cognition and academic achievement in children was used to guide outcome selection (Section 2.3.4), as well as outcomes identified in the physically active lessons systematic review (Section 4.5.9). Physical activity (including sedentary behaviour measurement) was assessed to measure activity levels during VFT sessions and whether the intervention had an effect on general PA levels (Figure 6-1). Cognitive functioning was not assessed due to the length of time, manpower and cost required to administer such instruments within school settings. As cognitive testing is administered on a one-to-one basis, this would have meant a high burden on time-restricted pupils and teachers amongst data collection for other outcomes. Academic achievement was assessed via two measures: on-task behaviour and student engagement (an addition to Howie & Pate's model; Figure 6-1). Whereas on-task behaviour (assessed as a form of classroom behaviour) has been previously found to improve following similar interventions (Section 4.5.11), student engagement was hereby assessed for the first time within the context of physically active lessons (Section 6.4.8). Academic achievement in the form of classroom grades were not assessed due to the additional burden required from classroom teachers in providing these. Standardised tests as a measure of academic achievement were also not assessed due to the additional one-to-one assessment time required.

Figure 6-1: Physical activity and academic outcomes assessed as part of Virtual Traveller intervention; extension of Howie & Pate (123)



Notes. Variables in black boxes were those present in Howie & Pate's original proposed model that were examined as part of the Virtual Traveller intervention. Variables in grey boxes were examined in addition to Howie & Pate's original proposed model. Variables in dotted boxes were not examined in the Virtual Traveller intervention.

6.1.1 Research questions

The main VFT study built on feasibility work (Chapter 5) (2, 4, 450) by examining the effects of a pilot six-week 'Virtual Traveller' VFT intervention on a range of outcomes in Year 4 pupils. The study asked the following questions:

1) Can Virtual Field Trips reduce sedentary time during primary school lessons?
2) Can Virtual Field Trips increase physical activity outside of the classroom?
3) Can Virtual Field Trips improve student engagement?
4) What is the fidelity of a longitudinal physically active Virtual Field Trips intervention?

6.2 Aims

The specific research aims of this study were:

Primary aim

Determine the effectiveness of the Virtual Traveller intervention to improve the objectively-assessed mean overall minutes of moderate-to-vigorous physical activity (MVPA) accumulated by Year 4 pupils three month follow-up (T4).

Secondary aims

1. Determine the effectiveness of the Virtual Traveller intervention to improve the following secondary outcomes amongst Year 4 pupils at T4:

a) Mean overall minutes of sedentary time (SB)
b) Mean overall minutes of light physical activity (LPA)
c) Mean school day minutes of SB
d) Mean school day minutes of LPA
e) Mean school day minutes of MVPA
f) Mean weekend day minutes of SB
g) Mean weekend day minutes of LPA
h) Mean weekend day minutes of MVPA
i) Mean lesson time minutes of SB
j) Mean lesson time minutes of LPA
k) Mean lesson time minutes of MVPA
l) Mean lesson time physical activity observation ratings
m) Mean on-task behaviour observation ratings
n) Mean student engagement questionnaire scores

2. Determine the effectiveness of the Virtual Traveller intervention during the intervention period (T1 & T2; weeks 2 and 4 of the intervention) compared to baseline on all outcome variables:

a) Mean overall minutes of SB
b) Mean overall minutes of LPA
c) Mean overall minutes of MVPA
d) Mean school day minutes of SB
e) Mean school day minutes of LPA
f) Mean school day minutes of MVPA
g) Mean weekend day minutes of SB

h) Mean weekend day minutes of LPA

i) Mean weekend day minutes of MVPA

j) Mean lesson time minutes of SB

k) Mean lesson time minutes of LPA

l) Mean lesson time minutes of MVPA

m) Mean lesson time physical activity observation ratings

n) Mean on-task behaviour observation ratings

o) Mean student engagement questionnaire scores

3. Assess how the Virtual Traveller intervention was delivered (process evaluation)

6.3 Hypotheses

Following results observed in previous physically active lesson interventions (Chapter 4) (3) and provisional results from the Masters pilot project (Chapter 5A) (2, 450), it was hypothesised that:

During the intervention period (T1 & T2) the Virtual Field Trip intervention group would:

1) Reduce their overall SB compared to the control group
2) Increase their overall LPA and MVPA compared to the control group
3) Reduce their SB within school hours compared to the control group
4) Increase their LPA and MVPA within school hours compared to the control group
5) Improve their on-task behaviour during school lessons compared to the control group

Literature review findings (Chapter 2) showed the importance of assessing process evaluation factors to help interpret school-based intervention outcomes. It was hence hypothesised that:

6) Implementation would have a significant impact on Virtual Field Trip outcomes

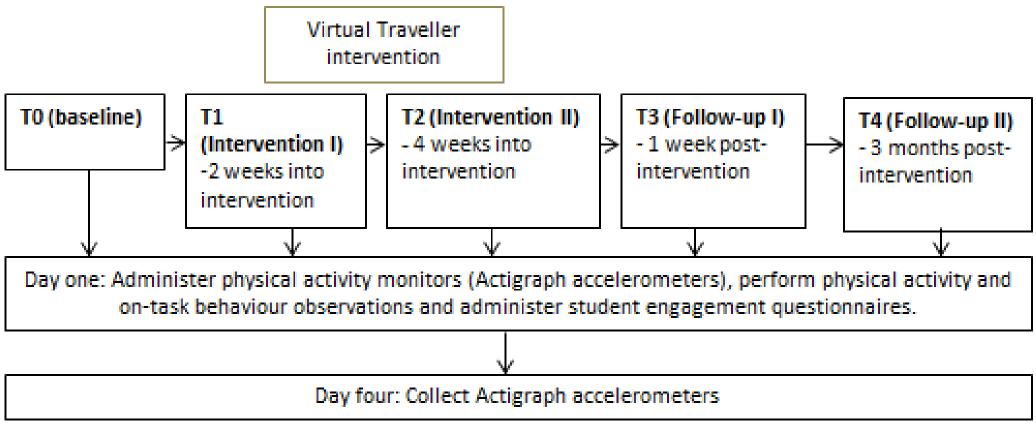
Hypotheses were not set for three-month follow-up measurements. As previous VFT research tested one-off VFT use and provided no assessment of longitudinal effects of VFT use, the direction of follow-up results was unknown. Hypotheses were also not set for student engagement, as to the author's knowledge this not been tested within school-based physically active lesson interventions before.

6.4 Protocol of Virtual Traveller study

6.4.1 Study design

Taking into account all previously-described work, a pilot six-week 'Virtual Traveller' intervention was developed and evaluated using a cluster-randomised controlled trial (RCT) with waiting list control group. Following initial recruitment, all participants completed baseline assessments (T0). Classes were then randomised to intervention or control groups via the Research Randomiser website (576). Measures were repeated at the second (T1) and fourth week (T2) of the 6-week intervention period and at one week- (T3) and three months post-intervention (T4; Figure 6-2). Waiting-list control classes received the full Virtual Traveller programme to use at the end of the study period. Development and running of the Virtual Traveller programme adhered to the Consolidation Standards of Reporting Trials (CONSORT) guidelines (497) and its extension concerning cluster RCTs (445).

Figure 6-2: Virtual Traveller study design diagram



6.4.2 Participants

Year 4 (aged 8-9) classes in primary schools in and around Greater London were approached to participate in the Virtual Traveller programme. Year 4 classes were approached, as opposed to Year 5 classes in the Masters pilot study (2), as the developed sessions were most relevant to their National Curriculum topics (Section 5.4.2).

6.4.3 Recruitment and retention strategies

Various strategies were embedded at all stages of the intervention to optimise recruitment and retention (577). Schools were recruited via two methods to maximise reach. Firstly, contact was made via Public Health and School Sports organisations in two Greater London boroughs and one South East borough. The researcher organised meetings with representatives from these organisations, with contacts agreeing to support the project then forwarding study flyers (Appendix 6B) to primary schools they thought may be interested by email. This recruitment approach was used as a very low follow-up rate (20%) was experienced by approaching schools on an individual basis in the Masters pilot study (2). Secondly, school enquiries to participate were sought via a free Wordpress website (www.virtualtravellerstudy.wordpress.com) with promotion via social media using the developed @VirtFieldTrip Twitter account. A face-to-face visit to interested schools to explain the study details was organised before schools gave final agreement to participate.

Participant retention was addressed via an ongoing incentive competition within each class. Accelerometers can often be cumbersome when worn by children for extended periods of time (578). To encourage wear in each phase of the intervention, a certificate was given to the child in each class with the longest wear-time (Appendix 6C). The child in each class with the longest overall wear time across intervention phases was given a certificate and £10 activity vouchers for leisure centre facilities in their local borough. Pupil names were written on each certificate by the class teacher to maintain participant anonymity. To prevent potential bias from this competition element, the researcher reminded all pupils at each data collection phase that the prize was not based on how active they were but for how long they wore the accelerometer.

6.4.4 Ethical approval

UCL ethical approval was granted (Ref: 3500-004). As reflected in teacher, pupil and parent informed consent documents (Appendices 6D-6I), this originally allowed video recording of class sessions to assist with observations. However, filming was not done due to logistic and school pupil confidentiality issues. Participation was first agreed with the class teacher, after providing teacher information and informed consent documents (Appendices 6D & 6E). The researcher then delivered a 10-minute introductory session to classes two weeks prior to baseline assessment. This session introduced the Virtual Traveller project and accelerometer devices before parent (Appendices 6F & 6G) and pupil (Appendices 6H & 6I) information sheets and informed consent forms were supplied for children to take home. Pupils with reading difficulties or who used English as a second language received an additional one-to-one description of the study by the researcher and a class teaching assistant. Each teacher was provided with a sheet to record pupils returning completed forms (Appendix 6J). Participants were identified by participant number only. Data was only collected in pupils with completed consent forms, however ethical approval allowed all students in each intervention classroom to complete the VFT sessions. A 10-minute debriefing session was provided by the researcher in each class after the final data collection phase.

6.4.5 Intervention description

Virtual Traveller was developed around topics from the Year 4 National Curriculum subjects of English and Maths (364). The programme consisted of 3 x 10-minute physically active VFTs a week over a 6-week period (18 sessions in total). Nine sessions were based on English and nine on Maths content (Table 6-1). Sessions were developed with consultative support from two Year 4 primary school teachers identified during previous qualitative feasibility work (Section 5.3) (4). Sessions could be run in any order to best suit content being taught by teachers at the time. Sessions could also be run at any point of Maths and English teaching, i.e. not restricted to being used as a starter or plenary only. Detailed examples of sample Maths and English Virtual Traveller sessions can be found in Appendices 6K & 6L respectively. After development post-feasibility work, sessions were provided as PowerPoint sessions with embedded Google Earth videos (Section 5.4.3.6). Additional Youtube videos and sound effects (521) were also included to add interest. All

Table 6-1: Summary of Virtual Traveller sessions

Maths	**English**
M1: Tens and Hundreds Challenge Pupils use their movements to show multiplications and divisions by tens and hundreds.	**E1: Kung Fu Punctuation 1 (White Belt)** Visit China for your Kung Fu Punctuation training. Use Kung Fu moves to represent appropriate punctuation in example sentences.
M2: Maths Marching Practice times tables and angles whilst marching for the Queen's Trooping the Colour. Choose the times table appropriate for your class.	**E2: Kung Fu Punctuation 2 (Black Belt)** Add some more complex punctuation to your Kung-Fu Punctuation repertoire, before a freestyle session.
M3: Maths: True or False? Use movements to show if you think statements related to Maths are true or false.	**E3: English: True or False?** Pupils use movements to show if you think statements related to English are true or false.
M4: London 2012 Olympics and beyond Explore the London Olympic park and the future of the Olympics. Count and time the actions of famous Olympians whilst simulating their actions.	**E4: Explanation Texts** Pupils show their understanding of explanation text features using movements.
M5: Metric Movements Practice metric measurements using movements to answer length, weight and capacity questions.	**E5: Mystery Monsters** You are given adjectives to an imaginary monster. Pupils use movements to show how they think the monster would move and act.
M6: Sports Galore Practice addition, multiplication and subtraction using sports movements.	**E6: Noun Reverse Charades** The class use movements to act out a mystery word for one pupil to guess.
M7: Rock around the Clock Learn how to use different periods of time using movements.	**E7: Persuasive Writing** The class use movements to show understanding of persuasive writing.
M8: Money, Money, Money! Practice calculations with money using movements to show the answers.	**E8: Frozen Vocabulary** Practice your class' own target spellings to practice definitions and spelling to movement. *requires spellings to have been set*
M9: Global Dance Count Count how many target moves you do to dance crazes.	**E9: Apostrophes & Plurals** Pupils use movements to indicate where apostrophes should go in possessive and plural sentences.

sessions featured Virtual Traveller branding (Figure 6-3), created using the free website Bitstrips: www.bitstrips.com. Teachers were supplied the sessions on a USB stick featuring the Virtual Traveller logo. A summary of all sessions is provided in Appendix 6M and the attached CD provides the full programme.

Figure 6-3: Virtual Traveller logo

6.4.6 Use of Behaviour Change Techniques (BCTs) in intervention

The BCTs embedded from the BCTTv1 (described in Section 5.4.1) during the intervention are listed in Figure 6-4. For example, a Virtual Traveller-branded teacher intervention log was placed on the wall by the teacher's computer as a prompt (BCT 7.1: Prompts/Cues) to remind them to run the sessions. Also, a material reward (BCT 10.2: Material Reward) to continue participating in the study was provided to pupils in the form of an ongoing accelerometer wear-time competition (Section 6.4.3).

6.4.7 Teacher Training

Following baseline measurements and randomisation to treatment groups, intervention teachers received a 30-minute training session run by the researcher. These were organised according to the teachers' availability, either before- or after-school, or during teachers' preparation, planning and assessment (PPA) time. Waiting-list control teachers received this training and all VFT sessions after all phases of data collection.

Training was provided using a prepared PowerPoint presentation (Appendix 6N). Firstly, the training briefly outlined research findings of the benefits of physical activity in children on health, education and wellbeing (~5 minutes). Teachers were then asked to reflect on the extent they integrate physical activity into their own teaching and discuss their experiences of this (~5 minutes). An outline of Virtual

Figure 6-4: Behaviour Change Techniques embedded in Virtual Traveller intervention

Taxonomy Category	Behaviour Change Techniques (495)	Definition	Example in Virtual Traveller intervention
During teacher training			
1. Shaping knowledge	4.1 Instruction on how to perform the behaviour	Advise or agree on how to perform the behaviour (includes skills training)	Provided an individual training session to each teacher: instructing how to run Virtual Traveller sessions and how they match to the English and Maths National Curriculum
2. Natural consequences	5.1 Information about health consequences	Provide information about health consequences of performing the unwanted behaviour	Teacher training included findings from previous research showing negative effects of extended sitting and benefits of physical activity on pupil's health, wellbeing and educational outcomes
3. Comparison of outcomes	9.1 Credible source	Present verbal or visual information from a credible source in favour of the behaviour	The scientific validity behind studies discussed in teacher training was shown at a basic level
4. Comparison of behaviour	6.3 Information about others' approval	Provide information about what other people think of the behaviour	Shared anonymised pupil and teacher feedback from VFT feasibility work (2, 4)
5. Goals & planning	1.4 Action planning	Prompt detailed planning of performance of the behaviour	Researcher worked with teachers during training to plan three Virtual Traveller sessions a week within Maths and English lessons during the intervention
During intervention			
6. Associations	7.1 Prompts/Cues	Introduce environmental or social stimuli designed to prompt behaviour	A teacher intervention log was placed by the teacher's computer to remind them to do Virtual Traveller sessions (Appendix 6O)

7. Feedback & Monitoring	2.3 Self-monitoring of behaviour	Establish a method for the person to monitor and record their behaviour	Teachers were prompted at all contact points to complete the teacher intervention log after each Virtual Traveller session
8. Repetition & substitution	8.2 Behaviour substitution	Prompt substitution of unwanted behaviour with a wanted behaviour	The intervention replaced inactive teaching practices with physically active Virtual Traveller sessions in Maths and English
9. Goals and planning	1.1 Goal setting (behaviour)	Set or agree a goal defined in terms of the behaviour to be achieved	Teachers agreed to aim to teach three Virtual Traveller sessions a week within Maths and English lessons during the intervention
10. Reward and threat	10.2 Material reward	Valued object provided if there has been effort in performing behaviour	Competition within each class at each assessment phase and overall for pupil who wore accelerometer belt the longest

Traveller was then given, detailing the length, intensity and features of the intervention. A sample Virtual Traveller session (M2: Maths Marching) was then demonstrated by the researcher on their laptop (~5 minutes). The teacher intervention log for Virtual Traveller sessions was then introduced (Appendix 6O). Teachers were requested to complete the session number delivered and rating out of 5 immediately after each session to minimise forgetting. Finally, the Virtual Traveller Teaching Guide was introduced and provided for teachers to use as a reference document during the intervention (Appendix 6P; ~5 minutes). This included brief information on how to access the Virtual Traveller sessions, a brief summary of all sessions and an answer key. The researcher also looked at teacher's upcoming short- and medium term-planning to see how the Virtual Traveller programme could best be embedded into their Maths and English teaching (~10 minutes). Email and telephone contact details for the researcher were also given to support all teachers with any queries about the Virtual Traveller intervention or measurement procedures.

6.4.7.1 Use of Behaviour Change Techniques in teacher training

The BCTs embedded during teacher training are listed in Figure 6-4. For example, the research evidence on health and educational consequences (BCT 5.1: Information about health consequences) of sedentary behaviour was presented to teachers. Also, the researcher worked with participating teachers to formulate action plans (BCT 1.4: Action plans) on how they would integrate the three Virtual Traveller sessions each week into their Maths and English teaching.

6.4.8 Outcomes

The effects of the Virtual Traveller programme on a number of health and educational outcomes were assessed in this study. These are addressed in accordance with both the aims and hypotheses of this study (Sections 6.2 & 6.3) and the wider PhD's aims and hypotheses (Chapter 3).

Primary outcome

Mean overall MVPA 3 months post-intervention (T4)

Secondary outcomes

1. Mean overall SB 3 months post-intervention (T4)
2. Mean overall LPA 3 months post-intervention (T4)
3. Mean overall MVPA 3 months post-intervention (T4)
4. Mean SB on school days 3 months post-intervention (T4)
5. Mean LPA on school days 3 months post-intervention (T4)
6. Mean MVPA on school days 3 months post-intervention (T4)
7. Mean weekend day minutes of SB 3 months post-intervention (T2 & T4)
8. Mean weekend day minutes of LPA 3 months post-intervention (T2 & T4)
9. Mean weekend day minutes of MVPA 3 months post-intervention (T2 & T4)
10. Mean lesson time accelerometer-assessed SB (T2 & T4)
11. Mean lesson time accelerometer-assessed LPA (T2 & T4)
12. Mean lesson time accelerometer-assessed MVPA (T2 & T4)
13. Mean lesson time physical activity observation ratings (T2 & T4)
14. Mean on-task behaviour observation ratings (T2 & T4)
15. Mean student engagement questionnaire scores (T2 & T4)

Previous research has shown positive effects of physical activity on educational outcomes (Section 2.3.4.2). Qualitative VFT work (Section 5.3) identified enthusiasm by pupils and teachers to VFTs as a novel teaching tool. By learning in this new, active and sociable way, pupils may develop more positive attitudes towards learning and their school environment (383). To assess these potential improvements, educational outcomes were assessed in this study in the form of student engagement. Student engagement is a multidimensional construct, describing broad behaviours and cognitions demonstrated in individual pupils that reflect their interest in learning and the school environment (579). It is recognised as an essential precursor for learning and malleable according to school factors such as interventions (579, 580). Student engagement was originally assessed to help predict and prevent student drop-out from school (581). However, it has more recently been recognised to provide a useful indicator of pupil attraction to the school environment (582).

A wide range of student engagement models have been proposed (582), typically featuring between two and four concepts. This study used a three-factor assessment of student engagement, as these are best reflected in research in primary-school age samples (583). Firstly, behavioural engagement has been defined as observable physical movements depicting individual pupils' engagement in educational activities, such as on-task behaviour and attendance (584). Affective engagement depicts pupils' emotional connectedness to the school environment, peers and teachers (582, 584). Finally, cognitive engagement is defined as a student's level of perceived capability and investment towards education (585). Physically active lesson research to date has assessed on-task behaviour as a form of behavioural student engagement (129, 381), although this has not been officially defined as such (Chapter 4). Wider student engagement in the form of affective and cognitive engagement has not yet been assessed in the context of physically active lessons. This study hence included a wide assessment of affective, behavioural and cognitive student engagement to provide a full assessment of physically active Virtual Traveller intervention effects on engagement.

6.4.9 Measures

Data was collected from all participants (intervention and control) at five time-points (Figure 6-2):

1. Time 0 (T0) (baseline)
2. Time 1 (T1) (baseline + 2 weeks)

3. Time 2 (T2) (baseline + 4 weeks)

4. Time 3 (T3) (baseline + 7 weeks)

5. Time 4 (T4) (T3 + 3 months)

The following measures were measured at each time-point: 1) accelerometer-based SB and PA; 2) observations of classroom physical activity; 3) observations of on-task behaviour; 4) student engagement questionnaire. Demographic and height and weight as anthropometric measures were collected at T0 only for descriptive purposes. In addition, intervention classes received process evaluation questionnaires at T1 & T2 only.

6.4.9.1 Anthropometric measures

Weight was assessed at baseline to the nearest 0.1 kg (Weight Watchers 8961U electronic scales, Milton Keynes, UK) and height to the nearest mm (2 metre tape measure). Previous research has shown digital home bathroom scales such as those used here to provide sufficiently accurate and consistent weights for public health research (586). Body Mass Index (BMI; kg÷ m^2) was then produced from these measurements, to assess potential differential VFT effects between BMI categories. Underweight, overweight and obesity prevalence was estimated using the 2^{nd}, 85^{th} and 95^{th} percentiles of the 1990 UK reference curves (587).

6.4.9.2 Accelerometer-based physical activity measurement

Potential changes in physical activity and sedentary time were assessed using Actigraph GT1M accelerometers (as used in the Masters pilot study (2)). These devices have been identified as having acceptable validity and reliability in children (440, 457). Actigraphs were provided to participants at five phases during the study (Figure 6-2). At each data collection phase, accelerometers were worn for four consecutive days including two weekdays and two weekend days. This allowed activity measurement variation to be captured during both school and leisure time. To limit device damage and participant discomfort, pupils were requested to not wear their accelerometers during water-based activities or sleep. Accelerometers were activated at 09:00 on Day 1 when accelerometers were distributed at the start of school and de-activated at 23:59 on Day 4. This provided a total of 86 hours maximum wear time for each data collection phase.

Accelerometers were attached to an adjustable elastic belt and worn on the right hip. As in the Masters pilot study (Section 5.2.3), a logo was attached to the front of each accelerometer to indicate which way the device should be worn. The researcher instructed participants on how to wear the device during an introductory session when informed consent forms were distributed (Section 6.4.4) and when devices were first supplied. Lesson time PA was measured in twenty-minute periods of VFT and control group sessions. VFT sessions typically lasted between 10- and 20-minutes and so results reflect a combination of VFT and non-VFT time.

To maximise the study sample, participants were included in analysis if they provided at least one day of valid accelerometer wear time during the study (588), including one VFT day in intervention pupils. A sensitivity analysis with pupils contributing at least three days of valid accelerometer wear time (including one VFT day in intervention pupils) was also run to assess the validity of this alternative inclusion method. Valid accelerometer wear time was defined as at least 500 minutes wear time between 07:00 and 00:00 (589). This 500 minute cut-off replicates criteria previously used in research utilising The International Children's Accelerometry Database (ICAD) (90): the world's largest resource of pooled child accelerometer data (590). Data was collected in 5-second epochs (29, 39) and analysed using Pulsford cut-points (536) (Section 5.4.4) to classify activity as sedentary: (<100 CPM), light (100-2240 CPM), moderate (2241-3840 CPM) or vigorous (≥3841 CPM). Non-wear was defined as 60 minutes of consecutive zeros (591). Using all valid days, a daily average for time in SB, LPA and MVPA was calculated in minutes per day. Raw data was extracted from each Actigraph and analysed using ActiLife software (Actigraph, LLC, Fort Walton Beach, Florida). Presence of rain during accelerometer measurement days was monitored using local weather centre data (592).

6.4.9.3 Observations

Two observation tools were used at each data collection point, to assess physical activity and on-task behaviour during lesson time. Both tools were applied simultaneously in the same observations to reduce researcher and class burden. During the intervention period, a VFT (intervention group) or typically taught Maths or English lesson (control group) was observed for each class. Teachers provided researchers with a class seating plan featuring participant numbers to enable identification during each observation. Sessions were observed for 20-minute periods using momentary time sampling techniques. Participating pupils were observed in turn for 4 seconds before the next child was observed (593) using a pre-recorded audio file, with data recorded on a standardised score sheet (Appendix 6Q). To allow inter-rater reliability of both measures, one session in each class (n=10; 20% of all observations) was observed by the PhD researcher and an additional Masters student. An observer training session was run in a baseline (T0) session to assess inter-rater reliability of both measures.

6.4.9.3.1 Children's Activity Rating Scale (CARS) (31)

As previously described (Section 5.4.5), an observational measure was used in this main VFT study to triangulate measurements. The Children's Activity Rating Scale (CARS) (31) was used, defining observed activities into five intensity categories: stationary, stationary with limb or trunk movements, slow movement, moderate movement or fast movement (Table 6-2) (Section 5.4.5.3). CARS has previously been triangulated with objective data in other child-based studies (594, 595) but has not yet been used to investigate physically active lesson interventions (Section 4.5.9). Five observations were taken in total for each participating class (Figure 6-2), providing a total of fifty observed sessions.

Table 6-2: Children's Activity Rating Scale (CARS) (31)

Observed activity code	Operational definition	Representative activity
1	Stationary/ motionless	Sitting and talking
2	Stationary with limb/trunk movements	Sitting and playing
3	Slow/easy movement	Slow walking
4	Moderate movement	Fast walking
5	Fast movement	Jogging

Note. Table from (416)

Data was collected as described in Section 6.4.9.3. An observer training session was run in a T0 session to assess absolute agreement in inter-rater reliability of CARS assessment. A two-way mixed intraclass correlation (ICC) was run to assess how closely raters' training assessments aligned (596), with the resulting ICC in the excellent range with ICC = 0.89 (597). Inter-rater reliability of CARS observations within intervention group lessons was within the excellent range of ICC = 0.78 and also in the excellent range in the control group with ICC =

0.71. To maximise the study sample, participants were included in analysis if they were observed at least once, including one VFT day in intervention pupils.

6.4.9.3.2 Observing Teachers and Pupils in Classrooms tool (OPTIC) (593)

Behavioural student engagement (Section 6.4.8) was observed using the Observing Pupils and Teachers in the Classroom (OPTIC) observation tool (593, 598). OPTIC has not been used in physically active lesson research to date (Section 4.5.11). However it was selected for its wide use in education research (598) and its simple, binary nature: important to consider given the simultaneous nature of data collection by the researcher in this study (Section 6.4.9.3). Behaviour was coded as either '1': on-task (making eye contact with teacher or task, following teacher's instructions) or '2': off-task. OPTIC was assessed simultaneously with CARS observations, using the same procedures (Section 6.4.9.3). An observer training session was run in a T0 session to assess absolute agreement in inter-rater reliability of OPTIC assessment. A two-way mixed intraclass correlation (ICC) (596) was run for this training assessment, found to be in the excellent range: ICC = 0.75 (597). Inter-rater reliability across all OPTIC observations was in the good range with ICC = 0.66. To maximise the study sample, participants were included in analysis if they were observed at least once, including once during the intervention period (T1 or T2) in intervention pupils.

6.4.9.4 Questionnaires

Five questionnaires were administered during the intervention. Two of these were teacher and pupil demographic questionnaires provided at baseline only, one was a student engagement questionnaire provided to pupils at all data collection phases and two were pupils and teacher process evaluation questionnaires provided twice during the intervention phase (Section 6.4.9.5).

6.4.9.4.1 Pupil and teacher demographic questionnaires

Pupil demographics were assessed using a nine-item parent questionnaire distributed at baseline (Appendix 6R). Ethnicity was assessed using NHS Ethnic Categories (599): with six overall categories of White, Mixed, Asian or Asian British, Black or Black British, Chinese and Any other ethnic group. Household income was assessed across five categories: Under £15,000, £15,000-£19,999, £20,000-£29,999, £30,000-£39,999, £40,000-£50,000 and over

£50,000. Sex, English as a first language, disability status and access to free school meals were assessed using simple binary responses.

Teacher demographics and their physical activity teaching practices were assessed with a ten-item teacher questionnaire at baseline (Appendix 6S). Sex and ethnicity were assessed as in the pupil questionnaire and years teaching experience was also assessed. General teacher health was assessed using a simple 5-point item: 'How is your health in general?' (Very good - Very bad). 5-point item Likert scales were also used to assess agreement with the statement 'I think children get enough physical activity during school time' (Not at all – Very much) and to assess the extent of 'Brain Break' use and integrating physical activity into non-PE teaching time (both Every day – Never). Teachers were also asked how often their class has PE a week (Once a week, Twice a week, Three times a week, More) and how often they lead PE teaching (Never, Once in a while, Most sessions, Every session). They were also asked if their school has Healthy Schools status (600): a national scheme recognizing the practice and auditing of health schemes within individual schools (Section 2.6.2).

6.4.9.4.2 Student Engagement Instrument - Elementary Version (SEI-E) (583)

Pupils' affective and cognitive engagement (Section 6.4.8) towards their school, peers and learning was measured using the Student Engagement Instrument – Elementary Version (SEI-E) (583). This is a primary-school version of the well-validated School Engagement Instrument (SEI) (581, 584). It features 24 items assessed on 4-point Likert scales, ranging from strongly disagree to strongly agree (Appendix 6T). The SEI-E takes 15-20 minutes to administer and assesses four constructs: three representing affective engagement and one representing cognitive engagement. Firstly, Teacher-Student Relationships (TSR: affective engagement) are assessed with 9 items, such as: 'Most teachers care about me as a person, not just a student'. Peer Support for Learning (PSL: affective engagement) is assessed with 6 items, such as 'Other students care about me'. Future Goals and Aspirations (FGA: cognitive engagement) are assessed with 5 items, such as 'School is important for reaching my future goals. Finally, Family Support for Learning (FSL: affective engagement) is assessed with 4 items, such as 'My family/guardian(s) want to know when something good happens at school' (583).

The SEI-E is a relatively new instrument but chosen from a field with few other tools available for primary-school ages (580, 584). As previous research has shown cognitive engagement to be more accurately reported by pupils themselves rather than teacher proxy reports (585); it seemed appropriate to use a direct pupil questionnaire measure. Validation for the SEI-E has not yet been ascertained outside the exploratory (n=953) and confirmatory factor analyses (n=990) of the original sample (583). Authors found acceptable internal consistency in Cronbach's alpha values ranging from .639 (FGA) to .820 (PSL) (583). Two items contain Americanised language of 'high school' and 'college' which were adjusted to 'secondary school' and 'university'. To maximise the study sample, participants were included in analysis if they completed the questionnaire at least once, including once during the intervention period (T1 or T2) in intervention pupils.

6.4.9.5 Process evaluation

As identified in the systematic review (Section 4.5.6), it is important that physically active lessons as relatively novel interventions are fully evaluated. This allows understanding of the context in which the intervention was delivered, the extent it was delivered as intended and allows issues to be identified before iterative development (443). Six methods were used to evaluate the processes of the pilot Virtual Traveller RCT. These were designed to align with the RE-AIM framework dimensions of Reach, Effectiveness, Adoption, Implementation and Maintenance (Section 5.4.6). Table 6-3 shows how each measure assesses each dimension.

Level	**Dimension**	**Definition**	**Data collection timeframe**	**Type of measurement**
Individual	Reach	1. Participation rates among eligible classes 2. Participation rates among eligible pupils 3. Representativeness of participants	T0 T0 T0	1. Researcher logged 2. Teacher-returned consent sheet 3. Teacher-returned consent sheet, pupil demographic questionnaires
Individual	Effectiveness	1. Effects on primary physical activity outcome measures 2. Effects on secondary outcome measures of physical activity, on-task behaviour and student engagement outcome measures 3. Perceptions of intervention sessions 4. Perceived physical exertion in intervention sessions	T1-T4 T1-T4 T1-T2 T1-T2	1. Accelerometer and observation measures (Chapter 7) 2. Accelerometer, observation and questionnaire measures (Chapters 7 & 8) 3. Teacher intervention log, teacher and pupil evaluation questionnaires, teacher interviews and pupil focus groups 4. Pupil evaluation questionnaire (OMNI scale), teacher interviews and pupil focus groups
Setting	Adoption	1. Representativeness of participating classes 2. Costs of intervention	T0 T1-T2	1. Teacher demographic questionnaires 2. Researcher reported
Setting	Implementation	1. Extent the intervention is delivered as intended 2. Time required to deliver intervention	T1-T2 T1-T2	1. Teacher intervention log, teacher interviews and pupil focus groups 2. Teacher interviews and pupil focus groups

Both	Maintenance	1. (Individual) Impact of attrition on outcomes 2. (Organisational) Continuation or modification of intervention beyond intervention period	T1-T4 T3-T4	1. Accelerometer, observation and questionnaire measures 2. Teacher interviews

Table 6-3: Process evaluation measures and their fit within the RE-AIM framework

6.4.9.5.1 Teacher returned consent sheet

Each participating teacher was provided with a sheet to record which pupils returned their informed consent documents (Appendix 6J). This allowed the researcher to note the number of non-participating students, with the researcher asking for teacher-proxy recordings of the sex and English language status of the overall class. Participating pupils were identified by pupil number only to maintain anonymity.

6.4.9.5.2 Teacher intervention log

Throughout the intervention, teachers were asked to complete a record log for each VFT they completed (Appendix 6O). This required them to give the session identification code (e.g. M2 representing Maths Marching; Appendix 6M) and rate the perceived success of the session out of 5.

6.4.9.5.3 Pupil evaluation questionnaires

Pupils completed a six-item Virtual Traveller evaluation questionnaire at weeks 2 (T1) and 4 (T2) of the 6-week programme (Appendix 6U). Three 5-point Likert items assessed pupils' satisfaction with the Virtual Traveller programme, including 'On a scale of 1 to 5, how much do you like Virtual Traveller sessions?' (Not very much – Very much). Two free-text items were also included for pupils to report what they liked and did not like about the Virtual Traveller intervention.

Children's OMNI scale of perceived exertion (562)

Pupil's perceived physical exertion during Virtual Traveller sessions (T1 & T2) was measured within the pupil evaluation questionnaire using the Children's OMNI scale of perceived exertion (562) (Section 5.4.5.4). Intervention group children were asked to rate how tired they were on an eleven-point scale from 0: 'not tired at all' to 10: 'very, very tired' alongside a corresponding picture of a character cycling at increasing steepness (Figure 5-8).

6.4.9.5.4 Teacher evaluation questionnaires

Teachers completed an eight-item Virtual Traveller evaluation questionnaire at weeks 2 (T1) and 4 (T2) of the 6-week programme (Appendix 6V). Six items were 5-point Likert scales assessing teachers' satisfaction with the Virtual Traveller programme, including 'Virtual Traveller sessions were easy to use' and 'I will recommend the Virtual Traveller programme to other teachers' (both Strongly disagree – Strongly agree). As with the pupil questionnaire, two free-text items were also included for teachers to report what they liked and did not like about the Virtual Traveller intervention.

6.4.9.5.5 Pupil focus groups

Pupil focus groups were scheduled one-week post-intervention (T3), when experiences of Virtual Traveller sessions were still recent. One mixed-sex group of six students per intervention class participated. Each teacher was asked to select two children of lower, middle and higher overall academic ability, as done in previous physically active lesson evaluation (392). The setting, instrumentation and analysis for the pupil focus groups was otherwise similar to those used in Study One (Section 5.3), with the researcher acting as a 'moderator' for the session (467) and a semi-structured questioning schedule used (Appendix 6W). The schedule consisted of nine open-ended questions exploring children's experiences of the Virtual Traveller intervention. This included perceptions of Maths and English intervention sessions specifically and general likes and dislikes about the intervention.

6.4.9.5.6 Teacher interviews

As with pupil focus groups, teacher interviews were scheduled one-week post-intervention (T3). The setting differed slightly from Study One (Section 5.3.4), as interviews were organised in-school at a time convenient to each teachers' schedule. The instrumentation and analysis (Section 5.3) was similar to Study One. The schedule (Appendix 6X) consisted of nine open-ended items exploring teachers' experiences of the Virtual Traveller intervention. This included perceptions of session length, pupil enjoyment, behaviour and understanding during the sessions. Challenges experienced using Virtual Traveller PowerPoint presentations were also explored.

6.5 Analysis

This study was a pilot cluster-randomised trial, with classes randomised to intervention groups rather than individual pupils. Multilevel modelling (MLM) was hence used to reflect the hierarchical relationships between pupils, classes and schools (403, 404). MLM allows combined analysis of both individual and group-level effects, giving a more accurate representation of data variability sources (406) (See Section 4.5.8.2 for MLM use in physically active lessons). As this was a pilot RCT, a priori sample size calculation was not performed.

In this research, associations of VFT intervention differences between and within the different levels of pupils and classes were explored. Preliminary descriptive statistics were performed using SPSS for windows (Version 19.0). Independent *t*-tests were performed for each assessment of sedentary behaviour, physical activity, behavioural- (on-task behaviour), affective- and cognitive- student engagement, comparing the scores of the intervention and control groups at T0 (baseline), T1 & T2 (intervention period), T3 and T4 (post-intervention). Differences of each outcome by school (class) and demographic variables were also assessed by independent t-tests and one-way ANOVAs. To understand potential differing effects of the VFT intervention within intervention participants, demographic differences within the intervention group were assessed via independent *t*-tests and one-way ANOVAs for lesson time outcomes of physical activity, on-task behaviour, student engagement and physical exertion. Alpha levels were set at $p<0.05$.

Principal Components Analysis (PCA) was used to assess whether the factor structure of the SEI-E questionnaire in this study was comparable to its originally derived factors (583). Direct Oblimin rotation was used to allow for inter-correlations among factors (601). Pattern matrix values were used to examine the unique contribution coefficients of SEI-E items to factors, although structure matrix values showing correlations of each item to factors were also reported (602). Factors with eigenvalues over 1.0 were selected (603) with only item factor loadings larger than 0.4 considered (604). Cronbach's α was calculated to assess internal reliability of all identified SEI-E constructs, with items deleted if improvements were possible (0.7-0.8: 'acceptable', 0.8-0.9: 'good', 0.9-1: 'excellent') (605). Pearson's *r* correlations were performed to assess correlation between identified SEI-E sub-scales at all time-points.

In a change to the published protocol (1), multilevel regression analyses were conducted using Stata (Version 12.0), instead of MLwiN (Version 2.35) (412). This was because insufficient published guidance existed to generate three-level multilevel models with

MLwiN (606), whereas detailed and varied guidance existed for Stata (607). MLM was performed in accordance with past physically active lesson intervention studies using this technique (379-380) (Section 4.5.8.2). Three-level models were constructed, with measurements at each time-point (level 1) nested within individual pupils (level 2) nested within class (level 3). Random intercept models were developed to assess the differences between levels in impact of intervention (Virtual Traveller or control) and time-point (baseline (T0), during (T1 & T2) and post-test (T3 & T4)) and the group-by-time interaction.

To address the primary study aims (Section 6.2), overall and school day SB, LPA and MVPA measures at T4 were used as the dependent variables. To address the secondary study aims (Section 6.2), overall and school day SB, LPA and MVPA measures during the intervention period (T2), as well as weekend sedentary time, weekend MVPA, lesson SB, LPA and MVPA and PA observation ratings, on-task behaviour ratings and student engagement questionnaire scores at T4 and T2 were used as the dependent variables. For each dependent variable, three models were built to investigate the effects of the intervention. The covariates model contained sex, ethnicity (both consistently associated with differentiated physical activity; Section 2.3.3) and measurement period (categorical: comparing scores of baseline (T0) with the intervention periods (T1 & T2) and follow-up periods (T3, T4)) as fixed effects. Model 1 added condition as a fixed effect: to investigate whether the intervention group differed from the control group. Model 2 contained Model 1 and the interaction between condition and measurement period (Condition x T1 and Condition x T2 and Condition x T3) as additional fixed effects. The model fit was evaluated by comparing the deviance of the covariates model with the deviance of Models 1 and 2. To assess the proportion of variance explained by within and between group differences, the Variance Partition Coefficient (VPC) was calculated. The VPC was calculated with the formula: σ^2_{u0} ($\sigma^2_{u0} + \sigma^2_{e0}$) where σ^2_{u0} represents the variance between classes (groups) and σ^2_{e0} represents the variance within classes. VPC ranges from 0 (no group differences; $\sigma^2_{u0} = 0$) and 1 (no within-group differences; $\sigma^2_{e0} = 0$) (608). Alpha levels were set at *p*<0.05.

6.6 Summary

This chapter outlined the study aims, hypotheses and protocol for the 'Virtual Traveller' pilot cluster-randomised controlled trial: the main study of this PhD. It discussed the content of

σ^2_{u0} σ^2_{u0} σ^2_{e0} σ^2_{u0}

σ^2_{e0}

σ^2_{u0} σ^2_{e0}

the intervention and its teacher training, as well as the processes used to recruit and retain participating schools. The various data collection tools used to assess demographic and outcome information were shown. Finally, the data analysis plan were reported. This protocol was actioned to allow evaluation of the Virtual Traveller intervention’s effects on physical activity (Chapter 7), on-task behaviour and student engagement outcomes (Chapter 8), as well as a process evaluation of its implementation (Chapter 9).

Chapter 7 Sample characteristics and physical activity findings from Study Two

7.1 Introduction

This chapter presents sample demographics and physical activity findings of Study Two: a pilot longitudinal randomised controlled trial (RCT) of physically active Virtual Field Trips named 'Virtual Traveller'. The intervention was run according to protocol details provided in Chapter 6, incorporating recommendations identified following the preceding systematic review (Chapter 4) and feasibility work (Chapter 5).

It addresses the thesis aims of: 3) evaluate the effects of physically active Virtual Field Trips on children's physical activity and 4) evaluate the effects of physically active Virtual Field Trips on children's sedentary time. It also addresses the thesis questions of: 3) can Virtual Field Trips increase physical activity? and 4) can Virtual Field Trips reduce sedentary time? It also addresses thesis hypothesis 1) physically active Virtual Field Trips will increase children's physical activity (Chapter 3). The chapter also addresses the primary study aim of: determining the effectiveness of Virtual Traveller intervention to improve objectively-assessed mean overall minutes of moderate-to-vigorous activity (MVPA) at three month follow-up (T4). It also assesses the secondary study aims of 1) determining the effectiveness of Virtual Traveller intervention to improve the T4 mean scores of: a) overall sedentary time (SB), b) overall light physical activity (LPA), as well as c) school day SB, d) school day LPA and e) school day MVPA. It also addresses the secondary study aims of 1f) weekend day minutes of SB, g) weekend day minutes of LPA, h) weekend day minutes of MVPA, i) lesson time minutes of SB, j) lesson time minutes of LPA, k) lesson time minutes of MVPA and l) lesson time physical activity observation ratings. The chapter also addresses secondary study aims of: 2) the effectiveness of the Virtual Traveller intervention during the intervention period (T1 & T2; weeks 2 and 4 of the intervention) compared to baseline on all aforementioned physical activity outcome variables (Section 6.2). Finally, this chapter assesses the study hypotheses that Virtual Traveller intervention pupils will: 1) reduce their overall SB, 2) increase their overall LPA and MVPA, 3) reduce their SB within school hours and 4) increase their LPA and MVPA within school hours compared to the control group (Section 6.3).

7.2 Sample

7.2.1 Sample size

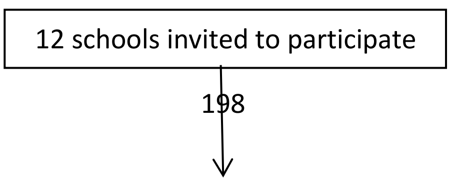
A full flowchart of study participants throughout the intervention can be found in Figure 7-1. Ten out of twelve invited schools participated in the intervention. One Year 4 class in each school participated, hence the term 'class' will be used henceforth to refer to both schools and classes. Consent was received from 264 out of 303 pupils (87.1%) present across the ten classes. Demographic data via parent questionnaire and BMI measurements was collected in all 264 participants at baseline. After baseline data collection, all 264 pupils were randomised by class into Virtual Traveller intervention or waiting list control groups, with 201 (76.14%) of these providing valid data at the final data collection point (T4). No schools withdrew during the course of the study. Missing data during the study occurred in pupils who did not want to participate during the given time-point (n=39/264; 14.8%), who were absent (n=48/264; 18.2%) and who relocated to another school (n=2/264; 0.01%; Figure 7-1). To maximize the study sample, pupils were allowed to participate later in the study if they provided missing data (Section 6.4.9.2).

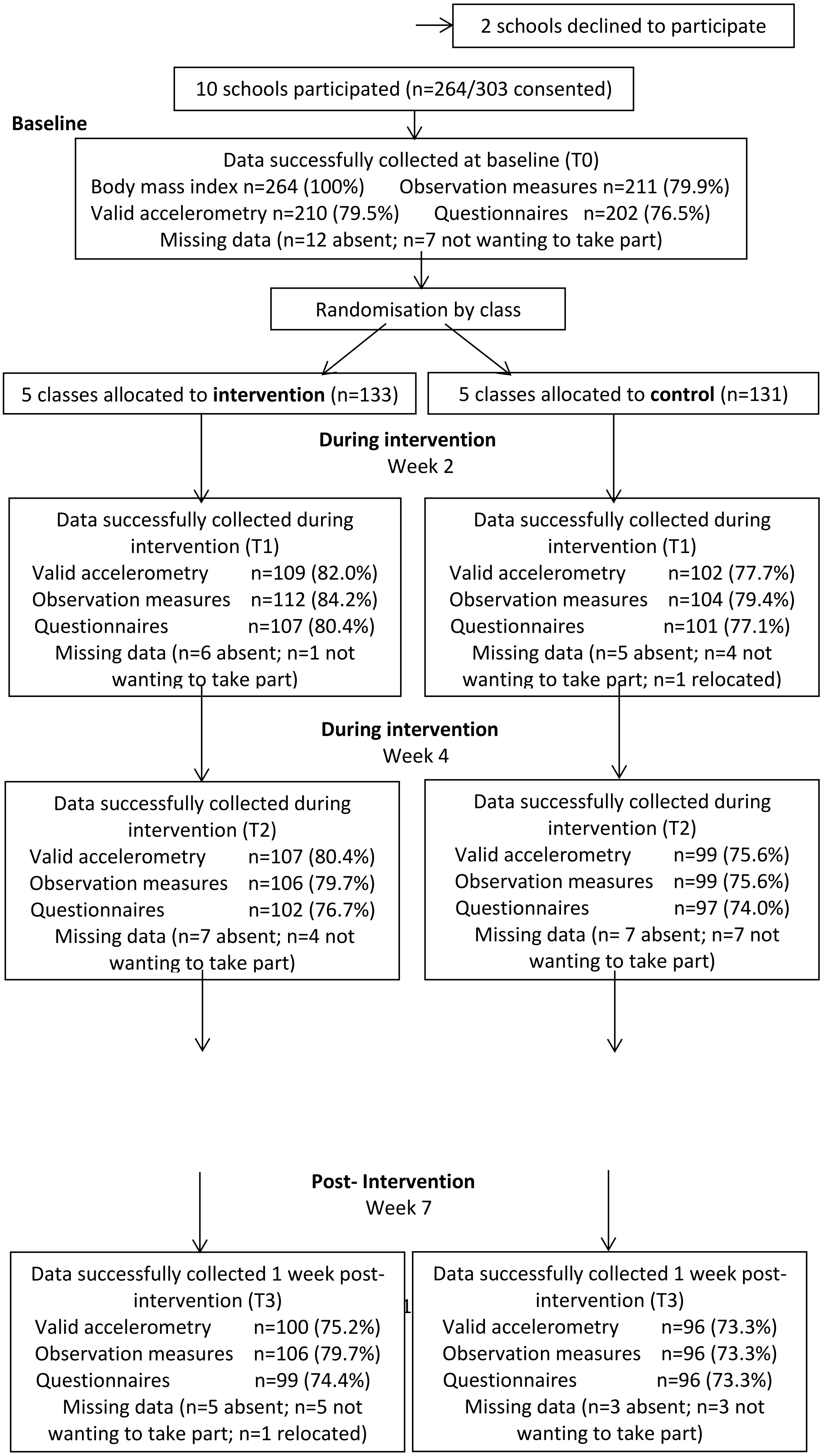
7.2.2 Participant inclusion criteria sensitivity analysis

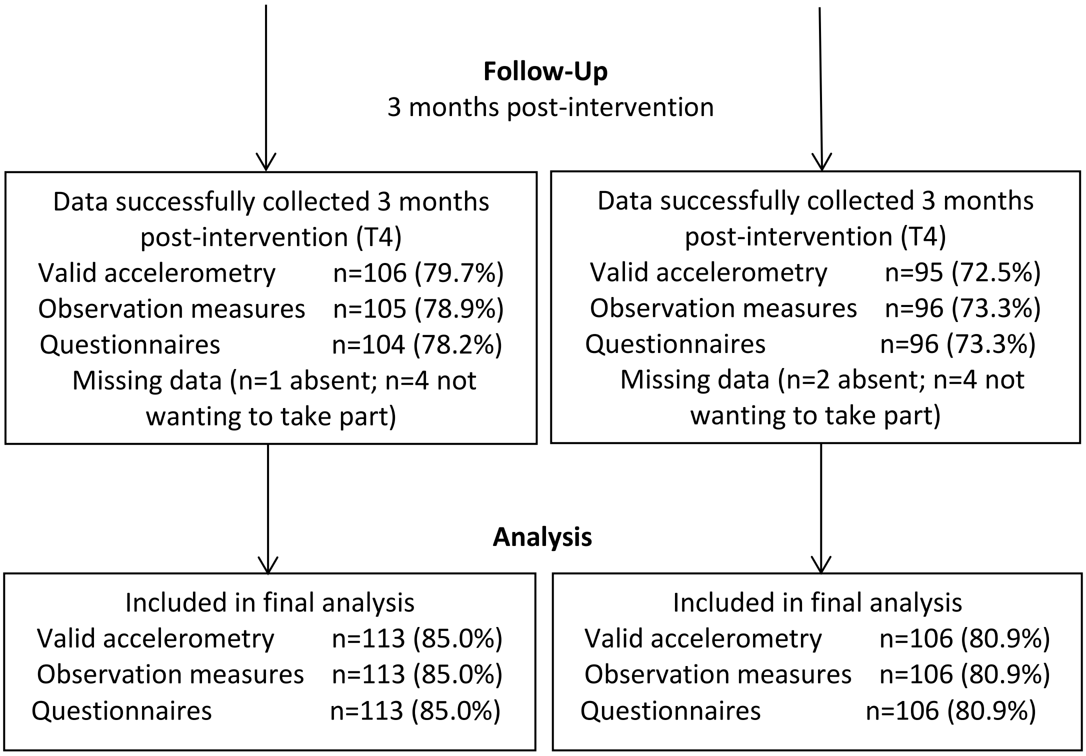
As previously described (Section 6.4.9.2), participants were originally included in the analytic sample if they provided at least one day of valid accelerometer wear time (≥500 minutes wear time between 07:00 and 00:00) during the study, including one VFT day in intervention pupils. This provided an overall analytic sample size of n=227 (74.9% of students whose consent was requested; n=115 intervention; 50.7%) for accelerometry and observation data and n=224 (n=114 intervention, 50.9%) for questionnaire data. However as described in the study protocol (Section 6.4.9.2), a sensitivity analysis was performed to compare the effects of including participants providing one and three days valid accelerometry data. Whereas including participants with one day valid accelerometry data across all time-points provided an analytic sample of n=227, a three day inclusion criteria provided a sample of n=219 (n=113 intervention, 51.6%). Chi-square analyses found no differences in demographics between one and three day samples (Appendix 7A).

Figure 7-1: Sample flowchart

Enrolment




2 schools declined to participate
10 schools participated (n=264/303 consented)
Baseline
Data successfully collected at baseline (T0)
Body mass index n=264 (100%) Observation measures n=211 (79.9%)
Valid accelerometry n=210 (79.5%) Questionnaires n=202 (76.5%)
Missing data (n=12 absent; n=7 not wanting to take part)
Randomisation by class
5 classes allocated to intervention (n=133)
5 classes allocated to control (n=131)
During intervention
Week 2
Data successfully collected during intervention (T1)
Valid accelerometry n=109 (82.0%)
Observation measures n=112 (84.2%)
Questionnaires n=107 (80.4%)
Missing data (n=6 absent; n=1 not wanting to take part)
Data successfully collected during intervention (T1)
Valid accelerometry n=102 (77.7%)
Observation measures n=104 (79.4%)
Questionnaires n=101 (77.1%)
Missing data (n=5 absent; n=4 not wanting to take part; n=1 relocated)
During intervention
Week 4
Data successfully collected during intervention (T2)
Valid accelerometry n=107 (80.4%)
Observation measures n=106 (79.7%)
Questionnaires n=102 (76.7%)
Missing data (n=7 absent; n=4 not wanting to take part)
Data successfully collected during intervention (T2)
Valid accelerometry n=99 (75.6%)
Observation measures n=99 (75.6%)
Questionnaires n=97 (74.0%)
Missing data (n= 7 absent; n=7 not wanting to take part)
Post- Intervention
Week 7
Data successfully collected 1 week post-intervention (T3)
Valid accelerometry n=100 (75.2%)
Observation measures n=106 (79.7%)
Questionnaires n=99 (74.4%)
Missing data (n=5 absent; n=5 not wanting to take part; n=1 relocated)
Data successfully collected 1 week post-intervention (T3)
Valid accelerometry n=96 (73.3%)
Observation measures n=96 (73.3%)
Questionnaires n=96 (73.3%)
Missing data (n=3 absent; n=3 not wanting to take part)


Follow-Up
3 months post-intervention
Data successfully collected 3 months post-intervention (T4)
Valid accelerometry n=106 (79.7%)
Observation measures n=105 (78.9%)
Questionnaires n=104 (78.2%)
Missing data (n=1 absent; n=4 not wanting to take part)
Data successfully collected 3 months post-intervention (T4)
Valid accelerometry n=95 (72.5%)
Observation measures n=96 (73.3%)
Questionnaires n=96 (73.3%)
Missing data (n=2 absent; n=4 not wanting to take part)
Analysis
Included in final analysis
Valid accelerometry n=113 (85.0%)
Observation measures n=113 (85.0%)
Questionnaires n=113 (85.0%)
Included in final analysis
Valid accelerometry n=106 (80.9%)
Observation measures n=106 (80.9%)
Questionnaires n=106 (80.9%)

There was also no difference in primary or secondary outcomes between one and three day samples (Appendix 7A). As such, the three day accelerometer criteria sample size was used in subsequent analysis to provide maximal data.

Further sensitivity analysis was performed to see if including a minimum of one weekend day within the three day inclusion criteria had any effects on sample size. Of the n=219 providing three days of valid accelerometry data, n=208 (95.0%) had at least one valid weekend day at any time-point. Chi-square analyses found no differences in demographics between samples with one weekend day and those without (Appendix 7B). There was also no difference in primary or secondary outcomes between three day and three day including one weekend day samples (Appendix 7B). As the inclusion of the additional weekend criteria produced no difference in the weekend variables it aimed to address, the three day criteria without weekend day stipulations (n=219) was maintained for all further analysis (Figure 7-1).

Of the 219 participants in the analytic sample, n=157 (71.7%) were 'remainers' (provided valid data at all time-points; n=82 intervention group), n=23 (10.5%) were 'lost to follow-up' (provided valid data but then dropped out for the remainder of the study; n=10 intervention group) and n=39 (17.8%) were 'returners' (providing study data intermittently; n=21 intervention group). Chi square analyses found no significant difference in these statuses between intervention groups, classes and demographics. Participants were more likely to not be included in the analytic sample if they were male ($x^2(1)=4.24$, $p<0.05$) but there were no other significant demographic differences. Physical activity data was normally distributed.

7.2.3 School and teacher demographics

All ten participating schools were located in the South East of England, specifically from the London Boroughs of Ealing (k=4; k=3 randomly allocated to intervention group) and Hillingdon (k=2; k=1 intervention group) and the Berkshire boroughs of Slough (k=2; k=0 intervention group) and Windsor and Maidenhead (k=2; k=1 intervention group). Table 7-1 presents summaries of relevant Public Health England Child Health Profile data for each of these boroughs alongside demographic data from this study sample. 2016 Child Health Profiles are presented as they summarise data from a wide range of government data sources, such as the National Child Measurement Programme (6). Levels of ethnic minority participants in all boroughs of Study Two are much higher than the national average. Overweight and obesity averages are similar between Study Two demographics and borough averages, with no significant differences between boroughs. Rates of ethnic minority participants are generally lower than borough averages, with significant differences between boroughs ($x^2(9)$ =19.49, p<0.05). Poverty levels are much higher than the borough average in Study Two, with rates up to three times higher in Windsor &

Table 7-1: Comparison of Public Health England Child Health Profiles and demographics in Study Two by borough

Demographic	Borough	Study Two	Borough average	Local average	National average
Ethnic minority	**Ealing** (609)	55.7% (n=49/88)	83.6%	71.3%*	28.9%
	Hillingdon (610)	32.6% (n=15/46)	61.2%	71.3%*	28.9%
	Slough (611)	70.7% (n=29/41)	81.8%	21.3%$^+$	28.9%
	Windsor & Maidenhead (612)	47.7% (n=21/44)	31.7%	21.3%$^+$	28.9%
Poverty	**Ealing**	35.2%^{0} (n=31/88)	19.2%	21.8%*	18.6%
	Hillingdon	21.7%^{0} (n=10/46)	17.9%	21.8%*	18.6%
	Slough	31.7%^{0} (n=13/41)	18.4%	13.7%$^+$	18.6%
	Windsor & Maidenhead	29.5%^{0} (n=13/44)	8.6%	13.7%$^+$	18.6%
Overweight or obese at age 10-11	**Ealing**	42.0% (n=37/88)	37.9%	37.2%*	33.2%
	Hillingdon	34.8% (n=16/46)	33.2%	37.2%*	33.2%
	Slough	41.5% (n=17/41)	39.0%	30.1%$^+$	33.2%
	Windsor & Maidenhead	27.3% (n=12/44)	29.2%	30.1%$^+$	33.2%

Notes. * indicates local area comparison figures are from London; $^+$ indicates local area comparison figures are from South East England, ^{0} indicates poverty identified in the study sample as participants with a net family income <£15,000.

Maidenhead but no significant differences between boroughs. These higher estimated levels in Study Two may be due to the proxy measure of poverty used: family income <£15,000. Parents may have under-reported their income as the questionnaire did not provide guidance on what income should actually be included in this sum (Appendix 6R). Parents may have been unsure whether to include their employment income only or through all forms of income including benefits.

As previously described (Section 6.4.9.4.1), all participating teachers completed a questionnaire at baseline with basic demographic questions on themselves, their teaching and their school. Ten classes participated in the study, with demographics of each school and participating class teacher found in Table 7-2. Nine classes were led by a female teacher (n=4 intervention, n=5 control). Seven teachers were White, two were Asian or Asian British and one was of mixed ethnicity. Teachers held a total of 92 years' teaching experience between them (34 years' experience in intervention group, 58 years' experience in control group). All teachers self- reported their health as either excellent (n=5) or good (n=5). Four participating schools had Healthy School status (600) (Section 2.6.2); n=2 intervention, n=2 control) and only one control group school did not provide pupils with afternoon play.

All schools provided pupils with two hours PE per week, as per UK government recommendations (70) (Section 2.3.3.1). In response to the statement 'I think children get enough physical activity during school time', the ten teachers provided a mean score of 3.0/5 (SD=0.78; M=3.0 (SD=0.66) intervention, M=3.0 (SD=0.89) control) indicating middling agreement. Five teachers described themselves to integrate physical activity into teaching on 'most days' (n=2 intervention, n=3 control), four to do so 'sometimes' (n=2 intervention, n=2 control) and one intervention teacher reported 'not often' doing so. One control group teacher described using Brain Breaks on 'most days', five teachers described using them 'sometimes' (n=1 intervention, n=4 control) and four intervention teachers used them 'not often'. One control group teacher said that they taught their class for PE during 'most sessions', four described doing so 'once in a while' (n=3 intervention, n=1 control) and five described 'never' doing so (n=2 intervention, n=3 control).

Table 7-2: Teacher and school demographics

Class	Intervention Group	School borough	Sex of teacher	Teacher ethnicity	Years teaching	Teacher self-reported health	PM Play	Healthy School status	PE hr/wk	Children get enough PA during school (out of 5)	How often integrate physical activity into teaching	How often use Brain Breaks	How often teach PE
1	Control	Slough	Female	Mixed	20	Good	Yes	No	2	4	Sometimes	Sometimes	Never
2	Intervention	Ealing	Female	White	5	Excellent	Yes	No	2	3	Sometimes	Sometimes	Never
3	Control	Hillingdon	Female	Asian	8	Good	Yes	No	2	4	Sometimes	Sometimes	Once in a while
4	Control	Slough	Female	White	2	Excellent	No	Yes	2	2	Most days	Most days	Never
5	Intervention	Ealing	Female	Asian	5	Good	Yes	Yes	2	2	Most days	Not often	Never
6	Intervention	Windsor	Female	White	15	Excellent	Yes	No	2	4	Sometimes	Not often	Once in a while
7	Intervention	Ealing	Male	White	2	Excellent	Yes	No	2	3	Not often	Not often	Once in a while
8	Control	Ealing	Female	White	20	Good	Yes	No	2	4	Most days	Sometimes	Never
9	Control	Windsor	Female	White	8	Good	Yes	Yes	2	4	Most days	Sometimes	Most sessions
10	Intervention	Hillingdon	Female	White	7	Excellent	Yes	Yes	2	3	Most days	Not often	Once in a while

7.2.4 Pupil demographics

A table comparing demographics of full (n=264) and analytic samples (n=219) is found in Appendix 7C; however only data on the analytic sample will be reported henceforth. 50.7% (n=111) of participants were male, with a mean age of 8.6 years (SD=0.49) (Table 7-3). 47.9% (n=105) were White, 40.2% were Asian or Asian British (n=88), 6.8% (n=15) were of mixed ethnicity, 5.0% (n=11) were Black or Black British and 0% were Chinese. 76.3% (n=167) of participants were born in the UK and 77.6% (n=170) spoke English as a first language. 1.4% (n=3) of participants were underweight, 61.2% (n=134) were normal weight, 30.1% (n=66) were overweight and 7.3% (n=16) were obese. 30.6% (n=67) lived in a household with a total income of less than £15,000, 37.4% (n=82) in £15,000-£19,999,

Table 7-3: Analytic sample pupil demographics

Demographics	**Analytic sample n= 219**	**Intervention group n=113**	**Control group n=106**	**p**
Sex Male	n=111 (50.7%)	n=52 (46.1%)	n=59 (55.7%)	0.16
Female	n=108 (49.3%)	n=61 (54.0%)	n=47 (44.3%)	
Age Mean (SD)	8.6 (0.49)	8.6 (0.49)	8.6 (0.49)	0.88
Ethnicity				
White	n=105 (47.9%)	n=60 (53.1%)	n=45 (42.5%)	0.27
Mixed	n=15 (6.8%)	n=5 (4.4%)	n=10 (9.4%)	
Asian or Asian British	n=88 (40.2%)	n=42 (37.2%)	n=46(43.4%)	
Black or Black British	n=11 (5.0%)	n=6 (5.3%)	n=5 (4.7%)	
Chinese	n=0 (0%)	n=0 (0%)	n=0 (0%)	
Born in UK	n=167 (76.3%)	n=89 (78.8%)	n=78 (73.6%)	0.37
English as first language	n=170 (77.6%)	n=88 (77.9%)	n=82 (77.4%)	0.93
BMI Category				
Underweight	n=3 (1.4%)	n=2 (1.8%)	n=1 (0.9%)	0.99
Normal	n=134 (61.2%)	n=68 (60.2%)	n=66 (62.3%)	
Overweight	n=66 (30.1%)	n=35 (31.0%)	n=31 (29.2%)	
Obese	n=16 (7.3%)	n=8 (7.1%)	n=8 (7.5%)	
Special Educational Needs	n=3 (1.4%)	n=2 (1.8%)	n=1 (0.9%)	0.60
Physical difficulties	n=3 (1.4%)	n=1 (0.9%)	n=2 (1.9%)	0.53
Free School Meals	n=50 (22.8%)	n=28 (24.8%)	n=22 (20.8%)	0.48
Total household income				
Under £15,000	n=67 (30.6%)	n=33 (29.2%)	n=34 (32.1%)	0.47
£15,000-£19,999	n=82 (37.4%)	n=47 (41.6%)	n=35 (33.0%)	
£20,000-£29,999	n=61 (27.9%)	n=31 (27.4%)	n=30 (28.3%)	
£30,000-£39,999	n=8 (3.7%)	n=2 (1.8%)	n=6 (5.7%)	
£40,000-£49,999	n=1 (0.5%)	n=0 (0%)	n=1 (0.9%)	

Notes: Independent t-tests found no significant differences of any demographic variables between intervention groups in both the full and analytical sample.

27.9% (n=61) in £20,000 -£29,999, 3.7% (n=8) in £30,000-£39,999 and 0.5% (n=1) in £40,000-£49,999. 22.8% (n=50) of participants received Free School Meals, 1.4% (n=3) of participants had Special Educational Needs and 1.4% (n=3) had physical difficulties. There were no significant differences in demographics between intervention and control groups (Table 7-3). Demographics by class are provided in Appendix 7D.

7.2.5 Accelerometer wear-time

Following the valid day criteria previously specified (Section 6.4.9.2) the analytic sample provided 3,308 valid days of accelerometer measurement out of a maximum 4,380 days (75.5%; Table 7-4). There was an average accelerometer wear-time of 65.5% across all measurement points (Table 7-5). There were no significant differences in overall average wear times between time-points or intervention groups. There were significant differences in wear-time between sexes, with longer wear-time recorded in boys at T3 (boys: M=57.1% wear-time (SD=33.36), girls: M=46.1% (SD=34.99); $t(217)=2.40$, $p<0.05$) and T4 (boys: M=57.6% wear-time (SD=33.75), girls: M=46.1% (SD=34.28); $t(217)=2.50$, $p<0.05$). One-way ANOVAs with post-hoc Bonferroni analysis found that Asian pupils recorded significantly less wear-time than White pupils at all time-points (T0: 69.8% wear-time (SD=26.67) vs 46.2% (SD=37.92); $F(3,218)=8.76$, $p<0.001$; T1: 65.7% (SD=25.55) vs 46.4% (SD=36.90); $F(3,218)=7.54$, $p<0.001$; T2 (59.4% (SD=29.92) vs 46.1% (SD=36.20); $F(3,218)=3.35$, $p<0.05$; T3: (61.1% (SD=31.26) vs 39.0% (SD=34.93); $F(3,218)=7.35$, $p<0.001$; T4 (60.7% (SD=31.10) vs 40.6% (SD=35.49); $F(3,218)=5.89$, $p=0.001$). Pupils having English as a first language recorded longer wear- time at all time-points (T0: 62.3% wear-time (SD=32.51) vs 47.6% (SD=37.48); $t(217)=2.70$, $p<0.05$); T1: 59.7% (SD=31.65) vs 44.4% (SD=36.43); $t(217)=2.87$, $p<0.01$); T2: 57.4% (SD=32.35) vs 44.4% (35.94); $t(217)=2.41$, $p<0.05$; T3: 55.6% (SD=33.23) vs 38.2% (35.97); $t(217)=3.16$, $p<0.01$; T4: 54.5% (SD=33.38) vs 42.9% (SD=36.75); $t(217)=2.11$, $p<0.05$). This finding may indicate that pupils or their families who did not speak English as a first language may have found accelerometer wear instructions difficult to understand. There were no significant differences in accelerometer wear-time by free school meals status, BMI category, family income, SEN or physical difficulty statuses and whether individuals were born in the UK.

Table 7-4: Valid days of physical activity assessment

Time	Day	Analytic sample (n=219)	Intervention (n=113)	Control (n=106)
T0	**School day 1**	n=202 (92.2%)	n=106 (93.8%)	n=96 (90.6%)
	School day 2	n=196 (89.5%)	n=103 (91.2%)	n=93 (87.7%)
	Weekend day 1	n=165 (75.3%)	n=87 (77.0%)	n=78 (73.6%)
	Weekend day 2	n=138 (63.0%)	n=71 (62.8%)	n=67 (63.2%)
	Total	n=701/876 (80.0%)	n=367/452 (81.2%)	n=334/424 (78.8%)
T1	**School day 1**	n=204 (93.2%)	n=105 (92.9%)	n=99 (93.4%)
	School day 2	n=188 (85.8%)	n=94 (83.2%)	n=94 (88.7%)
	Weekend day 1	n=152 (69.4%)	n=72 (63.7%)	n=80 (75.5%)
	Weekend day 2	n=128 (58.4%)	n=63 (55.8%)	n=65 (61.3%)
	Total	n=672/876 (76.7%)	n=334/452 (73.9%)	n=338/424 (79.7%)
T2	**School day 1**	n=200 (91.3%)	n=102 (90.3%)	n=98 (92.5%)
	School day 2	n=190 (86.8%)	n=98 (86.7%)	n=92 (86.8%)
	Weekend day 1	n=152 (69.4%)	n=80 (70.8%)	n=72 (67.9%)
	Weekend day 2	n=116 (53.0%)	n=64 (56.6%)	n=52 (49.1%)
	Total	n=658/876 (75.1%)	n=344/452 (76.11%)	n=314/424 (74.1%)
T3	**School day 1**	n=193 (88.1%)	n=99 (87.6%)	n=94 (88.7%)
	School day 2	n=182 (83.1%)	n=93 (82.3%)	n=89 (84.0%)
	Weekend day 1	n=146 (66.7%)	n=74 (65.5%)	n=72 (67.9%)
	Weekend day 2	n=116 (53.0%)	n=58 (51.3%)	n=58 (54.7%)
	Total	n=637/876 (72.7%)	n=324/452 (71.7%)	n=313/424 (73.8%)
T4	**School day 1**	n=193 (88.1%)	n=101 (89.4%)	n=92 (86.8%)
	School day 2	n=183 (83.6%)	n=95 (84.1%)	n=88 (83.0%)
	Weekend day 1	n=154 (70.3%)	n=83 (73.5%)	n=71 (67.0%)
	Weekend day 2	n=110 (50.2%)	n=59 (52.2%)	n=51 (48.1%)
	Total	n=640/876 (73.1%)	n=338/452 (74.8%)	n=302/424 (71.2%)
Total		n=3308/4380 (75.5%)	n=1707/2260 (75.5%)	n=1601/2120 (75.5%)

Notes: Chi-square analyses found no significant differences in valid accelerometer days between intervention and control groups at any time-point.

Table 7-5: Accelerometer wear-Time during study

Class	Intervention Group	n	Overall Wear-Time	Wear-Time T0	Wear-Time T1	Wear-Time T2	Wear-Time T3	Wear-Time T4
1	Control	19	67.1%	65.1%	68.0%	66.0%	67.1%	69.6%
2	Intervention	23	65.6%	74.5%	67.0%	66.5%	61.0%	58.8%
3	Control	21	66.2%	67.1%	74.0%	66.9%	65.9%	56.8%
4	Control	22	66.7%	69.5%	68.1%	68.6%	65.6%	61.6%
5	Intervention	24	65.8%	71.3%	65.5%	63.1%	64.4%	64.7%
6	Intervention	24	65.7%	70.0%	64.2%	68.6%	59.5%	66.2%
7	Intervention	17	65.2%	70.0%	55.3%	64.8%	63.8%	72.2%
8	Control	24	61.4%	67.2%	63.4%	60.9%	56.1%	59.4%
9	Control	20	67.1%	76.2%	71.6%	61.9%	63.8%	62.3%
10	Intervention	25	64.4%	68.4%	65.4%	64.3%	58.6%	65.4%
Overall		219	65.5%	69.9%	66.3%	65.2%	62.6%	63.7%

7.3 Overall physical activity in sample

This section address the primary study aim of: determining the effectiveness of the Virtual Traveller intervention to improve the objectively-assessed mean overall minutes of moderate-to-vigorous physical activity (MVPA) accumulated by Year 4 pupils three month follow-up (T4). It also assessed the secondary aims of 1a) overall SB and b) overall LPA, as well as changes to these outcomes during the intervention period (T1 & T2; aims 2a), b) and c)) (Section 6.2).

7.3.1 Intervention group differences

Mean overall accelerometer minutes by activity intensity and intervention group at all time-points are shown in Table 7-6. Mean daily minutes of activity by intervention group are provided in Appendix 7E. At T0 (baseline) there were no significant differences in overall accelerometer-assessed activity between intervention groups (intervention and control; Table 7-6). At T1 (first intervention assessment), the intervention group demonstrated significantly less sedentary time (M=2058.9 minutes (SD=647.13) in intervention vs M=2228.7 minutes (SD=569.23); $t(203)=1.99$, $p<0.05$) but also significantly less LPA (M=416.6, SD=142.95) in intervention vs M=458.3 minutes (SD=142.91); $t(204)=2.08$, $p<0.05$) than the control group (Table 7-6). There were no other significant differences in overall accelerometer-observed activity between intervention groups at any other time-point.

Table 7-6: Mean accelerometer minutes for all data measurement points by intervention group

Time -point	n	Intervention group	SB	LPA	MPA	VPA	MVPA
T0 (n=204)	108	Intervention	2216.2 (593.31)	474.5 (152.67)	118.8 (37.19)	75.1 (25.77)	193.9 (60.17)
	96	Control	2267.3 (548.68)	499.9 (152.21)	123.2 (37.84)	77.2 (27.59)	200.4 (62.03)
T1 (n=205)	106	Intervention	2058.9* (647.13)	416.6* (142.95)	109.4 (38.57)	69.0 (22.75)	178.5 (59.73)
	99	Control	2228.7 (569.23)	458.3 (142.91)	111.8 (33.19)	69.8 (26.39)	181.6 (55.23)
T2 (n=202)	104	Intervention	2147.1 (591.28)	448.0 (136.31)	113.4 (35.58)	71.4 (27.17)	184.8 (60.19)
	98	Control	2098.2 (590.88)	450.0 (164.88)	109.9 (37.68)	67.6 (26.94)	177.4 (62.59)
T3 (n=193)	99	Intervention	2104.8 (624.65)	445.4 (148.73)	108.3 (35.75)	67.9 (25.57)	176.2 (58.66)
	94	Control	2135.8 (627.19)	475.3 (188.86)	112.1 (35.52)	66.3 (23.28)	179.1 (55.71)
T4 (n=193)	101	Intervention	2207.6 (586.59)	450.2 (136.02)	113.2 (33.07)	68.9 (22.73)	182.1 (53.24)
	92	Control	2141.0 (611.42)	450.1 (146.99	113.0 (34.06)	68.4 (25.19)	181.4 (56.29)
Total (n=219)	113	Intervention	9842.9 (3049.29)	2049.2 (686.17)	516.6 (173.70)	323.2 (114.59)	839.9 (283.16)
	106	Control	9826.9 (2968.31)	2108.9 (709.48)	515.1 (170.04)	316.3 (113.73)	831.4 (277.91)

Note: * *p*<0.05.

7.3.2 Demographics differences

Boys were found to exhibit significantly more overall average MVPA (M=180.5 minutes (SD=57.89) vs M=174.5 minutes (SD=56.43); $t(200)=2.12$; $p<0.05$) than girls at the second intervention period (T2) and at three month follow-up (T4; Boys: M=190.0 (SD=54.33) vs girls: M=173.2 (SD=53.77; $t(191)=2.16$; $p<0.05$). Differences by UK born status were explored due to the diverse nature of participants (Table 7-3): with such differences not explored in previous physically active lesson research (436). Participants born in the UK demonstrated significantly more overall average MVPA (M=180.2, SD=56.83) than those born outside of the UK at T3 (M=158.3, SD=63.61; $t(196)=2.25$, $p<0.05$). There were no significant differences in overall physical activity by ethnicity, household income, BMI category or English language and free school meal statuses.

7.3.3 Meeting physical activity guidelines

Percentages of participants meeting PA recommendations of ≥60 minutes MVPA per valid day of accelerometer data (17) are provided in Table 7-7. Overall, 40.2% of days met these guidelines. Intervention group pupils were significantly more likely to meet physical activity

Table 7-7. Percent meeting physical activity recommendations of 60 minutes MVPA per day (17)

Time	Day	Intervention (n=113)	Control (n=106)
T0	**School day 1**	49.1% (n=52/106)	46.9% (n=45/96)
	School day 2	45.6% (n=47/103)	57.0% (n=53/93)
	Weekend day 1	34.5% (n=30/87)	38.5% (n-30/78)
	Weekend day 2	19.4% (n=14/72)	16.4% (n=11/67)
	Total	n=143/368 (38.9%)	n=139/334 (41.6%)
T1	**School day 1**	55.8% (n=63/105)**	39.4% (n=39/99)
	School day 2	56.4% (n=53/94)	42.6% (n=40/94)
	Weekend day 1	33.3% (n=24/72)	36.3% (n=29/80)
	Weekend day 2	25.8% (n=16/62)	20.3% (n=13/64)
	Total	n=156/333 (46.8%)	n=121/337 (35.9%)
T2	**School day 1**	54.9% (n=56/102)	44.9% (n=44/98)
	School day 2	51.0% (n=50/98)	48.9% (n=45/92)
	Weekend day 1	30.0% (n=24/80)	25.0% (n=18/72)
	Weekend day 2	26.6% (n=17/64)	23.1% (n=12/52)
	Total	n=147/344 (42.7%)	n=119/314 (37.9%)
T3	**School day 1**	49.5% (n=49/99)	48.9% (n=46/94)
	School day 2	42.6% (n=49/93)	50.6% (n=45/89)
	Weekend day 1	29.7% (n=22/74)	26.4% (n=19/72)
	Weekend day 2	26.3% (n=15/57)	17.2% (n=10/58)
	Total	n=135/323 (41.8%)	n=120/313 (38.3%)
T4	**School day 1**	48.5% (n=49/101)	52.2% (n=48/92)
	School day 2	55.8% (n=53/95)*	38.6% (n=34/88)
	Weekend day 1	27.7% (n=23/83)	25.4% (n=18/71)
	Weekend day 2	25.4% (n=15/59)	15.7% (n=8/51)
	Total	n=140/338 (41.4%)	n=108/302 (35.8%)
Total		n=721/1706 (42.3%)	n=607/1600 (37.9%)

Notes: * $p<0.05$; ** $p<0.01$

recommendations than control pupils during School day 1 at T1 (n=63/105 days met recommendations in intervention vs n=39/99 days in control; x^2=(1)=8.67, p<0.01) and during School day 2 at T4 (n=53/95 met recommendations in intervention vs n=34/88 in control; x^2=(1)=5.39, p<0.05; Table 7-7).

7.3.4 Weather effects on overall physical activity

With rainfall shown to significantly reduce children's PA (194) (Section 2.5.1), differences in overall physical activity between rainfall status was analysed. A total of 200 days were observed across all intervention periods (10 classes observed for four days at five time-points). Of these, twenty seven days (13.5%) featured rain (592), with thirteen of these during intervention class observations and fourteen during control group observations. Various significant differences in activity intensity were seen between wet and dry days, but there were no consistent patterns in intervention or control groups (Appendix 7F).

7.3.5 Multilevel modelling

Multilevel models (MLM) were calculated according to the processes described in Section 6.6. Co-variates, Model 1 and Model 2 are presented for each outcome, although reporting of analysis refers to Model 2 only: providing the most detailed level of adjustment. Ethnicity was coded as a binary variable (0=white, 1=non-white) for multilevel modelling purposes, as samples of Mixed and Black ethnicities were too small to enable adequate findings (Section 7.2.4). Full significance testing with p values and confidence intervals are presented for the primary study aim only (Section 7.3.5.1). Results for T4 and intervention period (T1 & T2) outcomes were indistinguishable for almost all physical activity outcomes, hence results are largely presented together. Tables of multilevel results for average overall physical activity during the intervention period are provided in Appendix 7G.

7.3.5.1 Primary study aim: Average overall MVPA at three-month follow-up (T4) & Secondary study aim 2c): Average overall MVPA time during intervention period (T1 & T2)

Table 7-8 shows the effects of the intervention (Model 2) on average accelerometer-assessed overall moderate-to-vigorous physical activity (MVPA) at T4. The VPC of Model 2 was 0.1072, indicating that 10.72% of variance in average overall MVPA at T4 was due to variation between classes and 89.28% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. There were no significant differences in model fit between the co-variates model, Model 1 or Model 2. In Model 2 there was a significant effect of sex (*B*=15.79 (3.71); 95% CI, 8.52, 23.06; $p<0.001$), reflecting that boys demonstrated greater average overall MVPA than girls at T4. In Model 2, there was a significant difference between average overall MVPA at T1 compared to T0 (*B*= -18.21 (8.22); 95% CI, -34.33, -2.10; $p<0.05$), T2 compared to T0 (*B*= -22.16 (8.25); 95% CI, -38.32, -5.99; $p<0.01$), T3 compared to T0 (*B*=-20.80 (8.33); 95% CI, -37.12, -4.48; $p<0.05$) and T4 compared to T0 (*B*= -18.46 (8.38); 95% CI, -34.87, -2.05; $p<0.05$), indicating that less MVPA was demonstrated by the overall sample at these time-points than at T0 (baseline). There was no significant effect of intervention on average overall MVPA at T4. There were no significant interactions between time-points and intervention group status. These findings show that average overall MVPA at T4 was not affected by the Virtual Traveller intervention.

Table 7-8. Multilevel modelling for primary study outcome of average overall accelerometer-assessed moderate-and-vigorous physical activity (MVPA) at T4 (3-month follow-up)

	Co-variates			Model 1			Model 2		
	ß	**SE**	**95% CI**	**ß**	**SE**	**95% CI**	**ß**	**SE**	**95% CI**
Fixed effects (SE)									
Intercept	191.86	5.26	181.56, 202.16 ***	192.04	6.12	180.04, 204.03 ***	194.75	7.24	180.56, 208.94 ***
Sex	15.88	3.71	8.62, 23.14 ***	15.87	3.71	8.60, 23.14 ***	15.79	3.71	8.52, 23.06 ***
Ethnicity	-4.95	3.83	-12.46, 2.57	-4.96	3.84	-12.49, 2.57	-4.99	3.84	-12.52, 2.53
T1[0]	-16.77	5.68	-27.91, -5.64 **	-16.78	5.68	-27.91, -5.64 **	-18.21	8.22	-34.33, -2.10 *
T2[0]	-15.34	5.70	-26.51, -4.16 **	-15.34	5.70	-26.52, -4.16**	-22.16	8.25	-38.32, -5.99 **
T3[0]	-19.24	5.77	-30.55, -7.94 **	-19.25	5.77	-30.55, -7.94 ***	-20.80	8.33	-37.12, -4.48 *
T4[0]	-15.09	5.77	-26.40, -3.79**	-15.10	5.77	26.40, -3.79 **	-18.46	8.38	-34.87, -2.05 *
Intervention				-0.32	5.69	-11.47, 10.84	-5.32	9.18)	-23.32, 12.67
T1*Intervention							2.66	11.36	-19.62, 24.93
T2*Intervention							13.09	11.41	-9.27, 35.45
T3*Intervention							2.87	11.54	-19.74, 25.48
T4*Intervention							6.36	11.54	-16.26, 28.99
Random effects (SE)									
Variance between classes	6.84 (2.90)			6.84 (2.90)			6.89 (2.90)		
Variance within classes	57.42 (1.29)			57.42 (1.29)			57.37 (1.29)		
Model deviance	-5457.32			-5457.32			-5456.53		

Notes: [0] indicates comparison of scores between given time-point and T0 (baseline); * p<0.05; ** p≤0.01; *** p≤0.001.

7.3.5.2 Secondary study aims 1a) Average overall SB at three-month follow-up (T4) & 2a): Average overall SB time during intervention period (T1 & T2)

Table 7-9 shows the effects of the intervention (Model 2) on average accelerometer-assessed overall sedentary behaviour (SB) at T4. The VPC of Model 2 was 0.0773, indicating that 7.73% of variance in average overall SB at T4 was due to variation between classes and 92.27% was due to variance within classes (calculated as shown in Section 6.6). Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. There were no significant differences in model fit (deviance) between the co-variates model, Model 1 or Model 2. There was no significant effect of intervention on average overall SB at T4. There were also no significant interactions between time-points and intervention group status. These findings show that average overall SB at T4 was not affected by the Virtual Traveller intervention.

Table 7-9. Multilevel modelling for average overall accelerometer-assessed sedentary behaviour (SB) at T4 (3-month follow-up)

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	2245.74 (52.11)***	2263.44 (59.05)***	2276.04 (71.31)***
Sex	55.36 (38.31)	53.56 (38.36)	52.79 (38.28)
Ethnicity	-58.45 (39.24)	-59.30 (39.28)	-60.70 (39.21)
$T1^0$	-99.27 (58.92)	-99.50 (58.92)	-37.09 (85.13)
$T2^0$	-115.23 (59.16)	-115.46 (59.16)	-166.41 (85.38)
$T3^0$	-119.89 (59.82)*	-120.20 (59.82)*	-130.32 (86.23)
$T4^0$	-63.99 (59.82)	-64.10 (59.82)	-125.22 (86.71)
Intervention		-32.06 (49.17)	-53.53 (89.41)
T1*Intervention			-121.33 (117.67)
T2*Intervention			98.27 (118.12)
T3*Intervention			19.02 (119.47)
T4*Intervention			116.49 (119.52)
Random effects (SE)			
Variance between classes	51.15 (30.97)	48.84 (31.03)	49.77 (30.78)
Variance within classes	595.69 (13.43)	595.68 (13.43)	594.11 (13.39)
Model deviance	-7787.99	-7787.78	-7785.24

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * $p \leq 0.05$; *** $p \leq 0.001$.

7.3.5.3 Secondary study aims 1b): Average overall LPA at three-month follow-up (T4) & 2b): Average overall LPA time during intervention period (T1 & T2)

Table 7-10 shows the effects of the intervention (Model 2) on average accelerometer-assessed overall light physical activity (LPA) at T4. The VPC of Model 2 was 0.3729, indicating that 37.29% of variance in average overall LPA at T4 was due to variation between classes and 62.71% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. There were no significant differences in model fit between the co-variates model, Model 1 or Model 2. In Model 2, there was a significant difference between average overall LPA at T1 compared to T0 (*B*= -45.04 (19.18); 95% CI, -82.63, -7.46; $p<0.05$), T2 compared to T0 (*B*= -55.72 (19.24); 95% CI, -93.43, -18.02; $p<0.01$) and T4 compared to T0 (*B*= -53.48 (19.53); 95% CI, -91.77, -15.20; $p<0.01$), indicating that less LPA was demonstrated by the overall sample at these time-points than at T0 (baseline). There was no significant effect of intervention on average overall LPA at T4.

Table 7-10. Multilevel modelling for average overall accelerometer-assessed light physical activity (LPA) at T4 (3-month follow-up)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	497.53 (27.75)***	508.17 (37.66)***	512.81 (38.75)***
Sex	13.62 (8.74)	13.56 (8.74)	13.34 (8.72)
Ethnicity	-12.57 (9.28)	-12.59 (9.28)	-12.78 (9.26)
$T1^0$	-52.06 (13.26)***	-52.06 (13.26)***	-45.04 (19.18)*
$T2^0$	-41.48 (13.32)**	-41.49 (13.32)**	-55.72 (19.24)**
$T3^0$	-27.76 (13.47)*	-27.77 (13.47)*	-27.61 (19.42)
$T4^0$	-37.99 (13.47)**	-38.00 (13.47)**	-53.48 (19.53)**
Intervention		-21.17 (51.01)	-29.53 (53.75)
T1*Intervention			-13.80 (26.51)
T2*Intervention			27.39 (26.61)
T3*Intervention			-0.59 (26.91)
T4*Intervention			29.49 (26.92)
Random effects (SE)			
Variance between classes	80.19 (18.64)	79.48 (18.48)	79.56 (18.50)
Variance within classes	134.09 (3.02)	134.09 (3.02)	133.81 (3.01)
Model deviance	-6316.44	-6316.35	-6314.33

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * $p<0.05$; ** $p\leq0.01$; *** $p\leq0.001$.

There were no significant interactions between time-points and intervention group status. These findings show that average overall LPA at T4 was not affected by the Virtual Traveller intervention.

7.4 School day physical activity

This section address the secondary study aims of: 1) determining the effectiveness of Virtual Traveller intervention to improve the following mean scores of objectively-assessed outcomes at three month follow-up (T4): c) school day SB and d) school day light LPA and e) school day MVPA, as well as changes to these outcomes during the intervention period (T1 & T2; aims 2d), e) and f)) (Section 6.2).

7.4.1 Intervention group differences

At T0 (baseline), there were no differences in school day average activity between intervention groups (Table 7-11). At T1 (first intervention assessment), the intervention group demonstrated significantly greater average school day MVPA (M=60.8 minutes, SD=8.31) than controls (M=56.1 minutes, 10.38 SD; $t(202)=3.62$, $p<0.001$). At T2 (second intervention assessment) and T3, there were no differences in average school day activity between intervention groups. However at T4, control pupils (M=144.6 minutes, SD=24.18) conversely demonstrated significantly more average school day LPA than intervention pupils (M=138.0 minutes, SD=11.98; $t(191)=2.49$, $p<0.05$; Table 7-11). Overall across all time-points, there were no significant differences in average school day activity between intervention groups (Table 7-11).

Table 7.11. Mean school day average minutes of accelerometer-assessed activity by intervention group

Time-point	Intervention group	n	SB	LPA	MPA	VPA	MVPA
T0 (n=204)	Intervention	108	654.8 (43.79)	145.1 (24.77)	37.3 (7.49)	23.4 (5.11)	60.6 (10.26)
	Control	96	647.4 (39.34)	149.4 (27.43)	37.9 (7.48)	24.3 (6.95)	62.0 (13.27)
T1 (n=204)	Intervention	105	652.6 (42.19)	139.2 (24.98)	36.7* (4.93)	24.1*** (5.12)	60.8 *** (8.31)
	Control	99	654.2 (43.20)	141.1 (26.42)	34.7 (6.51)	21.2 (5.48)	56.1 (10.38)
T2 (n=201)	Intervention	103	647.8 (46.04)	143.2 (22.31)	36.0 (5.85)	23.0 (6.01)	59.0 (10.03)
	Control	98	647.5 (45.59)	145.4 (25.84)	36.3 (6.29)	22.2 (5.87)	58.3 (11.04)
T3 (n=193)	Intervention	99	654.4 (34.31)	144.1 (19.77)	36.8 (5.53)	22.6 (5.23)	59.4 (9.04)
	Control	94	648.1 (45.15)	149.0 (37.40)	37.4 (6.21)	22.5 (5.26)	59.9 (9.88)
T4 (n=193)	Intervention	101	651.5 (29.12)	137.9* (11.98)	36.8 (4.73)	22.0 (3.99)	58.8 (7.03)
	Control	92	649.6 (30.58)	144.6 (24.18)	37.3 (5.23)	21.3 (3.43)	58.6 (6.53)
Overall (n=219)	Intervention	113	650.1 (27.99)	142.2 (18.17)	36.5 (4.66)	22.9 (3.84)	59.8 (7.01)
	Control	106	649.5 (24.66)	146.8 (25.46)	36.6 (4.94)	22.3 (4.13)	58.2 (10.15)

Notes: * p<0.05; *** p≤0.001

7.4.2 Demographic differences

At T0 (baseline), girls were found to exhibit significantly more overall average school day SB (M=657.6 minutes (SD=40.63) vs M=645.7 minutes (SD=42.27); $t(201)=2.04$, $p<0.05$) and significantly less MVPA (M=63.6 minutes (SD=10.65) vs 58.6 minutes (SD=12.40; $t(201)=3.10$, $p<0.01$) than boys. During the intervention period, girls demonstrated significantly less school day MVPA at T1 only (57.1 minutes (SD=9.48) vs M=59.9 minutes (SD=9.66); $t(202)=2.08$, $p<0.05$). No sex differences were found for school day physical activity at either follow-up period (T3 & T4).

Participants without English as a first language had less school day SB (M=636.8 minutes (SD=48.71) vs M=655.7 (SD=38.64); $t(201)=2.76$, $p<0.01$) and greater LPA (M=145.2 minutes

(SD=34.22) vs M=127.5 (SD=26.97); *t*(169)=3.35, *p*=0.001) and MVPA (M=55.0 minutes (SD=25.41) vs M=49.2 minutes (SD=11.57); *t*(169)=1.99, *p*<0.05) at T0 compared to those with English as a first language, with no significant differences at any other time-points. Asian pupils demonstrated significantly more overall school day LPA than white pupils at all time-points other than baseline (T0). For example at T2, Asian pupils (M=152.1 minutes, SD=30.27; *p*<0.001) demonstrated significantly more school day LPA than white pupils (M=136.7 minutes, SD=15.17; *t*(200)=6.64, *p*<0.001) . There were no significant differences in school day physical activity by UK born or free school meal statuses, household income or BMI category.

7.4.3 Multilevel modelling

Tables of multilevel results for average school day physical activity during the intervention period are provided in Appendix 7H.

7.4.3.1 Secondary study aims 1c): Average school day SB at three-month follow-up (T4) & 2d): Average school day SB time during intervention period (T1 & T2)

Table 7-12 shows the effects of the intervention (Model 2) on average accelerometer-assessed school day sedentary behaviour (SB) at T4. The VPC of Model 2 was 0.0796, indicating that 7.96% of variance in average school day SB at T4 was due to variation between classes and 92.04% was due to variance within classes (calculated as shown in Section 6.6). Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. There were no significant differences in model fit (deviance) between the co-variates model, Model 1 or Model 2. Ethnicity added significant explanation to Model 2 (*B*= -6.27 (2.65); 95% CI, -11.47, -1.07; *p*<0.05), indicating that white pupils recorded higher sedentary time at T4 than non-white pupils. There were no significant differences between average school day SB at T1 and SB at T2, T3 or T4. There was no significant effect of intervention on average school day SB at T4. There were also no significant interactions between time-points and intervention group status. These findings show that average school day sedentary behaviour was not affected by the Virtual Traveller intervention at T4, nor during the intervention period (T1 & T2).

Table 7-12. Multilevel modelling for average school day accelerometer-assessed sedentary behaviour (SB) at T4 (3-month follow-up)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	655.90 (3.53)***	655.04 (4.01)***	652.59 (4.84)***
Sex	-3.32 (2.58)	-3.22 (2.59)	-3.17 (2.59)
Ethnicity	-6.28 (2.65)*	-6.27 (2.65)*	-6.27 (2.65)*
$T1^0$	2.00 (3.97)	2.01 (3.97)	6.82 (5.75)
$T2^0$	-3.47 (3.99)	-3.46 (3.99)	0.21 (5.78)
$T3^0$	0.09 (4.03)	0.11 (4.03)	0.74 (5.82)
$T4^0$	-0.64 (4.03)	-0.63 (4.03)	2.24 (5.86)
Intervention		1.59 (3.37)	6.14 (6.06)
T1*Intervention			-9.19 (7.94)
T2*Intervention			-6.97 (7.99)
T3*Intervention			-1.05 (8.06)
T4*Intervention			-5.40 (8.06)
Random effects (SE)			
Variance between classes	3.58 (2.20)	3.42 (2.26)	3.46 (2.25)
Variance within classes	40.06 (0.91)	40.06 (0.91)	40.02 (0.90)
Model deviance	-5076.44	-5076.33	-5075.38

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * $p \leq 0.05$; *** $p \leq 0.001$.

7.4.3.2 Secondary study aims 1d): Average school day LPA at three-month follow-up (T4) & 2e): Average school day LPA time during intervention period (T1 & T2)

Table 7-13 shows the effects of the intervention (Model 2) on average accelerometer-assessed school day light physical activity (LPA) at T4. The VPC of Model 2 was 0.4799, indicating that 47.99% of variance in average school day LPA at T4 was due to variation between classes and 52.01% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. There were no significant differences in model fit between the co-variates model, Model 1 or Model 2. In Model 2, there was a significant difference between average school day LPA at T1 compared to T0 (B= -9.30 (2.74); 95% CI, -14.68, -3.92; p=0.001), T2 compared to T0 (B= -5.63 (2.75); 95% CI, -11.02, -0.23; $p<0.05$) and T4 compared to T0 (B= -5.82 (2.80); 95% CI, -11.30, -0.34; $p<0.05$), indicating that less LPA was demonstrated by the overall sample at these time-points than at T0 (baseline). There was no significant effect of intervention on average school day LPA at T4. There were also no significant interactions between time-points and intervention group status. These findings show that average school day light physical activity at T4 was not affected by the Virtual Traveller intervention.

Table 7-13. Multilevel modelling for average school day accelerometer-assessed light physical activity (LPA) at T4 (3-month follow-up)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	149.97 (5.85)***	151.96 (8.10)***	152.63 (8.20)***
Sex	-1.36 (1.25)	-1.36 (1.25)	-1.38 (1.25)
Ethnicity	0.87 (1.33)	0.87 (1.33)	0.88 (1.33)
$T1^0$	-7.44 (1.90)***	-7.44 (1.90)***	-9.30 (2.74)***
$T2^0$	-3.84 (1.91)*	-3.84 (1.91)*	-5.63 (2.75)*
$T3^0$	-0.98 (1.93)	-0.98 (1.93)	-1.23 (2.78)
$T4^0$	-6.49 (1.93)***	-6.49 (1.93)***	-5.82 (2.80)*
Intervention		-3.98 (11.24)	-5.24 (11.50)
T1*Intervention			3.58 (3.80)
T2*Intervention			3.43 (3.81)
T3*Intervention			0.45 (3.85)
T4*Intervention			-1.30 (3.85)
Random effects (SE)			
Variance between classes	17.78 (4.04)	17.67 (4.02)	17.67 (4.02)
Variance within classes	19.17 (0.43)	19.17 (0.43)	19.15 (0.43)
Model deviance	-4372.89	-4372.83	-4371.55

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * *p*<0.05; *** *p*≤0.001.

7.4.3.3 Secondary study aims 1e): Average school day MVPA at three-month follow-up (T4) & 2f): Average school day MVPA time during intervention period (T1 & T2)

Table 7-14 shows the effects of the intervention (Model 2) on average accelerometer-assessed school day moderate-to-vigorous physical activity (MVPA) at T4. The VPC of Model 2 was 0.1172, indicating that 11.72% of variance in average school day MVPA at T4 was due to variation between classes and 88.21% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. A significant improvement of model fit was seen between Model 2 compared to the co-variates model ($\Delta x^2(2)=6.62$; $p<0.05$) and Model 1 ($\Delta x^2(1)=6.1$; $p<0.05$), suggesting effects of the Virtual Traveller intervention of school day MVPA at T4.

In Model 2 there was a significant effect of sex (*B*=2.27 (0.62); 95% CI, 1.05, 3.48; $p<0.001$), reflecting that boys demonstrated greater average school day MVPA than girls at T4. There was a significant difference between average school day MVPA at T1 compared to T0 (*B*= -5.83 (1.37); 95% CI, -8.52, -3.14; $p<0.001$), T2 compared to T0 (*B*= -3.57 (1.38); 95% CI, -6.27, -0.87; $p<0.01$) and T4 compared to T0 (*B*= -3.28 (1.40); 95% CI, -6.02, -0.54; $p<0.05$), reflecting that that more MVPA was demonstrated by pupils at these time-points than at T4. There was no significant effect of intervention on average school day MVPA at T4. However there was a significant interaction between time-points and intervention group status at T1 (*B*= 6.02 (1.90); 95% CI, 2.30, 9.74; $p<0.01$), showing greater MVPA in the intervention group than the control group during T1 (first intervention period). These findings show that average school day MVPA may have been improved by the Virtual Traveller intervention at T1 only. No such effects were seen at the second intervention period or at any follow-up period.

Table 7-14. Multilevel modelling for average school day accelerometer-assessed moderate-and-vigorous physical activity (MVPA) at T4 (3-month follow-up)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	60.18 (0.92)***	59.57 (1.05)***	60.66 (1.23)***
Sex	2.28 (0.62)***	2.28 (0.62)***	2.27 (0.62)***
Ethnicity	0.04 (0.65)	0.13 (0.65)	0.15 (0.65)
$T1^0$	-2.71 (0.95)**	-2.70 (0.95)**	-5.83 (1.37)***
$T2^0$	-2.54 (0.96)**	-2.53 (0.96)**	-3.57 (1.38)**
$T3^0$	-1.59 (0.96)	-1.59 (0.97)	-1.97 (1.39)
$T4^0$	-2.51 (0.97)**	-2.50 (0.97)**	-3.28 (1.40)*
Intervention		1.07 (1.01)	-0.98 (1.57)
T1*Intervention			6.02 (1.90)**
T2*Intervention			1.96 (1.91)
T3*Intervention			0.68 (1.93)
T4*Intervention			1.45 (1.93)
Random effects (SE)			
Variance between classes	1.40 (0.52)	1.26 (0.52)	1.27 (0.52)
Variance within classes	9.63 (0.22)	9.63 (0.22)	9.57 (0.22)
Model deviance	-3671.16	-3670.64	-3664.54

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * $p<0.05$; ** $p\leq0.01$; *** $p\leq0.001$.

7.5 Weekend day physical activity

This section address the study aims of: of 1) determining the effectiveness of Virtual Traveller intervention to improve the T4 mean scores of: f) weekend day minutes of SB, g) weekend day minutes of LPA, h) weekend day minutes of MVPA, as well as changes to these outcomes during the intervention period (T1 & T2; aims 2g), h) and i)) (Section 6.2).

7.5.1 Intervention group differences

At T0 (baseline), there were no differences in school day and weekend day average activity intensity between intervention groups (Table 7-15). At T1 (first intervention assessment), intervention pupils demonstrated significantly greater average weekend day MPA (M=30.8 minutes, SD=5.93) than controls (M=28.8 minutes, SD=6.14; $t(157)=2.00$,

Table 7.15. Mean weekend day average minutes of accelerometer-assessed activity by intervention group

Time-point	Intervention group	n	SB	LPA	MPA	VPA	MVPA
T0 (n=171)	Intervention	89	633.1 (58.77)	128.9 (30.08)	30.7 (8.18)	20.4 (12.39)	51.1 (18.69)
	Control	82	645.3 (51.74)	134.1 (28.94)	31.3 (8.38)	18.4 (6.46)	49.9 (12.03)
T1 (n=160)	Intervention	77	638.9 (41.68)	121.6 (29.12)	30.6* (5.93)	18.9 (4.83)	49.6 (9.66)
	Control	83	641.4 (44.99)	122.4 (32.71)	28.8 (6.14)	18.3 (6.43)	47.2 (10.52)
T2 (n=155)	Intervention	83	630.8 (38.61)	120.9 (18.61)	29.7 (7.77)	17.7 (5.18)	47.7 (11.46)
	Control	72	641.6 (36.51)	129.5 (35.15)	30.8 (8.07)	19.4 (6.69)	50.3 (13.33)
T3 (n=149)	Intervention	75	636.6 (52.63)	119.3 (16.62)	31.3 (6.50)	27.6 (8.96)	50.1 (9.03)
	Control	74	627.9 (76.56)	115.1 (18.37)	31.4 (6.15)	26.1 (9.10)	49.1 (9.70)
T4 (n=155)	Intervention	84	639.6 (53.34)	116.5 (14.28)	31.6 (6.65)	18.0 (5.08)	49.5 (9.36)
	Control	71	638.6 (51.16)	117.8 (14.08)	32.6 (6.45)	17.7 (4.09)	50.2 (9.09)
Overall (n=209)	Intervention	107	633.3 (35.75)	122.0 (19.00)	30.5 (5.75)	19.5 (4.76)	48.9 (8.88)
	Control	102	639.8 (34.11)	128.0 (28.97)	30.7 (5.55)	19.3 (4.11)	48.8 (8.64)

Notes: * $p<0.05$

$p<0.05$). There were no significant differences by intervention group in weekend day physical activity at T2 (second intervention assessment), T3 or T4 (Table 7-15). Overall across all time-points, there were no significant differences in average weekend day activity between intervention groups (Table 7-15).

7.5.2 Demographic differences

No sex differences were found for weekend day overall physical activity at baseline (T0), T1 (first intervention assessment) or either follow-up period (T3 & T4). At T2, significantly more MVPA was performed in boys (M=50.8 minutes, SD=15.61) compared to girls (M=1.9, SD=11.18; $t(114)=3.53$, $p=0.001$). At T0, significantly less LPA was seen in white pupils (M=116.7 minutes, SD=19.98) compared to Asian pupils (M=132.0 minutes, SD=40.17; $F(3,170)=3.89$, $p=0.10$), with this relationship also seen at T1 (M=116.7 minutes, SD =19.98 vs M=139.6 minutes, SD=33.18; $F(3,160)=3.29$, $p<0.05$) and T2 (M=119.5 minutes, SD=14.35 vs M=133.1, SD=38.82; $F(3,154)=2.89$, $p<0.05$). There were no significant differences in weekend physical activity by English language-, UK born- or free school meal-statuses, household income or BMI category.

7.5.3 Multilevel modelling

Tables of multilevel results for non-significant average weekend day physical activity outcomes at T4, as well as all outcomes during the intervention period are provided in Appendix 7I.

7.5.3.1 Secondary study aims 1f): Average weekend day SB at three-month follow-up (T4) & 2g): Average weekend day SB time during intervention period (T1 & T2)

There was no significant effect of intervention on average weekend day SB at T4, nor significant interactions between time-points and intervention group status. These findings show that average weekend day sedentary behaviour at T4 was not affected by the Virtual Traveller intervention (Appendix 7I).

7.5.3.2 Secondary study aims 1g): Average weekend day LPA at three-month follow-up (T4) & 2h): Average weekend day LPA time during intervention period (T1 & T2)

Table 7-16 shows the effects of the intervention (Model 2) on average accelerometer-assessed weekend day light physical activity (LPA) at T4. The VPC of Model 2 was 0.2969, indicating that 29.69% of variance in average weekend day LPA at T4 was due to variation between classes and 70.31% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. A significant improvement of model fit was seen between Model 2 compared to Model 1 ($\Delta x^2(1)=4.11$; $p<0.05$) but not the co-variates model, indicating increased explanatory value associated with adding intervention by time-point interactions.

In Model 2, there was a significant difference between average school day LPA at T1 compared to T0 (*B*= -10.09 (3.58); 95% CI, -17.12, -3.07; $p<0.01$), T3 compared to T0 (*B*= -20.38 (3.69); 95% CI, -27.62, -13.15; $p<0.001$) and T4 compared to T0 (*B*= -17.70 (3.73); 95% CI, -25.02, -10.39; p<0.001), indicating that less LPA was demonstrated by the overall

Table 7-16. Multilevel modelling for average weekend day accelerometer-assessed light physical activity (LPA) at T4 (3-month follow-up)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	131.37 (3.73)***	132.59 (4.92)***	134.32 (5.22)***
Sex	1.69 (1.71)	1.67 (1.71)	1.47 (1.71)
Ethnicity	0.36 (1.83)	0.34 (1.83)	0.32 (1.82)
$T1^0$	-8.13 (2.54)***	-8.13 (2.54)***	-10.09 (3.58)**
$T2^0$	-6.06 (2.57)*	-6.06 (2.57)*	-4.02 (3.72)
$T3^0$	-15.12 (2.59)***	-15.12 (2.59)***	-20.38 (3.69)***
$T4^0$	-14.85 (2.57)***	-14.85 (2.57)***	-17.70 (3.73)***
Intervention		-2.41 (6.32)	-5.50 (7.09)
T1*Intervention			3.81 (5.06)
T2*Intervention			-3.73 (5.11)
T3*Intervention			10.33 (5.17)*
T4*Intervention			5.38 (5.12)
Random effects (SE)			
Variance between classes	9.71 (2.39)	9.63 (2.37)	9.71 (2.38)
Variance within classes	23.11 (0.59)	23.11 (0.59)	22.99 (0.58)
Model deviance	-3619.96	-3619.89	-3615.78

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * $p<0.05$; ** $p\leq0.01$; *** $p\leq0.001$.

sample at these time-points than at T0. There was no significant effect of intervention on average weekend day LPA at T4. There was a significant interaction between T3 and intervention (*B*=10.33 (5.17); 95% CI, 0.21, 20.46; $p=0.045$), indicating a greater rate of decline in control group scores compared to previous time-points at T3 compared to intervention group scores. These findings suggest that average weekend day light physical activity at T4 was not affected by the Virtual Traveller intervention.

7.5.3.3 Secondary study aims 1h): Average weekend day MVPA time at three-month follow-up (T4) & 2i): Average weekend day MVPA time during intervention period (T1 & T2)

There was no significant effect of intervention on average weekend day MVPA at T4, nor significant interactions between time-points and intervention group status. These findings show that average weekend day MVPA behaviour at T4 was not affected by the Virtual Traveller intervention (Appendix 7I).

7.6 Lesson time physical activity

This section address the secondary study aims of: 1) determining the effectiveness of Virtual Traveller intervention to improve the T4 mean scores of: i) lesson time minutes of SB, j) lesson time minutes of LPA, k) lesson time minutes of MVPA and l) lesson time physical activity observation ratings, as well as changes to these outcomes during the intervention period (T1 & T2; aims 2j), k), l) and m)) (Section 6.2).

7.6.1 Accelerometer assessment

Mean minutes of activity intensity at all time-points during lesson time in the overall sample and intervention groups are shown in Table 7-17 and Figure 7-2. Mean minutes of activity intensity during lesson time by class are shown in Appendix 7J.

7.6.1.1 Intervention group differences

There were no significant differences in lesson accelerometer-assessed physical activity between intervention groups at T0 (baseline; Table 7-17). At T1 (first intervention assessment), intervention pupils performed significantly less SB (M=10.3 minutes (SD=1.86) vs M=16.3 minutes (SD=1.56) in control group; $t(204)=24.96$, $p<0.001$), greater LPA (M=7.7 minutes (SD=1.50) vs M=3.5 minutes (SD=1.43) in control group; $t(204)=20.71$, $p<0.001$) and MVPA (M=1.9 minutes (SD=1.14) vs M=0.2 minutes (SD=0.29) in control group; $t(204)=14.58$, $p<0.001$) (Table 7-17). At T2 (second VFT intervention assessment), intervention pupils performed significantly less SB (M=10.0 minutes (SD=1.86) vs M=16.6 minutes (SD=1.42) in control group; $t(200)=29.42$, $p<0.001$) and greater LPA (M=7.7 minutes (SD=1.39) vs M=3.1 minutes (SD=1.28) in control group; $t(200)=24.42$, $p<0.001$) and MVPA (M=2.3 minutes

(SD=0.98) vs M=0.3 minutes (SD=0.32) in control group; $t(200)=19.23$, $p<0.001$) compared to the control group (Table 7-17).

Table 7-17. Mean accelerometer minutes and CARS observation ratings during 20-minute lesson periods

Time-point	Intervention group	n	SB	LPA	MPA	VPA	MVPA	CARS
T0	Intervention	108	16.4 (1.28)	3.4 (1.17)	0.2 (0.24)	0.2 (0.09)	0.3 (0.31)	1.4 (0.10)
	Control	96	16.5 (1.31)	3.2 (1.23)	0.2 (0.23)	0.1 (0.10)	0.26 (0.31)	1.4 (0.13)
T1	Intervention	107	10.3*** (1.86)	7.7*** (1.50)	1.3*** (0.96)	0.9*** (0.71)	1.9*** (1.14)	3.6*** (0.22)
	Control	99	16.3 (1.56)	3.5 (1.43)	0.2 (0.21)	0.1 (0.10)	0.22 (0.29)	1.4 (0.11)
T2	Intervention	104	10.0*** (1.75)	7.7*** (1.39)	1.5*** (0.89)	1.0*** (0.70)	2.3*** (0.98)	3.6*** (0.20)
	Control	98	16.6 (1.42)	3.1 (1.28)	0.2 (0.23)	0.1 (0.10)	0.3 (0.32)	1.4 (0.13)
T3	Intervention	99	15.6* (2.52)	3.6 (1.81)	0.5*** (0.65)	0.2*** (0.43)	0.7*** (0.97)	1.5 (0.15)
	Control	93	16.4 (1.36)	3.4 (1.25)	0.2 (0.21)	0.1 (0.10)	0.3 (0.28)	1.42 (0.11)
T4	Intervention	101	16.3 (1.37)	3.4 (1.33)	0.2 (0.24)	0.1 (0.10)	0.3 (0.31)	1.4 (0.12)
	Control	92	16.6 (1.20)	3.2 (1.30)	0.2 (0.21)	0.1 (0.08)	0.3 (0.27)	1.4 (0.10)
Overall	Intervention	113	14.2*** (5.57)	5.2*** (0.85)	0.7*** (0.33)	0.4*** (0.26)	1.1*** (0.43)	2.3*** (0.19)
	Control	106	16.5 (0.77)	3.3 (0.73)	0.2 (0.12)	0.1 (0.06)	0.3 (0.16)	1.4 (0.09)

Notes: CARS stands for Children's Activity Rating Scale; * $p<0.05$; *** $p\leq0.001$

There were no significant differences in PA between T1 and T2 intervention assessments in the intervention group, suggesting activity did not reduce with repeated exposure to the Virtual Traveller intervention. Across the 20 minutes of assessed lesson time, pupils in VFT intervention sessions (n=113, 20 sessions in five classes) averaged 50.4% (SD=6.45) in SB, 38.6% (SD=5.29) in LPA, 7.2% (SD=3.27) in MPA, 4.9% (SD=2.59) in VPA and 12.1% (SD=3.71) in MVPA. Control group pupils during the same period (n=106, 20 sessions in five classes) averaged 82.4% (SD=5.31) in SB, 16.3% (SD=4.73) in LPA, 0.9% (SD=0.81) in MPA, 0.3% (SD=0.38) in VPA and 1.2% (SD=1.13) in MVPA (Figure 7-2). The contribution of accelerometer-assessed lesson time PA to overall day PA was calculated during intervention time-points (T1 & T2; Table 7-18). At both T1 and T2, Virtual Traveller lesson time contributed significantly less SB and significantly more LPA, MPA, VPA and MVPA to overall day PA in VFT intervention pupils than control lesson time. For example in T2, Virtual Traveller intervention sessions contributed 3.9% of day MVPA, compared to just 0.5% in control lessons.

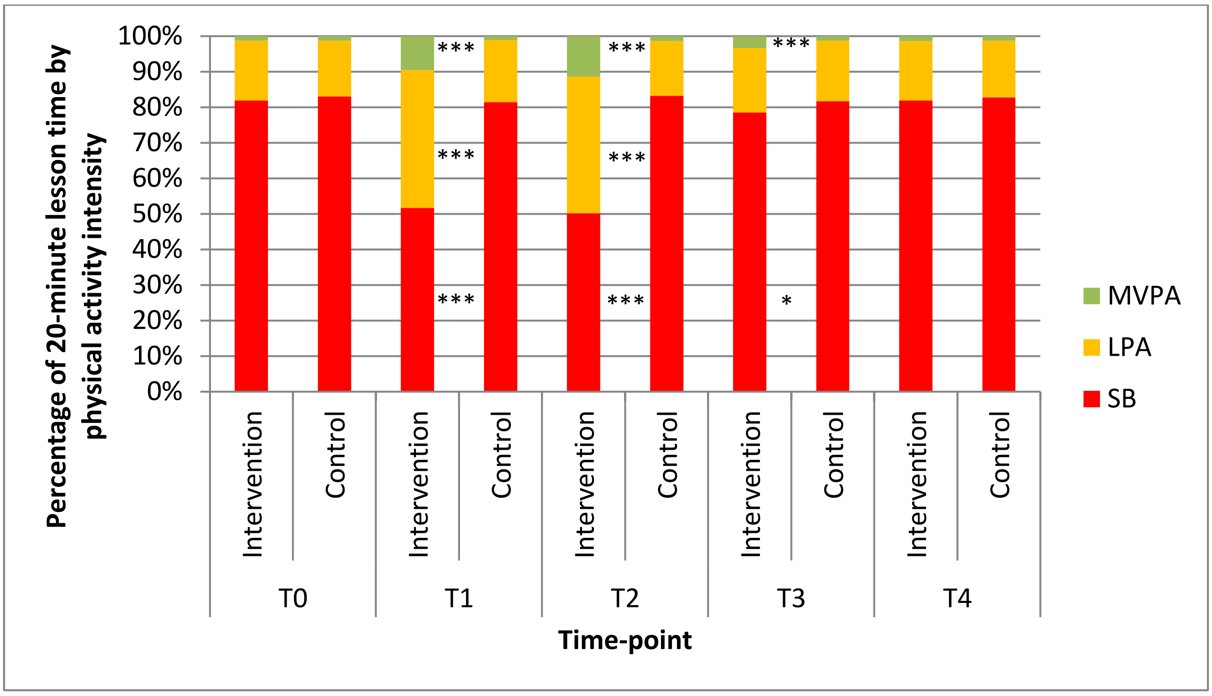
At T3 (1 week post-intervention), intervention pupils performed significantly less SB (M=15.6 minutes (SD=2.52) in intervention group vs M=16.4 minutes (SD=1.36) in control group; $t(190)=2.46$, $p<0.05$) and greater MVPA (M=0.7 minutes (SD=0.97) in intervention group vs M=0.3 minutes (SD=0.27) in control group; $t(190)=4.03$, $p<0.001$) (Table 7-17). At T4 (3-months follow-up), there were no significant differences in accelerometer-assessed lesson time physical activity by intervention group.

Table 7-18: Mean percent contribution of 20-minute lesson periods to overall day activity during intervention

Time-point	**Intervention group**	**n**	**SB**	**LPA**	**MPA**	**VPA**	**MVPA**
T1	Intervention	105	1.6%*** (0.30)	5.7%*** (1.34)	3.8*** (2.66)	4.0%*** (3.45)	3.3%*** (1.96)
	Control	99	2.5% (0.29)	2.5% (1.01)	0.5% (0.67)	0.3% (0.61)	0.4% (0.57)
T2	Intervention	102	1.6%*** (0.29)	5.4%*** (1.23)	4.2%*** (2.58)	4.4%*** (3.05)	3.9%*** (1.85)
	Control	98	2.6% (0.30)	2.2% (0.94)	0.6 (0.69)	0.3% (0.50)	0.5% (0.58)

Note: *** $p \leq 0.001$

Figure 7-2. Mean minutes of activity intensity at each measurement point during 20-minute lesson period



Notes. * *p*<0.05; *** *p*≤0.001

7.6.1.2 Demographic differences

At T0 (baseline), significantly higher MVPA was shown in those born in the UK (M=0.3 minutes, SD=0.33) compared to those born overseas (M=0.2 minutes, SD=0.20; *t*(202)=2.37, *p*<0.05). At T1 (first intervention assessment), significant differences in MVPA were identified between ethnic groups (*F*(3,201)=6.12, *p*=0.001), with Bonferroni analysis finding white pupils (n=101; M=1.5 minutes, SD=1.33) to have greater MVPA than both Asian (n=82; M=0.8 minutes, SD=0.96; *p*<0.01) and black pupils (n=8; M=0.3 minutes, SD=0.30; *p*<0.05). Significantly more MVPA was also shown in T1 by those born in the UK (M=1.2 minutes, SD=1.27) compared to those born overseas (M=0.7 minutes, SD=0.86; *t*(204)=2.53, *p*<0.05) and participants who spoke English as a first language (M=1.2 minutes, SD=1.26) compared to those who did not (M=0.8 minutes, SD=0.91; *t*(204)=2.15, *p*<0.05). At T2 (second intervention assessment), intervention group girls (M=2.5 minutes, SD=1.04) demonstrated significantly more MVPA than boys (M=2.1 minutes, SD=0.87; *t*(200)=2.07, *p*<0.05). VPA was also significantly different between ethnic groups in intervention pupils (*F*(103)=4.65, *p*<0.01), with Bonferroni analysis finding white pupils (M=1.3 minutes, SD=0.75) to demonstrate significantly more VPA than Asian pupils (M=0.8 minutes, SD=0.63; p=0.05). At T3, there was significantly more in-class VPA at T3 in girls (M=0.2 minutes, SD=0.42) compared to boys (M=0.1 minutes, SD=0.17; t(195)=2.67, p<0.01). At T4 (3-months follow-up), there were no significant differences in accelerometer-assessed lesson time physical activity by demographics.

7.6.1.3 Weather effects on lesson time physical activity

Two out of fifty days (4%) where lesson time physical activity was observed featured rain (592). Both of these days were at T1 (first intervention assessment), with one of these during intervention class observations and one during control group observations (Appendix 7K). In intervention classes, significantly higher T1 lesson time SB (M=10.1 minutes (SD=1.89) vs M=11.2 minutes (SD=1.46); t(105)=2.33, p<0.05) and significantly lower MVPA (M=2.1 minutes (SD=1.11) vs M=0.8 minutes (SD=0.48); t(105)=4.68, p<0.001) were found on wet days compared to dry days. In control classes, significantly higher T1 lesson time SB (M=16.5 minutes (SD=1.46) vs M=15.3 minutes (SD=1.79); t(97)=2.79, p<0.01) yet lower LPA (M=3.3 minutes (SD=1.33) vs M=4.4 (SD=1.61; t(97)=3.01, p<0.01) were found on wet days compared to dry days.

7.6.2 Observation assessment: Children's Activity Rating Scale (CARS)

All participants were observed using CARS at least once during the study. The majority of participants (n=159/219; 72.6%) were observed with CARS at all five time-points. The number of completed observations ranged from 86.8% (control group at T4) to 95.6% (intervention group at T2; Table 7-19). There was no significant difference in observations completed between intervention groups at any time-point nor overall.

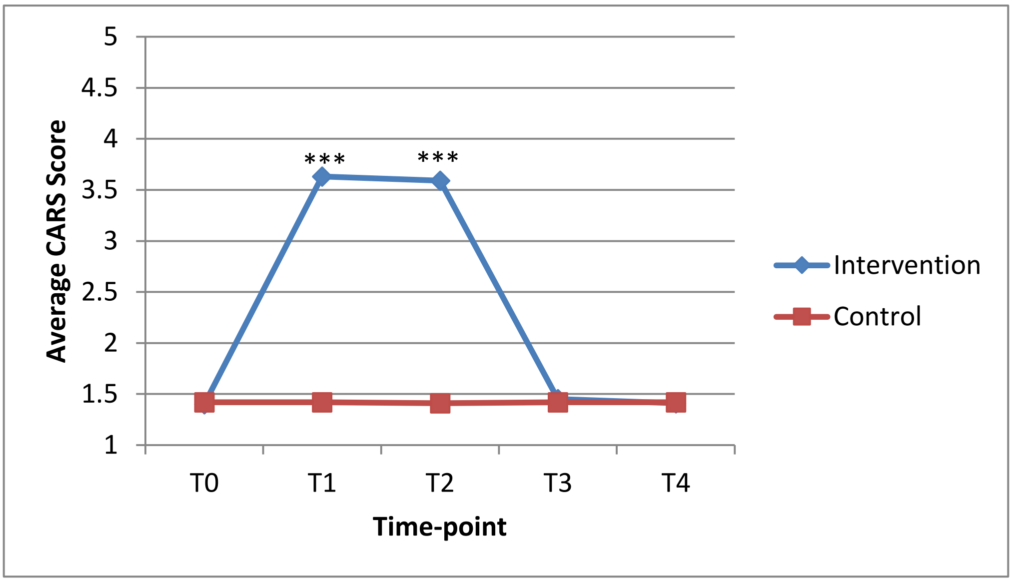
Table 7-19: Valid Children's Activity Rating Scale (CARS) observations

Time	Analytic sample (n=219)	Intervention (n=113)	Control (n=106)
T0	n=204 (93.2%)	n=108 (95.6%)	n=96 (90.6%)
T1	n=206 (94.1%)	n=107 (94.7%)	n=99 (93.4%)
T2	n=202 (92.2%)	n=104 (92.0%)	n=98 (92.5%)
T3	n=192 (87.7%)	n=99 (87.6%)	n=93 (87.7%)
T4	n=193 (88.1%)	n=101 (89.4%)	n=92 (86.8%)
Overall	997/1095 (91.1%)	519/565 (91.9%)	478/530 (90.2%)

7.6.2.1 Intervention group and demographic differences

Mean CARS observation ratings during lesson time in the overall sample and intervention groups at all measurement points are shown in Table 7-17 & Figure 7-3. Mean minutes of observed activity intensity during lesson time by class are shown in Appendix 7J. There were no significant differences in lesson accelerometer-assessed physical activity at T0 (baseline). During the intervention period, intervention pupils were observed to be significantly more active in T1 (M=3.6/5 (SD=0.22) compared to the control group (M=1.4/5 (SD=0.11; $t(204)=90.37$, $p<0.001$) and also during T2 (M=3.6/5 (SD=0.20) in intervention group vs M=1.4/5 (SD=0.15) in control group; $t(200)=90.29$, $p<0.001$). This is equivalent to movement of between 'easy' to 'moderate' intensity in the intervention group, compared to between 'stationary' or 'stationary with limb movement' in the control group (31) (Section 6.4.9.3.1). There was no significant difference in CARS scores within the intervention group during the intervention period (T1 & T2), showing activity remained relatively stable even when the intervention became less novel. There was no significant difference in CARS scores by intervention group in T3 or T4. There were no significant differences in CARS observation ratings by demographics in the overall sample. No demographic differences of observed physical activity were found within intervention participants during the intervention period (T1 & T2).

Figure 7-3. Average Children's Activity Rating Scale (CARS) lesson time physical activity scores between intervention groups at each time-point



Notes: *** p≤0.001; CARS is scored from 1 (stationary, motionless) to 5 (fast movement).

7.6.3 Multilevel modelling

Multilevel models were calculated according to the processes described in Section 6.6. Tables of multilevel results for average lesson time physical activity during the intervention period are provided in Appendix 7L.

7.6.3.1 Secondary study aims 1i): Average lesson time SB at three-month follow-up (T4) & 2j): Average lesson time SB during intervention period (T1 & T2)

Table 7-20 shows the effects of the intervention (Model 2) on average accelerometer-assessed lesson time sedentary behaviour (SB) at T4. The VPC of Model 2 was 0.11666, indicating that 11.67% of variance in average lesson time SB at T4 was due to variation between classes and 88.33% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. A significant improvement of model fit (deviance) was seen between Model 2 compared to the co-variates model ($\Delta x^2(2)=321.58$; $p<0.001$) and Model 1 ($\Delta x^2(1)=304.73$; $p<0.001$), suggesting effects of the Virtual Traveller intervention of lesson time SB at T4.

There were no significant differences between average lesson time SB at T0 and SB at T1, T2, T3 or T4 without accounting for intervention status. There was no significant effect of intervention on average lesson time SB at T4 but significant interactions between time-points and intervention group status at T1 (B= -5.86 (0.31); 95% CI, -6.48, -5.24; $p<0.001$) and T2 (B=-6.45 (0.31); 95% CI, -7.07, -5.83; $p<0.001$), indicating reduced SB at these time-points in intervention pupils compared to T4. These findings show that lesson time SB can be reduced with Virtual Traveller.

Table 7-20. Multilevel modelling for lesson time accelerometer-assessed sedentary behaviour (SB) at T4 (3-month follow-up)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	16.47 (0.48)***	17.88 (0.22)***	16.47 (0.21)***
Sex	0.03 (0.14)	0.44 (0.14)	0.06 (0.10)
Ethnicity	0.07 (0.15)	0.04 (0.14)	0.03 (0.11)
$T1^0$	-3.32 (0.21)***	-3.32 (0.21)***	-0.25 (0.23)
$T2^0$	-3.26 (0.22)***	-3.26 (0.22)***	0.11 (0.23)
$T3^0$	-0.49 (0.22)*	-0.50 (0.22)*	-0.17 (0.23)
$T4^0$	0.00 (0.22)	0.00 (0.22)	0.07 (0.23)
Intervention		-2.80 (0.17)***	-0.14 (0.26)
T1*Intervention			-5.86 (0.31)***
T2*Intervention			-6.45 (0.32)***
T3*Intervention			-0.55 (0.32)
T4*Intervention			-0.11 (0.32)
Random effects (SE)			
Variance between classes	1.40 (0.32)	0.15 (0.10)	0.21 (0.07)
Variance within classes	2.17 (0.05)	2.17 (0.05)	1.59 (0.04)
Model deviance	-2204.67	-2187.82	-1883.09

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * *p*≤0.05; *** *p*≤0.001.

7.6.3.2 Secondary study aims 1j): Average lesson time LPA at three-month follow-up (T4) & 2k): Average lesson time LPA during intervention period (T1 & T2)

Table 7-21 shows the effects of the intervention (Model 2) on average accelerometer-assessed lesson time light physical activity (LPA) at T4. The VPC of Model 2 was 0.0789, indicating that 7.89% of variance in average lesson time LPA at T4 was due to variation between classes and 82.11% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. A significant improvement of model fit was seen between Model 2 compared to the co-variates model ($\Delta x^2(2)=242.35$; $p<0.001$) and Model 1 ($\Delta x^2(1)=225.47$; $p<0.001$), suggesting effects of the Virtual Traveller intervention of lesson time LPA at T4.

Table 7-21. Multilevel modelling for lesson time accelerometer-assessed light physical activity (LPA) at T4 (3-month follow-up)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	3.24 (0.34)***	2.25 (0.16)***	3.18 (0.16)***
Sex	-0.01 (0.11)	-0.03 (0.11)	-0.04 (0.09)
Ethnicity	0.04 (0.12)	0.08 (0.11)	0.08 (0.09)
T1^0	2.41 (0.17)***	2.42 (0.17)***	0.29 (0.20)
T2^0	2.17 (0.17)***	2.17 (0.17)***	-0.14 (0.20)
T3^0	0.24 (0.17)	0.25 (0.17)	0.18 (0.20)
T4^0	0.00 (0.17)	0.00 (0.17)	-0.02 (0.20)
Intervention		1.94 (0.12)***	0.17 (0.21)
T1*Intervention			4.06 (0.27)***
T2*Intervention			4.43 (0.27)***
T3*Intervention			0.08 (0.28)
T4*Intervention			0.02 (0.27)
Random effects (SE)			
Variance between classes	0.96 (0.22)	0.12 (0.06)	0.12 (0.06)
Variance within classes	1.72 (0.04)	1.37 (0.03)	1.37 (0.03)
Model deviance	-1971.10	-1954.22	-1728.75

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** $p \leq 0.001$.

There were no significant differences between average lesson time LPA at T0 and SB at T1, T2, T3 or T4 without accounting for intervention status. There was no significant effect of intervention on average lesson time LPA at T4 but significant interactions between time-points and intervention group status at T1 (B=4.06 (0.27); 95% CI, 3.53, 4.59; $p<0.001$) and T2 (B=4.43 (0.27); 95% CI, 3.89, 4.96; $p<0.001$), indicating increased LPA at these time-points in intervention pupils compared to T4. These findings show that lesson time LPA can be increased with Virtual Traveller.

7.6.3.3 Secondary study aims 1k): Average lesson time MVPA at three-month follow-up (T4) & 2l): Average lesson time MVPA during intervention period (T1 & T2)

Table 7-22 shows the effects of the intervention (Model 2) on average accelerometer-assessed lesson time moderate-to-vigorous physical activity (MVPA) at T4. The VPC of Model 2 was 0.1014, indicating that 10.14% of variance in average lesson time MVPA at T4 was due to variation between classes and 89.86% was due to variance within classes. Significance of the intercept was only present in the co-variates model (Intercept=0.29; $p<0.05$) and Model 2 (Intercept=0.34; $p<0.001$), indicating that only these models explained significantly more variance than comparative single-level models. A significant improvement of model fit was seen between Model 2 compared to the co-variates model ($\Delta x^2(2)$=212.03; p<0.001) and Model 1 ($\Delta x^2(1)$=196.54; p<0.001), suggesting effects of the Virtual Traveller intervention of lesson time MVPA at T4.

There was a significant effect of ethnicity (B=-0.10 (0.04); 95% CI, -0.18, -0.02; p<0.05), indicating that white pupils had higher average lesson time MVPA at T4 than non-white pupils. Interestingly, models for T4 and T2 outcomes produced noticeably different regression co-efficients and significance values for ethnicity, unlike in any other model (Section 7.3.5). Significance of ethnicity using T2 MVPA as an outcome (B= -0.16 (0.06); 95% CI, -0.27, -0.05; p=0.005; Table 7-23), was greater than when using MVPA at T4 as an outcome. This indicates that the differences between white and non-white pupils were stronger at T2, with white pupils performing greater average lesson time MVPA. This demonstrates that the Virtual Traveller intervention may have had different effects between ethnic groups during the intervention period.

There were no significant differences between average lesson time MVPA at T0 and SB at T1, T2, T3 or T4 without accounting for intervention status (Table 7-22). There was no significant effect of intervention on average lesson time MVPA at T4 but significant interactions between time-points and intervention group status at T1 (B=1.74 (0.12); 95% CI, 1.50, 1.98; p<0.001), T2 (B=2.02 (0.12); 95% CI, 1.78, 2.26; p<0.001) and T3 (B=0.44 (0.12); 95% CI, 0.20, 0.69; p<0.001) indicating increased MVPA at these time-points in intervention pupils compared to T4. These findings show that lesson time MVPA can be increased with Virtual Traveller.

Table 7-22. Multilevel modelling for lesson time accelerometer-assessed moderate-to-vigorous physical activity (MVPA) at T4 (3-month follow-up)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	0.29 (0.14)*	-0.12 (0.07)	0.34 (0.08)***
Sex	-0.02 (0.05)	-0.01 (0.05)	-0.02 (0.04)
Ethnicity	-0.10 (0.05)	-0.11 (0.05)*	-0.10 (0.04)*
T1^0	0.86 (0.07)***	0.87 (0.07)***	-0.05 (0.09)
T2^0	1.06 (0.07)***	1.06 (0.07)***	0.01 (0.09)
T3^0	0.23 (0.08)**	0.24 (0.08)**	-0.01 (0.09)
T4^0	0.02 (0.08)	0.02 (0.08)	-0.01 (0.09)
Intervention		0.82 (0.06)***	-0.04 (0.10)
T1*Intervention			1.74 (0.12)***
T2*Intervention			2.02 (0.12)***
T3*Intervention			0.44 (0.12)***
T4*Intervention			0.05 (0.12)
Random effects (SE)			
Variance between classes	0.41 (0.10)	0.04 (0.04)	0.07 (0.29)
Variance within classes	0.75 (0.02)	0.75 (0.02)	0.62 (0.01)
Model deviance	-1150.68	-1135.19	-938.65

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * *p*<0.05; ** *p*≤0.01; *** *p*≤0.001.

Table 7-23. Multilevel modelling for lesson time accelerometer-assessed moderate-to-vigorous physical activity (MVPA) during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	0.29 (0.21)	-0.30 (0.08)***	0.37 (0.09)***
Sex	-0.01 (0.67)	0.01 (0.07)	-0.02 (0.05)
Ethnicity	-0.13 (0.07)	-0.18 (0.07)**	-0.16 (0.06)**
T1^0	0.87 (0.08)***	0.87 (0.08)***	-0.05 (0.09)
T2^0	1.07 (0.08)***	1.07 (0.08)***	0.01 (0.09)
Intervention		1.21 (0.07)***	-0.05 (0.10)
T1*Intervention			1.74 (0.13)***
T2*Intervention			2.01 (0.13)***
Random effects (SE)			
Variance between classes	0.60 (0.14)	0.01 (0.20)	0.08 (0.04)
Variance within classes	0.80 (0.02)	0.80 (0.02)	0.66 (0.02)
Model deviance	-747.06	-729.58	-614.67

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); ** *p*≤0.01; *** *p*≤0.001.

7.6.3.4 Secondary study aims 1l): Lesson time physical activity observation ratings at three-month follow-up (T4) & 2m): Lesson time physical activity observation ratings during intervention period (T1 & T2)

Table 7-24 shows the effects of the intervention (Model 2) on average physical activity observed using the Children's Activity Rating Scale (CARS) during lesson time at T4. The VPC of Model 2 was 0.2632, indicating that 26.32% of variance in CARS scores at T4 was due to variation between classes and 73.68% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. A significant improvement of model fit (deviance) was seen between Model 2 compared to the co-variates model ($\Delta x^2(2)=1416.66$; $p<0.001$) and Model 1 ($\Delta x^2(1)=1394.72$; $p<0.001$), suggesting effects of the Virtual Traveller intervention on CARS scores at T4.

There was a significant effect of ethnicity (*B*= -0.02 (0.01); 95% CI, -0.04, 0.00; $p<0.05$), indicating that white pupils had greater CARS scores at T4 than non-white pupils. There were no significant differences between average CARS scores at T0 and SB at T1, T2, T3 or T4 without accounting for intervention status. There was no significant effect of intervention on CARS scores at T4 but significant interactions between time-points and intervention group status at T1 (*B*=2.24 (0.03); 95% CI, 2.19, 2.29; $p<0.001$) and, T2 (*B*=2.20 (0.03); 95% CI, 2.14, 2.25; $p<0.001$), indicating increased CARS scores and hence overall physical activity at these time-points in intervention pupils compared to T4. These findings show that CARS scores as a measure of observed physical activity are sensitive enough to detect increases associated with Virtual Traveller.

Table 7-24. Multilevel modelling for lesson time physical activity observed by the Children's Activity Rating Scale (CARS) at T4 (3-month follow-up)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	1.40 (0.15)***	0.94 (0.05)***	1.44 (0.03)***
Sex	0.01 (0.04)	0.00 (0.04)	0.00 (0.01)
Ethnicity	-0.03 (0.04)	0.00 (0.04)	-0.02 (0.01)*
$T1^0$	1.17 (0.06)***	1.17 (00.06)***	-0.01 (0.02)
$T2^0$	1.14 (0.06)***	1.15 (0.06)***	-0.01 (0.02)
$T3^0$	0.04 (0.06)	0.04 (0.06)	-0.01 (0.02)
$T4^0$	0.01 (0.06)	0.01 (0.06)	-0.01 (0.02)
Intervention		0.90 (0.04)***	-0.03 (0.04)
T1*Intervention			2.24 (0.03)***
T2*Intervention			2.20 (0.03)***
T3*Intervention			0.05 (0.03)
T4*Intervention			0.02 (0.03)
Random effects (SE)			
Variance between classes	0.45 (0.10)	1.25 (8.77)	0.05 (0.01)
Variance within classes	0.56 (0.01)	0.56 (0.01)	0.14 (0.01)
Model deviance	-854.13	-832.19	562.53

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * p<0.05; *** p≤0.001.

7.7 Discussion

This chapter reported the analysis of physical activity outcomes assessed during the Virtual Traveller intervention of Study Two. It presented descriptive statistics and multilevel modelling of average overall, school day, weekend day and lesson time physical activity assessed using accelerometry, as well as lesson time physical activity assessed using the Children's Activity Rating Scale (CARS) observational tool. Outcomes at three month follow-up (T4) and during the intervention period (T2) were presented, although these were largely similar within any given physical activity intensity and time-point. Table 7-25 provides a summary of physical activity outcome findings arising from this analysis.

Table 7-25. Summary of physical activity findings from multilevel modelling

Outcome		Effect of intervention?	Demographic differences
Primary outcome			
Overall PA (Section 7.3)	MVPA	No	More MVPA in boys than girls
Secondary outcomes			
Overall PA (Section 7.3)	SB	No	No
	LPA	No	No
School day PA (Section 7.4)	SB	No	More SB in white pupils than non-white pupils
	LPA	No	No
	MVPA	+ Higher in intervention group at T1 (first intervention period) only	More MVPA in boys than girls
Weekend day PA (Section 7.5)	SB	No	No
	LPA	No	No
	MVPA	No	More MVPA in boys than girls
Lesson time PA (Section 7.6)	SB	+ Higher in intervention group at T1 & T2 only (both intervention periods)	No
	LPA	+ Higher in intervention group at T1 & T2 only	No
	MVPA	+ Higher in intervention group at T1, T2 & T3 (1 week follow-up)	More MVPA in white pupils than non-white pupils
	CARS	+ Higher in intervention group at T1 & T2 only	More activity in white pupils than non-white pupils

Notes. Multilevel modelling was completed for these outcomes at T2 (second intervention period) and T4 (three month follow-up). Results were largely identical for both and so results are presented together here; CARS stands for Children's Activity Rating Scale.

7.7.1 Overall physical activity

Across all measurement points, 40.2% of days met these guidelines (Section 7.3.3): lower than the 51% seen in the Millennium Cohort Study (52) which used the same Pulsford cut-points (536) but greater than levels seen in the 2008 Health Survey for England (51) using Freedson cut-points (534). This chapter found the Virtual Traveller intervention to not be associated with any differences in overall physical activity at any intensity as assessed with multilevel modelling (Section 7.3.5). Some differences in overall physical activity were seen by demographics, with boys demonstrating greater MVPA than girls at the second intervention period (T2) and three month follow-up (T4) (Section 7.3.2). Such findings reflect past research showing girls to demonstrate consistently less physically activity across different countries, study designs and assessment methods (50, 52, 55) (Section 2.3.3). However although statistically significant, it must be noted that these differences in MVPA were so small that no clinical significance can be claimed. Arguably, increased MVPA that got pupils to meet the government guidance of one hour daily activity (17) would be clinically significant. Overall activity was subsequently divided into school, weekend day and lesson time components to understand if Virtual Traveller was associated with changes elsewhere.

7.7.2 School day physical activity

Virtual Traveller was shown to be associated with greater school day MVPA at the first intervention period (T1) only. However, it must be noted that this difference was small (4.7 minutes; Table 7-11), There were no other effects on school day physical activity at any intensity or at any time-point (Section 7.4). Only one published physically active lesson intervention assessed school day activity beyond school time only (Section 4.5.9), finding significantly greater overall activity and MVPA in intervention pupils compared to controls (383). This previous study had a larger sample size (n=454 from 24 schools), as well as longer (3 years) and more intense provision of active lessons (two 10-minute activities each day) (383) than Virtual Traveller. With a dose of 10-minutes in length three times per week, Virtual Traveller sessions may have been too discrete to permit increased levels of activity over the school day. This session length was chosen to enable flexibility of teaching across Maths and English lessons as a starter or plenary (Section 6.4.5), as suggested by teachers in feasibility work (Section 5.3.5.1.3). The lack of maintained effect on school day MVPA throughout the intervention is not related to decreased lesson time activity, as lesson activity levels were maintained throughout the intervention (Section 7.4). No detriment to school day activity with intervention provision suggests that there was no compensation effect of Virtual Traveller on school day activity (Section 2.4.5).

Differences in school day physical activity were seen by demographics. Multilevel modelling found more school day MVPA in boys than girls, with descriptive statistics showing lower levels at T0 and T1 (Section 7.4.3.3). The provision of Virtual Traveller hence did not improve girls' overall school day activity. Additionally, multilevel analyses found more school day SB to be recorded in white pupils compared to non-white pupils (Section 7.4.3.1). Ethnic differences in activity levels have been much less consistently reported in UK samples

(Section 2.3.3), however typically Asian students are assessed as least active (52, 63). Contrasting findings in this sample may reflect the particularly deprived and ethnically diverse sample observed compared to local and national populations (Section 7.2.4). In an unusual occurrence for physically activity lesson research (436), less white pupils participated than non-white pupils. White students may have demonstrated more sedentary time as they may have less same-ethnicity peers; however such suggestions are purely speculative given the uncommon nature of this sample.

7.7.3 Weekend day physical activity

No effects of Virtual Traveller were seen for weekend day physical activity at any time-point (Section 7.5). This is in contrast to the only other physically active lesson to assess weekend activity, finding significantly increased overall levels (383) (Section 4.5.9). As speculated for school day physical activity (Section 7.7.2), the lack of change in this study may reflect the relatively low dose of Virtual Traveller intervention. This lack of change with intervention provision suggests that there was no compensation effect of Virtual Traveller on subsequent weekend day activity (Section 2.4.5). As seen for school day activity, more weekend day MVPA was seen in boys compared to girls however no differences were seen for ethnicity.

7.7.4 Lesson time physical activity

Significant effects of the Virtual Traveller intervention were seen across all levels and assessment of lesson time activity during the intervention period. Accelerometer-assessed physical activity showed reductions in SB and increases to LPA and MVPA during intervention lessons (Section 7.6). Such findings for intervention period physical activity were similarly observed across assessment methods in all studies identified in the physically active lesson systematic review (Section 4.5.9). Despite significant findings, just over half of all intervention lesson time was recorded by accelerometers as sedentary (Table 7-17). This reflects a lack of accelerometer calibration for on-the-spot movements such as Active Video Games, as previously discussed (Section 5.4.4) (2, 256). Although an investigation of accelerometer cut-points ensured a validated set with the lowest realistic sedentary cut-off was used (536) (Section 5.4.4.1), this was not sufficient to capture the full level of activity observed.

CARS observations also identified significantly higher activity in intervention lessons, with 'easy' to 'moderate' intensity seen in the intervention group compared to 'stationary' to 'stationary with limb movement' intensity seen in the control group (Section 7.6.2). Two studies identified in the systematic review (Section 4.5.9.1) used observational tools alone to assess lesson time physical activity (384, 385), also finding activity to be higher in intervention sessions. Both studies used the System for Observing Fitness Instruction Time (SOFIT) (414) designed for PE observations (Section 5.4.5.3). SOFIT is a more complex rating system than CARS, accounting for student activity as well as lesson context and instructor involvement (414). Statistically significant findings for observed activity seen during Virtual Traveller lesson times may be partly indicative of the simple CARS tool used. This gap in accelerometer versus observed-physical activity seen in Virtual Traveller shows this extra assessment method was warranted in this study to better capture actual activity.

Lesson time activity was found to differ by ethnicity in descriptive analyses and multilevel modelling, with more MVPA and CARS observed activity seen for white pupils than non-white pupils (Section 7.6). This suggests that the Virtual Traveller intervention may have different effects by ethnic group, potentially being more effective for white pupils. Although as previously noted, this sample is uncommon in its diversity compared to other UK physical activity interventions (436). Interestingly, no significant sex differences in lesson time physical activity were seen, suggesting Virtual Traveller is equally effective in boys and girls. This is in contrast to previous research which has found girls to be less active and more sedentary during typically taught lessons (56). As girls are consistently seen to be less active than boys (50, 52, 55) (Section 2.3.3), these findings suggest that Virtual Traveller could be delivered with equal activity benefits to both sexes.

Positive effects on lesson time activity were observed for accelerometer-assessed MVPA in the intervention group at T3 (one week follow-up) only. No other differences existed between groups at any other activity intensity or follow-up time-point (Section 7.6). The presence of a prolonged MVPA difference beyond the intervention period was significant but small in terms of time (0.68 minutes in intervention group vs 0.26 minutes in control group; Table 7-17). This difference was also not detected in CARS observations, suggesting any significant increases could be the result of chance or were undetected by the researcher. A lack of prolonged effects across activity intensities at both follow-ups suggests that Virtual

Traveller sessions must be frequently provided for any sustained benefits. These results concur with a recent review (274) (Section 2.7.2), which found a lack of effects of interventions on children's activity at six month follow-up. Real-world implementation would depend on a variety of complex factors such as available time and teacher motivation, as discussed in previous assessments of implementation in school physical activity intervention (284) (Section 2.7.3). Perceptions of participating teachers in Study Two are assessed in Chapter 9.

7.7.5 Addressing questions and hypotheses of thesis and Study 2

Research questions and hypotheses can now be answered by taking analysis of school day, weekend day and lesson time physical activity outcomes into account. Thesis question 3) can Virtual Field Trips increase physical activity? (Chapter 3) can be answered affirmatively for lesson time contexts but not so for overall, school or weekend day activity. Similarly, thesis question 4) can Virtual Field Trips reduce sedentary time? can be answered affirmatively for lesson time contexts only. Findings from this chapter also addresses thesis hypothesis 1) physically active Virtual Field Trips will increase children's physical activity (Chapter 3), by showing that VFTs do increase physical activity but during lesson time only. Study question 1): can Virtual Field Trips reduce sedentary time during primary school lessons (Section 6.3) can be answered affirmatively, although changes are small. Study question 2) are Virtual Field Trips associated with increased physical activity outside of the classroom can largely be answered negatively, with increased MVPA detected during school days at the first intervention period only. Study hypotheses surrounding the potential of Virtual Traveller to: 1) reduce overall SB, 2) increase overall LPA and MVPA, 3) reduce SB within school hours and 4) increase LPA and MVPA within school hours compared to control group can all be answered negatively, as significant differences between groups were only seen during intervention lesson time.

7.7.6 Strengths and weaknesses of physical activity assessment in Study Two

A strength of Study Two is its assessment of physical activity across whole school and weekend days. As seen in the physically active lesson systematic review (Section 4.5.9), only one other study to date has assessed physical activity beyond school time only (383). This allowed assessment of overall patterns of activity beyond the school environment. Another strength is the iterative development of physical activity assessment leading up to this study. As discussed in Chapter 5 (Section 5.4.4), no accelerometer cut-points exist that are calibrated for the on-the-spot movements elicited by VFTs (2) and Active Video Games (256). Piloting (Section 5.2), the accelerometer cut-point literature review (Section 5.4.4.1) and exploration of other potential measurement tools (Section 5.4.5) allowed a triangulation of physical activity accelerometry and observation best suited to VFTs given the resources available. Only two previous physically active lesson interventions triangulated their objective measurements with observations in this way (298) (Section 4.5.9.1) (384, 385). Hence although around half of intervention lesson time was still assessed as sedentary via accelerometers, observations provided a more accurate perception of activity levels.

However, there are also limitations of physical activity assessment in Study Two. The observational Children's Activity Rating Scale (CARS) (31) was not trialed prior to this study. Small-scale testing of all outcomes at pilot stage would have identified any practical issues before larger scale implementation (448). Only 20% of CARS observations were assessed by multiple observers: the lead researcher and a Masters student. Although ethical approval was originally granted for all observations to be video-recorded and facilitate multiple observations, individual school child protection policies did not allow this. However, overall inter-rater reliability was 'excellent' (Section 6.4.9.3.1) suggesting validity with this technique. Accelerometer data could also have been triangulated with self-report questionnaires as in other research (176), to especially understand the types of activities and sedentary behaviour performed inside and outside of school. However this would have led to extra participant burden to complete questionnaires. The use of observational methods seems warranted here given the valuable lesson time findings identified.

A potential 'Hawthorne effect' may have led the mere provision of accelerometers to be an intervention in itself: with children increasing their PA levels to please the researcher (29). In an attempt to address this, the pupil competition running in classes throughout the study (Section 6.4.3) was designed and promoted to be judged on wear-time rather than active time. However it cannot be known if recorded activity was affected by the mere provision of accelerometers or not. The study did not feature reasons for accelerometer non-compliance, such as forgetting or devices fitting badly (29). Also, the study did not account for multiple testing in the assessment of the many physical activity outcomes across overall, school-, weekend-day and lesson time activity (613).

7.8 Conclusion

This chapter found the six-week Virtual Traveller intervention of Study Two to not be associated with any improvements in overall, school day or weekend day physical activity at any time-point. However, this analysis did find significantly reduced sedentary behaviour and increased light and moderate-to-vigorous physical activity during intervention lesson times (T1 & T2). Small but significantly positive effects were seen at one week follow-up (T3) for MVPA only, although this may be due to chance. Other lesson time physical activity increases were not maintained at either one week (T3) or three month (T4) follow-ups. This suggests that lesson time physical activity may be increased if physically active Virtual Field Trip (VFT) provision is maintained. Collectively, this chapter showed that activity elicited by VFTs did not contribute to any significant change in daily physical activity levels.

Chapter 8 Student engagement findings from Study Two

8.1 Introduction

This chapter presents student engagement findings of Study Two: a longitudinal randomised controlled trial of physically active Virtual Field Trips named 'Virtual Traveller'. It addresses the thesis aims of: 5) evaluating the effects of physically active Virtual Field Trips on children's on-task behaviour and 6) evaluating the effects of physically active Virtual Field Trips on student engagement. It also addresses the thesis questions of: 5) can Virtual Field Trips introduce physical activity without compromising on-task behaviour? and 6) can Virtual Field Trips improve student engagement? It also addresses thesis hypothesis 2) physically active Virtual Field Trips will not compromise on-task behaviour (Chapter 3) and study hypothesis 5) Virtual Traveller will improve intervention pupils on-task behaviour during school lessons compared to the control group (Section 6.3).

This chapter also addresses the secondary Study 2 aims of: 1) determining the effectiveness of Virtual Traveller intervention to improve the T4 mean scores of: m) on-task behaviour observation ratings and o) student engagement questionnaire scores (Section 6.2). It also addresses 2) the effectiveness of the Virtual Traveller intervention during the intervention period (T1 & T2; weeks 2 and 4 of the intervention) compared to baseline on n) on-task behaviour observation ratings and o) student engagement questionnaire scores. On-task behaviour as a measure of behavioural student engagement (Section 6.4.8) was assessed using the Observing Pupils and Teachers (OPTIC) observation tool (593) (Section 6.4.9.3.2). Affective and cognitive student engagement was assessed using the Student Engagement Instrument – Elementary Version (SEI-E) (583) (Section 6.4.9.4.2).

8.2 Behavioural student engagement: On-task behaviour assessed with the Observing Pupils and Teachers in the Classroom (OPTIC) observation tool

8.2.1 Sample size

OPTIC observations were performed simultaneously alongside Children's Activity Rating Scale (CARS) observations (as described in the protocol; Section 6.4.9.3). As such, the sample size was the same as for CARS (Table 7-19), with all n=219 participants observed using OPTIC at least once during the study.

8.2.2 Descriptive statistics and preliminary analysis

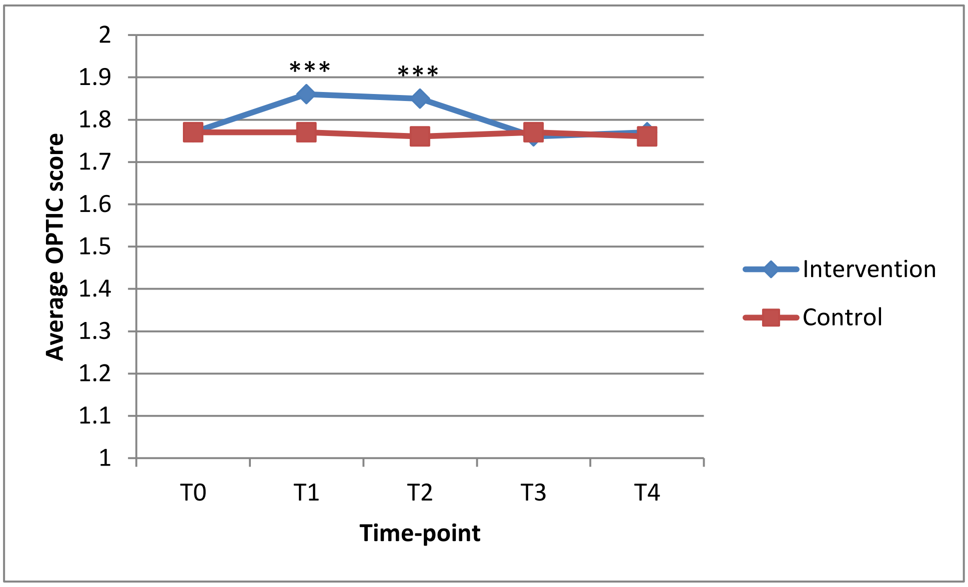
To allow for easier interpretation of results, OPTIC scores were reverse-coded so that '1' represented off-task behaviour and '2' represented on-task behaviour (making eye contact with teacher or task, following teacher's instructions). Mean OPTIC observation ratings during lesson time in intervention groups at all measurement points are shown in Table 8-1 and Figure 8-1. There were no significant differences in observed on-task behaviour at T0 (baseline). At T1 (first intervention assessment), there was significantly greater on-task behaviour in intervention (M=1.86/2, SD=0.06) compared to control pupils (M=1.77/2, SD=0.07; $t(209)=10.20$, $p<0.001$). This was also seen at T2 (second intervention assessment), with significantly greater on-task behaviour seen in intervention (M=1.85/2, SD=0.08) compared to control pupils (M=1.76/2, SD=0.06; $t(200)=9.23$, $p<0.001$). There were no significant differences between intervention groups at T3 and T4 follow-ups. The overall average OPTIC scores across all time-points were significantly different between intervention groups, with significantly greater on-task behaviour seen in intervention M=1.80/2, SD=0.03) compared to control pupils (M=1.76/2, SD=0.04; $t(154)=7.14$, $p<0.001$). Mean minutes of OPTIC scores by class are shown in Appendix 8A. There were no significant differences in OPTIC observation ratings by demographics in the overall sample nor between intervention period assessments (T1 & T2) in intervention pupils.

Table 8-1. Mean student engagement scores at all time-points

Time-point	Intervention group	n	TSR	PSL	FGA	FSL	n	OPTIC
T0	Intervention	103	23.3 (2.82)	20.4 (3.23)	16.9 (2.88)	13.5 (1.91)	108	1.77 (0.07)
	Control	92	23.4 (2.89)	20.3 (3.85)	16.8 (2.74)	13.6 (1.89)	96	1.77 (0.06)
T1	Intervention	102	24.3** (2.39)	20.6 (3.03)	16.9 (2.80)	13.6 (1.81)	107	1.86*** (0.06)
	Control	96	23.6 (2.84)	20.3 (2.98)	16.7 (2.66)	13.5 (1.86)	99	1.77 (0.07)
T2	Intervention	101	23.8** (2.83)	20.7 (2.97)	16.8 (2.77)	13.6 (1.75)	104	1.85*** (0.08)
	Control	97	22.9 (3.08)	20.3 (2.91)	16.7 (2.53)	13.5 (1.82)	98	1.76 (0.06)
T3	Intervention	97	22.9 (3.26)	20.4 (3.05)	16.8 (2.81)	13.5 (1.92)	99	1.76 (0.07)
	Control	93	22.8 (2.84)	20.3 (2.95)	16.7 (2.58)	13.4 (1.83)	93	1.77 (0.06)
T4	Intervention	100	22.9 (2.89)	20.4 (2.87)	16.9 (2.75)	13.4 (1.88)	101	1.77 (0.07)
	Control	92	22.9 (2.91)	20.3 (2.66)	16.8 (2.46)	13.5 (1.76)	92	1.76 (0.07)
Overall	Intervention	113	23.5 (2.46)	20.6 (3.11)	16.8 (3.02)	13.6 (1.82)	113	1.80*** (0.03)
	Control	106	23.2 (2.76)	20.4 (3.00)	16.7 (2.66)	13.6 (1.88)	106	1.76 (0.04)

Notes: ** $p<0.01$; *** $p<0.001$; TSR, PSL, FSL & FGA are all constructs from the Student Engagement Instrument-Elementary Version (SEI-E); TSR stands for Teacher-Student Relationship (maximum score of 28); PSL stands for Peer Support for Learning (maximum score of 24); FGA stands for Future Goals and Aspirations (maximum score of 20); FSL stands for Family Support for Learning (maximum score of 16); OPTIC stands for the Observing Pupils and Teachers in the Classroom tool assessing on-task behaviour, with behaviour rated overall during 20-minute lessons as between off-task (1) or on-task (2).

Figure 8-1. Average OPTIC on-task behaviour observation ratings between intervention groups at each time-point, where T1 & T2 represent the Virtual Traveller intervention period



Notes: OPTIC stands for the Observing Pupils and Teachers in the Classroom tool assessing on-task behaviour, with behaviour rated overall during 20-minute lessons as between off-task (1) or on-task (2).

8.2.3 Multilevel modelling

Multilevel models (MLM) were calculated according to the processes described in Section 6.6. Co-variates, Model 1 and Model 2 are presented for each outcome, although reporting of analysis refers to Model 2 only: providing the most detailed level of adjustment. As done for physical activity analysis (Section 7.3.5), sex and ethnicity (binary coded as 0=white, 1=non-white) were included as covariates in all multilevel models. As with the majority of physical activity outcomes (Chapter 7), results for T4 and intervention period (T1 & T2) outcomes were indistinguishable for all OPTIC and SEI-E sub-scale outcomes, hence results are presented together.

8.2.3.1 Secondary study aims 1m): OPTIC on-task behaviour observation ratings at three-month follow-up (T4) & 2n): OPTIC on-task behaviour observation ratings during the intervention period (T1 & T2)

Table 8-2 shows the effects of the intervention (Model 2) on OPTIC on-task behaviour observation ratings during the Virtual Traveller study. The VPC of Model 2 was 0.125, indicating that 12.50% of variance in on-task behaviour at T4 was due to variation between classes and 87.50% was due to variance within classes (calculated as shown in Section 6.6). Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. A significant improvement of model fit (deviance) was seen between Model 2 compared to the co-variates model ($\Delta x^2(2)=59.45$; $p<0.001$) and Model 1 ($\Delta x^2(1)=51.31$; $p<0.001$), showing that adjusting for intervention and interaction terms added significant explanatory value towards explaining Virtual Traveller's effects on on-task behaviour at T4.

Sex and ethnicity did not add significant explanatory value, suggesting there was no difference in on-task behaviour effects between these demographics. There were no significant differences between on-task behaviour at T1-T4 compared to T0, nor of intervention alone. However there were interaction effects between intervention and T1 (*B*=0.08 (0.01); 95% CI, 0.06, 0.11; $p<0.001$) and T2 (*B*=0.09 (0.01); 95% CI, 0.06, 0.11; $p<0.001$): showing increased on-task behaviour in the intervention group at both intervention periods. This increased on-task behaviour had decreased closer to baseline levels at one week follow-up (T3: *B*= -0.01 (0.01). These findings show that on-task behaviour as assessed by OPTIC was significantly improved during the Virtual Traveller intervention but that these effects did not remain at T4. A table of multilevel results for OPTIC ratings during the intervention period is provided in Appendix 8B.

Table 8-2. Multilevel modelling for on-task behaviour observed with the Observing Teaching and Pupils in Classrooms tool (OPTIC) at T4 (3-month follow-up)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	1.77 (0.01)***	1.75 (0.01)***	1.77 (0.01)***
Sex	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Ethnicity	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
$T1^0$	0.04 (0.01)***	0.04 (0.01)***	0.00 (0.01)
$T2^0$	0.04 (0.01)***	0.04 (0.01)***	-0.01 (0.01)
$T3^0$	-0.01 (0.01)	-0.01 (0.01	0.00 (0.01)
$T4^0$	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)
Intervention		0.04 (0.01)***	0.00 (0.01)
T1*Intervention			0.08 (0.01)***
T2*Intervention			0.09 (0.01)***
T3*Intervention			-0.01 (0.01)
T4*Intervention			0.00 (0.01)
Random effects (SE)			
Variance between classes	0.02 (0.01)	0.01 (0.01)	0.01 (0.01)
Variance within classes	0.07 (0.01)	0.07 (0.01)	0.07 (0.01)
Model deviance	1229.77	1237.91	1289.22

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** p≤0.001.

8.3 Affective and Cognitive student engagement: Student Engagement Instrument Elementary Version (SEI-E)

8.3.1 Sample size

All participants (n=219) provided SEI-E questionnaire responses during at least one study time-point. The majority of participants (n=152/219; 69.4%) completed the SEI-E questionnaire on all five occasions. The number of completed questionnaires ranged from 85.9% (intervention group at T3) to 91.5% (control group at T2) (Table 8-3). There was no significant difference in questionnaires completed between intervention groups at any time-point nor overall.

Table 8-3: Completed Student Engagement Instrument Elementary Version (SEI-E) questionnaires

Time	Analytic sample (n=219)	Intervention (n=113)	Control (n=106)
T0	n=195 (89.0%)	n=103 (91.2%)	n=92 (86.8%)
T1	n=198 (90.4%)	n=102 (90.3%)	n=96 (90.6%)
T2	n=198 (90.4%)	n=101 (89.4%)	n=97 (91.5%)
T3	n=190 (86.8%)	n=97 (85.9%)	n=93 (87.7%)
T4	n=192 (87.7%)	n=100 (88.5%)	n=92 (86.8%)
Overall	973/1095 (88.9%)	503/565 (89.0%)	470/530 (88.7%)

8.3.2 Principal Components Analysis

To the author's knowledge, the SEI-E has not yet been tested in a UK primary-school sample. Principal Components Analysis (PCA) was hence used to identify the composite sub-scale scores in this sample (as described in Section 6.6). A four-factor solution was identified (factors with eigenvalue ≥1), explaining 60.54% of the cumulative variance (Table 8-4). Only two items did not meet the minimum pattern matrix item factor loading criteria (>0.4) in their original accompanying SEI-E sub-scale. These were Teacher-Student Relationships (TSR) item 4: 'My teachers are there for me when I need them' and TSR item 6: 'My teachers are honest with me' (Table 8-4). These two items were both removed to produce a seven-item TSR scale in subsequent analysis. The factor labels proposed in the original SEI-E paper (583) were hence retained in this study, with twenty-two out of twenty-four original items retained in subsequent analysis.

8.3.1.1 Internal reliability and sub-scale correlations

Cronbach's alpha analysis assessed internal consistency for each of the PCA-identified SEI-E sub-scales overall and at each time-point (Table 8-5). Overall across all time-points, Peer Support for Learning (PSL) and Future Goals and Aspirations (FGA) sub-scales were found to have excellent internal reliability (a=≥0.70), whilst Teacher-Student Relationships (TSR) and Family Support for Learning (FSL) sub- scales have good internal reliability (a=0.60-0.69). This contrasts somewhat to the original SEI-E pilot paper (583), where TSR and PSL were found to have excellent internal reliability and FSL and FGA were found to have good internal reliability. Examining each sub-scale at each time-point, all but one sub-scale (TSR at Time 4, a=0.56) were assessed to be good or excellent (a=>0.60; Table 8-5).

Table 8-4. Factors loadings for Student Engagement Instrument – Elementary Version (SEI-E) items from Pattern and Structure matrices (n=219)

Item *	Factors determined through Principal Components Analysis			
	TSR	PSL	FGA	FSL
Adults at my school are fair towards students most of the time (TSR1)	**0.71** (0.73)			
Adults at my school listen to the students (TSR2)	**0.68** (0.69)			
Teachers at my school care about students (TSR3)	**0.71** (0.70)			
My teachers are there for me when I need them (TSR4)	0.36 (0.35)			
The rules at my school are fair (TSR5)	**0.66** (0.69)			
My teachers are honest with me (TSR6)	0.32 (0.40)			
I like talking to the teachers here (TSR7)	**0.79** (0.76)			
I feel safe at school (TSR8)	**0.53** (0.60)			
Most teachers care about me as a person, not just as a student (TSR9)	**0.61** (0.64)			
Other students care about me (PSL1)		**0.73** (0.72)		
Students at my school are there for me when I need them (PSL2)		**0.80** (0.80)		
Other students here like me the way I am (PSL3)		**0.70** (0.71)		
I enjoy talking to the students here (PSL4)		**0.84** (0.84)		
Students here respect what I have to say (PSL5)		**0.72** (0.73)		
I have friends at school (PSL6)		**0.64** (0.64)		
I plan to go to university after I finish secondary school (FGA1)			**0.82** (0.83)	
Continuing to learn after secondary school is important (FGA2)			**0.66** (0.68)	
School is important for reaching my future career goals (FGA3)			**0.81** (0.83)	
My education will create many chances for me to reach my future goals (FGA4)			**0.82** (0.80)	
I am hopeful about my future (FGA5)			**0.49** (0.49)	

Item *	Factors determined through Principal Components Analysis TSR	PSL	FGA	FSL
My family/guardian(s) are there for me when I need them (FSL1)				**0.64** (0.63)
When I have problems at my school my family/guardian(s) are ready to help me (FSL2)				**0.74** (0.74)
My family/guardian(s) want to know when something good happens at school (FSL3)				**0.70** (0.70)
My family/guardian(s) want me to keep trying when things are tough at school (FSL4)				**0.68** (0.68)

Notes: TSR, PSL, FSL & FGA are all constructs from the Student Engagement Instrument-Elementary Version (SEI-E); TSR stands for Teacher-Student Relationships, PSL stands for Peer Support for Learning, FGA stands for Future Goals and Aspirations, FSL stands for Family Support for Learning; Non-bracketed items denote pattern matrix loadings, used to form subsequent factors. Pattern matric factor loadings over 0.4 are in bold. Bracketed items denote structure matrix loadings. *Brackets denote the original questionnaire coding of the SEI-E item.

Table 8-5. Internal reliability of post-PCA SEI-E sub-scales

Time-point	n	Construct	Number of items	Cronbach's *α*	Skewness	Kurtosis	Shapiro-Wilk
T0	195	Teacher-Student Relationships (TSR)	7	0.62	-0.70	0.42	0.95***
		Peer Support for Learning (PSL)	6	0.86	-0.83	0.32	0.89***
		Future Goals and Aspirations (FGA)	5	0.80	-0.83	0.31	0.91***
		Family Support for Learning (FSL)	4	0.67	-0.81	0.69	0.92***
T1	198	Teacher-Student Relationships (TSR)	7	0.65	-0.79	0.79	0.94***
		Peer Support for Learning (PSL)	6	0.84	-0.78	0.17	0.89***
		Future Goals and Aspirations (FGA)	5	0.80	-0.83	0.31	0.91***
		Family Support for Learning (FSL)	4	0.65	-0.84	0.78	0.92***
T2	198	Teacher-Student Relationships (TSR)	7	0.63	-0.66	0.18	0.95***
		Peer Support for Learning (PSL)	6	0.76	-0.78	0.17	0.89***
		Future Goals and Aspirations (FGA)	5	0.75	-0.83	0.31	0.91***
		Family Support for Learning (FSL)	4	0.71	-0.84	0.78	0.92***
T3	190	Teacher-Student Relationships (TSR)	7	0.63	-0.61	-0.22	0.95***
		Peer Support for Learning (PSL)	6	0.79	-0.81	0.36	0.89***
		Future Goals and Aspirations (FGA)	5	0.75	-0.85	0.38	0.91***
		Family Support for Learning (FSL)	4	0.62	-0.84	0.88	0.92***
T4	192	Teacher-Student Relationships (TSR)	7	0.56	-0.74	0.59	0.95***
		Peer Support for Learning (PSL)	6	0.78	-0.76	0.31	0.91***
		Future Goals and Aspirations (FGA)	5	0.80	-0.83	0.37	0.91***
		Family Support for Learning (FSL)	4	0.61	-0.79	0.78	0.92***
Overall	219	Teacher-Student Relationships (TSR)	35	0.61	-0.74	0.43	0.86***
		Peer Support for Learning (PSL)	30	0.79	-0.80	0.23	0.89***
		Future Goals and Aspirations (FGA)	25	0.76	-0.83	0.35	0.90***
		Family Support for Learning (FSL)	20	0.67	-0.82	0.82	0.92***

Note: *** $p < 0.001$

Shapiro-Wilk analysis found all identified SEI-E sub-scales at all time-points to be non-normally distributed (614) (Table 8-5). All variables were strongly negatively skewed (<-.60; scores clustered to the right, with the tail extending to the left) and all but one (TSR at T3) showed positive kurtosis (>0.20; peaked distribution of scores). This indicates that SEI-E scores generally indicated high overall responses to TSR, PSL, FGA and FSL sub-scales. Data from the original SEI-E pilot paper noted data to be non-normally distributed but did not provide details on skewness or kurtosis (583). Non-parametric analyses were subsequently used for this non-normally distributed data. Spearman rho correlations were used to assess relationship between identified SEI-E factors, with Mann-Whitney *U* and Kruskal-Wallis tests used to perform preliminary data analysis on SEI-E outcomes.

Across all time-points, significant Spearman rho correlations were only found between TSR and FGA (r=0.28, p<0.01; Table 8-6). This contrasts to the original SEI-E pilot paper, where Spearman correlations between all factors were >0.30 and significant (583). At each time-point, significant correlations were found between TSR and FGA (T0: r=0.28, p<0.01; T1: r=0.32; p<0.01; T2: r=0.34, p<0.01, T3: r=0.20, p<0.01, T4: r=0.24, p<0.01). At T0, additional significant correlations were found between FGA and PSL (r=0.16, p<0.05). No additional significant correlations were found between sub-scales at T1 or T2. At T3, additional significant correlations were found between FGA and PSL (p<0.05). Finally at T4, additional significant correlations were found between FGA and PSL (r=0.19, p<0.01) and between PSL and FSL (r=0.15, p<0.05; Table 8-6).

Table 8-6. Spearman's rho correlation coefficients of SEI-E items following principal components analysis

T0	TSR	PSL	FGA	FSL	T1	TSR	PSL	FGA	FSL
TSR	-				TSR	-			
PSL	-0.04	-			PSL	-0.05	-		
FGA	0.28**	0.16*	-		FGA	0.32**	0.13	-	
FSL	0.07	0.07	0.04	-	FSL	0.14	0.09	0.07	-
T2	**TSR**	**PSL**	**FGA**	**FSL**	**T3**	**TSR**	**PSL**	**FGA**	**FSL**
TSR	-				TSR	-			
PSL	-0.09	-			PSL	-0.08	-		
FGA	0.34**	0.13	-		FGA	0.20**	0.18*	-	
FSL	0.03	0.10	0.05	-	FSL	0.04	0.10	0.04	-
T4	**TSR**	**PSL**	**FGA**	**FSL**	**Overall**	**TSR**	**PSL**	**FGA**	**FSL**
TSR	-				TSR	-			
PSL	-0.08	-			PSL	-0.10	-		
FGA	0.24**	0.19**	-		FGA	0.28**	0.16	-	
FSL	0.10	0.15*	0.06	-	FSL	0.09	0.13	0.05	-

Notes: * p<0.05; ** p<0.01; TSR stands for Teacher-Student Relationships, PSL stands for Peer Support for Learning, FGA stands for Future Goals and Aspirations, FSL stands for Family Support for Learning

8.3.2 Descriptive statistics and preliminary analysis

There were no significant differences between intervention groups in any SEI-E sub-scales at T0 (baseline), T1 (first intervention assessment), or either follow-up period (T3 & T4; Table 8-1; Figures in Appendix 8C). At T2 (second intervention assessment), there was significantly greater TSR sub-scale ratings in intervention pupils (Median=25.00) compared to control pupils (Median=24.00; U(198)=4067.5, p<0.05). There was no significant overall mean difference in sub-scales across all time-points. There were no significant differences in overall SEI-E sub-scales between any demographics. There was also no significant difference in any sub-scales in intervention pupils between intervention periods (T1 & T2).

8.3.3 Multilevel modelling

Multilevel models were calculated according to the processes described in Section 6.6. As found for physical activity (Chapter 7) and on-task behaviour outcomes (Section 8.2.3), results for T4 and intervention period (T1 & T2) outcomes were indistinguishable for all SEI-E sub-scales and so results are presented together. Tables of multilevel results for non-significant average SEI-E outcomes at T4, with all outcomes during the intervention period provided in Appendix 8D.

8.3.3.1 Secondary study aims 1m): student engagement questionnaire (SEI-E) scores at three-month follow-up (T4) & 2o): SEI-E questionnaire scores during the intervention period (T1 & T2)

Teacher Student Relationships (TSR) sub-scale

There was no significant effect of intervention on TSR at T4, nor significant interactions between time-points and intervention group status. These findings show that TSR at T4 were not affected by the Virtual Traveller intervention (Appendix 8D).

Peer Support for Learning (PSL) sub-scale

There was no significant effect of intervention on PSL at T4, nor significant interactions between time-points and intervention group status. These findings show that PSL at T4 was not affected by the Virtual Traveller intervention (Appendix 8D).

Future Goals and Aspirations (FGA) sub-scale

There was no significant effect of intervention on FGA at T4, nor significant interactions between time-points and intervention group status. These findings show that FGA at T4 were not affected by the Virtual Traveller intervention (Appendix 8D).

Family Support for Learning (FSL) sub-scale

There was no significant effect of intervention on FSL at T4, nor significant interactions between time-points and intervention group status. These findings show that FSL at T4 was not affected by the Virtual Traveller intervention (Appendix 8D). Collectively, this analysis has shown that student engagement as assessed with the SEI-E questionnaire was not significantly changed by the Virtual Traveller intervention.

8.4 Discussion

This chapter reported the analysis of student engagement outcomes assessed during the Virtual Traveller intervention of Study Two. It firstly presented descriptive statistics and multilevel modelling of on-task behaviour as a form of behavioural engagement (Section 6.4.8), assessed using the Observing Pupils and Teachers in the Classroom (OPTIC) (593) observation tool (Section 6.4.9.3.2). Secondly, it presented descriptive analysis, principal components analysis and multilevel modelling of affective and cognitive student engagement (Section 6.4.8), assessed using the Student Engagement Instrument-Elementary Version (SEI-E) questionnaire (583) (Section 6.4.9.4.2).

8.4.1 On-task behaviour

This chapter showed that Virtual Traveller sessions featuring physically active VFTs did increase on-task behaviour compared to typically-taught, control lessons. These findings hence extend the expectations of thesis question 5) can Virtual Field Trips introduce physical activity without compromising on-task behaviour? and thesis hypothesis 2) physically active Virtual Field Trips will not compromise on-task behaviour (Chapter 3), by showing a benefit rather than merely a lack of detriment. This chapter also addressed study aim 3n) determining the effectiveness of Virtual Traveller intervention during the intervention period (T1 & T2; weeks 2 and 4 of the intervention) compared to baseline on on-task behaviour observation ratings (Section 6.3), with significant, positive benefits found. Five out of six studies identified in the systematic review (Section 4.5.11.1) similarly found on-task behaviour to increase with physically active lessons (132, 377, 378, 381, 392), with the remaining study finding no change in intervention pupils but a decrease in control pupils (129). Study Two hence adds to a growing literature supporting the positive effects of physically active teaching on on-task behaviour.

However, this chapter also found that these increases in on-task behaviour were confined to the intervention period only, with gains not extending to either one week (T3) or three month (T4) follow-up periods. Hence study aim 2h) determining the effectiveness of Virtual Traveller intervention to improve the T4 mean scores of on-task behaviour observation ratings (Section 6.2) found a lack of effectiveness at three month follow-up. These findings suggest the need for maintained physically active VFTs to provide sustained positive effects on on-task behaviour. No physically active lesson studies assessing effects on on-task behaviour have assessed changes to the outcome following intervention provision (129, 132, 377, 378, 380, 392) (Section 4.5.11.1). This study is hence the first to show decay of on-task behaviour increases after the completion of a physically active lesson intervention.

No demographic differences in sex and ethnicity were seen for on-task behaviour: assessed as a measure of behavioural student engagement (Table 8-2). This suggests that the Virtual Traveller intervention had an equally positive effect on on-task behaviour between sexes and ethnicities. Only one physically active lesson study identified in the systematic review tested on-task behaviour effects by sex, also finding no significant differences between demographics (380) (Section 4.5.11.1). No previous physically active lesson studies have analysed the effects on on-task behaviour by ethnicity, hence it is unknown if the positive effect seen here across ethnicities has been mirrored elsewhere.

8.4.2 Student engagement

This chapter found none of the student engagement sub-scales assessed by the Student Engagement Instrument – Elementary Version (SEI-E) questionnaire to be significantly changed by the Virtual Traveller intervention. This lack of effect was derived from study aims 2i) determining the effectiveness of Virtual Traveller intervention to improve the T4 mean scores of student engagement questionnaire scores and 3o) determining the effectiveness of Virtual Traveller intervention during the intervention period (compared to baseline on student engagement questionnaire scores (Section 6.2). These findings answer thesis question 6 (Chapter 3) and study question 3 (Section 6.1.1): can Virtual Field Trips improve student engagement? by showing that the Virtual Traveller intervention could be integrated into teaching without detriment to student engagement.

Study Two provided the first assessment of student engagement outcomes in physically active lesson research beyond on-task behaviour alone (Section 4.5.11). It also provided the first validation and use of the SEI-E (583) in a UK sample. Minor adjustments were made to two questionnaire items to edit Americanised language (Section 6.4.9.4.2). All sub-sections were found to have good or excellent internal reliability at all time-points in this sample (Section 8.3.1.1), giving strong preliminary support for the use of the SEI-E in UK primary school populations. The novel nature of both the SEI-E and physically active lesson research in UK samples, makes comparison with published research slightly limited.

Demographics were found to be significant predictors of all SEI-E sub-scores in multilevel modelling. Sex was a significant predictor for three sub-scores, with girls scoring higher than boys in Teacher Student Relationships (TSR) and Future Goals and Aspirations (FGA) and boys conversely scoring higher than girls in Peer Support for Learning (PSL). This is in comparison to the initial SEI-E validation study, which found girls to demonstrate higher scores across all sub-scores (583). This reflects a 'gender gap' in student engagement identified in educational psychology research (615), with girls consistently demonstrating higher student engagement across all dimensions. The explanations behind this gap are varied and complex (616), including girls desiring and receiving more teacher support to assist their studies and facilitate engagement compared to boys (615). Although student engagement assessed by SEI-E was not effected by physically active lessons, these findings still longitudinally validate a new student engagement measure specifically for primary-school aged children in a UK sample.

Ethnicity was a significant predictor for two sub-scores, with white pupils scoring lower than non-white pupils in Peer Support for Learning (PSL) and conversely white pupils scoring higher than non-white pupils in Family Support for Learning (FSL). Ethnicity was not assessed in the initial validation study (583), with no subsequent studies assessing SEI-E differences by ethnicity to the researcher's knowledge. The effects of ethnicity on student engagement and attainment have been explored in UK (617) and American contexts (618), identifying complex influences across individual, parental and societal factors. This regular presence of significant demographic predictors for SEI-E (affective and cognitive student engagement) contrasts with on-task behaviour (behavioural engagement; Section 6.4.8) and physical activity outcomes (Chapter 7), where sex and ethnicity largely were not significant contributors. Previous physically active lesson work has largely failed to account for such important variables (Section 4.5.7.2), arguably omitting important explanatory value. The significant contributions of sex and ethnicity variables towards understanding intervention outcomes here highlights the need for such demographics to be fully recorded and analysed in future interventions.

8.4.3 Strengths and weaknesses of student engagement assessment

A strength of assessment in Study Two is its novel extension of student engagement outcomes beyond on-task behaviour alone. As seen in the systematic review (Section 4.5.11), on-task behaviour was found to be improved by physically active lesson interventions but no research had investigated broader engagement. Another strength is the novel use of the Student Engagement Instrument – Elementary Version (SEI-E) (583) in both an intervention context and in a UK sample.

A weakness of the student engagement measures used is that no tools were trialed prior to Study Two, meaning that on-task behaviour observations and student engagement questionnaires were immediately tested in a controlled trial situation. The SEI-E had never been tested in published UK research before and so piloting would have allowed validation prior to full-scale assessment here. There may also be a potential observer effect, with pupils potentially modifying their on-task behaviour to please the researchers (132). Additionally, unlike in some other physically active lesson interventions (377, 383, 390) (Section 4.5.11), academic achievement outcomes in the form of classroom grades or standardised tests were not assessed in Study Two. This is because school-reported grades would have required an additional burden on teachers, and standardised tests would require a great deal of additional assessment time and resources if managed by the researcher (Section 6.1). Hence although on-task behaviour was found to be significantly higher during intervention periods (Section 8.2), it is unknown from this work if similar relationships would be evident for achievement outcomes of key concern to teachers (443).

8.5 Conclusion

This chapter found the six-week Virtual Traveller intervention of Study Two to significantly increase on-task behaviour. However, these positive effects on on-task behaviour were not maintained at either one week (T3) or three month (T4) follow-ups. This suggests that on-task behaviour can be increased if physically active Virtual Field Trip provision is maintained. The Virtual Traveller intervention provided no detriment to any student engagement questionnaire outcome. This chapter provided the first published assessment of student engagement beyond on-task behaviour alone. It also provided the first validation and use of the Student Engagement Instrument-Elementary Version (SEI-E) in a UK sample.

Chapter 9 Process evaluation of Study Two

9.1 Introduction

This chapter presents process evaluation findings of Study Two: a longitudinal randomised controlled trial of physically active Virtual Field Trips named 'Virtual Traveller'. As recommended by the Medical Research Council (279), it is important for interventions to be fully evaluated to understand the processes occurring within them (Section 5.4.6). Accordingly as outlined in the systematic review (Section 4.5.6) (3), the majority of physically active lesson studies have evaluated their interventions. However, the extent of this evaluation was shown to vary greatly. The majority of studies only used fairly superficial and simple teacher session logs (277, 298, 373, 374, 376, 377, 378, 381, 383, 386, 389, 391), giving slight insight into which sessions were implemented and crude assessment of their success. Much rarer, in-depth evaluation of the processes and experiences of interventions were seen, such as teacher interviews (325, 373), teacher focus groups (383) and pupil focus groups (325, 374) (Section 4.5.6). Identified physically active lesson studies also gave little rationale given for the process evaluation methods they used. Only one study used a structure to select and present their process evaluation methods (373), aligning their evaluation according to the RE-AIM framework (399). As previously described in greater detail (Section 5.4.6), the RE-AIM framework is designed to evaluate interventions against a range of comprehensive and robust criteria: Reach, Efficacy, Adoption, Implementation and Maintenance (399, 569). These criteria assess evaluation across both the individual- (participant/facilitator; Reach, Effectiveness, Maintenance) and setting-levels (environment; Adoption, Implementation, Maintenance; Figure 6-3) (399).

This thesis has already shown the developed Virtual Traveller intervention to have no effect on overall activity levels but to significantly improve lesson time physical activity (Chapter 7) and on-task behaviour (Chapter 8). However, the processes underpinning these intervention effects have not yet been explored (283). A full process evaluation of the Virtual Traveller intervention was run to identify potential explanations for observed effects and to allow revisions to the intervention in post-PhD iterations. This chapter addresses thesis aim of: 7) evaluate the processes underlying a developed physically active Virtual Field Trip intervention and thesis question 7) to what extent will a physically active Virtual Field Trips intervention be implemented in primary-school teaching (Chapter 3)? The chapter also addresses the Study 2 secondary aim of: 3) assess how the Virtual Traveller intervention was delivered (Section 6.2).

9.2 Methods

The methods used to assess the Virtual Traveller programme against each of the five RE-AIM criteria are described in the Virtual Traveller protocol (Section 6.4.9.5). Teacher sheets logging receipt of pupils' returned informed consent documents (Appendix 6J) were obtained from all ten participating classes. Teacher intervention logs (Appendix 6O) were obtained from all five participating intervention classes. Pupil VFT evaluation questionnaires (Appendix 6U) including the one-item Children's OMNI scale of perceived exertion were completed by 90% (n=103/115) of intervention pupils at T1 and 85% (n=98/115) at T2. Teacher evaluation questionnaires (Appendix 6V) were completed by all five intervention teachers. Pupil focus groups and teacher interviews were run in four out of five intervention classes, as Class 2 chose not to participate in this phase of evaluation. In total n=24 pupils (21% (n=24/115) of total intervention group sample) participated across the focus groups. This included six pupils from each of the four participating intervention classes remaining in process evaluation and featured thirteen boys (54%; n=13/24). As described in the study protocol (Section 6.4.9.5.5) and actioned in previous physically active lesson evaluation (392), pupils were purposively invited to feature two children of lower, middle and higher overall academic ability in each intervention class. Findings are reported according to the structure of RE-AIM criteria (Reach, Efficacy, Adoption, Implementation and Maintenance), as presented in Figure 6-3.

9.3 Findings

9.3.1 Reach

To evaluate the adequacy of the sample in this study, Reach assesses the pupil-level of participation and whether participating pupils are representative of the entire potentially eligible population (399, 443). It has been assessed here by comparing the characteristics of all consenting pupil participants with non-participants. A full flowchart of participating and non-participating classes and pupils is provided in Figure 7-1.

9.3.1.1 Participation rates among eligible classes

Ten out of twelve (83.3%) contacted schools agreed to participate in the study. The two declining schools reported time pressures as their reason for non-participation. This response was gained from a headteacher in one school and a Year 4 class teacher in the second school. Both declining schools did not currently hold Healthy Schools Status (600), compared with 60% (n=6/10) of participating schools.

9.3.1.2 Participation rates among eligible pupils

Of the three hundred and three pupils eligible to participate in the study, two hundred and sixty four (87%) consented to participate. Reasons for non-consent reported by class teachers included forgetting to return forms (n=36/39; 92%) and apprehension of accelerometers and their use (n=3/39; 8%).

9.3.1.3 Representativeness of participants

The representativeness of consenting participants (n=264: regardless of whether they were included in the analytic sample) compared to non-consenting pupils (n=39) was assessed. Sex and English language statuses of pupils within the class as a whole were gained from the teacher, whereas demographics for consenting pupils were gained from their pupil demographic questionnaire (Appendix 6R). There were no significant differences in sex and English language status between participating and non-participating pupils (Table 9-1). This suggests that attempts by the researcher to encourage participation (Section 6.4.3) were relatively as effective across these demographics.

Table 9-1. Demographics of participating and non-participating pupils

Demographics	**Participating pupils (n=264)**	**Non-participating pupils (n=39)**	**p**
Sex Male	n=137 (51.9%)	n=18 (46.2%)	0.51
Female	n=127 (48.1%)	n=21 (53.8%)	
English as first language	n=205 (77.7%)	n=25 (64.1%)	0.07

9.3.2 Effectiveness

The effects of the Virtual Traveller intervention on primary and secondary physical activity outcomes has been previously described in Chapter 7 and effects on secondary on-task behaviour and student engagement outcomes described in Chapter 8. These outcome measures represent typical assessments of intervention success (399, 570). However, subjective perceptions on the effectiveness of the Virtual Traveller intervention from participating pupils and teachers have yet to be explored. These insights from participants experiencing the intervention first-hand provide important information on components of the intervention that may be associated with desirable or undesirable effects (399).

9.3.2.1 Perceptions of intervention sessions

Perceptions of the effectiveness of the Virtual Traveller programme were collected via teacher and pupil evaluation questionnaires, teacher interviews and pupil focus groups (as described in Section 6.4.9.5).

9.3.2.1.1 Pupil perceptions

Pupil questionnaire ratings of the Virtual Traveller intervention were relatively high across T1 and T2 measurement points (Table 9-2). There were no significant differences in overall pupil evaluation questionnaire item scores between T1 and T2 intervention periods. There were significantly different scores between classes in Q2: "How much do you like Virtual Traveller sessions" at T2, with Class 7 demonstrating significantly higher ratings than all other classes ($F(4,97)=2.84$, $p<0.05$). There were no other differences in evaluation questionnaire scores by class. At T1 only, males reported significantly higher responses to Q4: "Virtual Traveller sessions help me learn' (M=4.0, SD=1.08) compared to girls (M=3.6, SD=1.06; $t(101)=2.01$, $p<0.05$). At T2 only, pupils without English as a second language gave significantly higher scores to Q2 (M=4.4, SD=0.96) than pupils who did (M=3.7, SD=1.35; $t(96)=2.25$, $p<0.05$). There were no other differences by pupil demographics.

Table 9-2. Average ratings from Virtual Traveller pupil evaluation questionnaire

Questionnaire item	Class	T1 (n=103)	T2 (n=98)
Q1. How tired did Virtual Traveller sessions make you? (OMNI scale)	Class 2	2.9/11 (1.82)	3.0/11 (2.66)
	Class 5	2.3/11 (1.75)	3.0/11 (2.09)
	Class 6	2.2/11 (1.77)	2.3/11 (2.08)
	Class 7	2.0/11 (2.17)	1.9/11 (1.99)
	Class 10	2.9/11 (1.70)	3.0/11 (2.42)
	Overall	2.4/11 (1.80)	2.7/11 (2.27)
Q2. How much do you like Virtual Traveller sessions?	Class 2	3.5/5 (1.29)	3.9/5 (1.20)
	Class 5	3.9/5 (1.36)	3.6/5 (1.38)
	Class 6	3.7/5 (1.28)	3.4/5 (1.50)
	Class 7	3.9/5 (0.80)	4.8/5 (0.43)
	Class 10	3.4/5 (1.27)	3.8/5 (1.28)
	Overall	3.6/5 (1.23)	3.8/5 (1.31)
Q3. I think Virtual Traveller sessions are fun	Class 2	3.5/5 (1.25)	3.9/5 (1.15)
	Class 5	3.7/5 (1.43)	3.6/5 (1.42)
	Class 6	3.8/5 (1.30)	3.6/5 (1.37)
	Class 7	4.1/5 (0.96)	4.6/5 (0.51)
	Class 10	3.8/5 (1.23)	3.7/5 (1.23)
	Overall	3.8/5 (1.25)	3.8/5 (1.24)
Q4. Virtual Traveller sessions help me learn	Class 2	3.8/5 (1.12)	4.1/5 (1.13)
	Class 5	3.7/5 (1.04)	3.4/5 (1.17)
	Class 6	3.7/5 (1.20)	3.6/5 (1.08)
	Class 7	3.9/5 (0.80)	4.1/5 (1.00)
	Class 10	3.6/5 (1.20)	3.5/5 (1.28)
	Overall	3.7/5 (1.08)	3.7/5 (1.16)

Note: The OMNI scale is an eleven-point scale, ranging from 0 (not tired at all) to 10 (very, very tired); Q's 2-4 are rated on a 5-point Likert scale where 0 = not very much and 5= very much.

Pupil focus groups also provided insight into perceptions of Virtual Traveller sessions. Some students (n=7/24) described the movements involved to be repetitive, such as "*you end up jumping a lot sometimes.. it would be good if we could run around more instead*" (Class 7) and "*there were a lot of true and false questions which got annoying sometimes*" (Class 5). Some pupils (n=5) also described how they would like to have lessons outside instead: "*it's ok to move inside sometimes but it would be good if we could have more classes outside as well*" (Class 10). A range of session difficulties were described by pupils. For example, "*sometimes the answers were really easy, like times table ones.. so we just did the movements* *really quickly*" (Class 5) compared to "*sometimes you don't know the answer and you don't want to move too much so everyone knows you're wrong*" (Class 6).

9.3.2.1.2 Teacher perceptions

Teacher evaluation questionnaire ratings of the Virtual Traveller intervention were relatively high across T1 and T2 (Table 9-3). Significance testing was not possible due to the small number of participating teachers (n=5) but some patterns can be tentatively described. Interestingly, all teachers rated children's enjoyment of Virtual Traveller sessions to be very high across time-points (21/25 at T1 and 22/25 at T2; Table 9-3). Ratings between T1 and T2 were generally similar, suggesting stable perceptions with repeated exposure to Virtual Traveller sessions. For example, there was a two-point increase in perceptions of session ease-of-use (Q1) in T2 compared to T1, suggesting that using PowerPoint Virtual Traveller sessions became easier over time. There was a two-point decrease in perceptions of enjoyment (Q2) during the intervention, suggesting that repeated exposure to such sessions may make them less enjoyable for teachers to deliver. As also shown in Table 9-3, overall differences across all items and intervention teachers were four points higher at T2 compared to T1, suggesting increased overall satisfaction as the Virtual Traveller intervention progressed.

The intervention log provided additional information on teacher ratings of delivered sessions (Table 9-4). Ratings were generally high across all sessions; with overall mean ratings of Maths sessions (3.9/5, SD=0.42) higher than English sessions (3.7/5; SD=0.11). Sessions rated particularly highly included M4 (London 2012 Olympics and beyond) with 4.8/5 (SD=0.45) from five teachers and E4 (Explanation Texts) with 4.3/5 (SD=0.50) from four teachers (Table 9-4). Lower rated sessions included M6 (Sports Galore) with 2.7/5 (SD=0.58) and E6 (Noun Reverse Charades) with 2.7/5 (SD=0.58), both from three teachers.

Table 9-3. Average ratings from Virtual Traveller teacher evaluation questionnaire

Questionnaire item	Class	T1 (n=5)	T2 (n=5)
Q1. Virtual Traveller sessions were easy to use	2	3/5	3/5
	5	2/5	3/5
	6	5/5	5/5
	7	4/5	4/5
	10	3/5	4/5
	Overall	17/25	19/25
Q2. Virtual Traveller sessions were enjoyable to use	2	4/5	3/5
	5	3/5	3/5
	6	4/5	4/5
	7	4/5	4/5
	10	5/5	4/5
	Overall	20/25	18/25
Q3. Since teaching Virtual Traveller, I feel more confident in incorporating physical activity into lessons	2	4/5	5/5
	5	5/5	5/5
	6	4/5	4/5
	7	4/5	4/5
	10	4/5	4/5
	Overall	21/25	22/25
Q4. I will continue to add physical activity into my teaching	2	5/5	5/5
	5	4/5	4/5
	6	5/5	5/5
	7	3/5	3/5
	10	4/5	5/5
	Overall	21/25	22/25
Q5. I will recommend the Virtual Traveller programme to other teachers	2	2/5	3/5
	5	2/5	3/5
	6	5/5	4/5
	7	3/5	3/5
	10	4/5	4/5
	Overall	16/25	17/25
Q6. My pupils have enjoyed Virtual Traveller	2	4/5	4/5
	5	4/5	4/5
	6	5/5	5/5
	7	4/5	5/5
	10	4/5	4/5
	Overall	21/25	22/25
Overall		116/150	120/150

Further insight into teacher perceptions of the effectiveness of Virtual Traveller was provided from teacher interviews. Perceptions regarding strengths, limitations and deviations of implementation are discussed in Section 9.3.4. As discussed in Section 9.2, it must be noted that an interview was not held with the teacher of Class 2, who rated sessions lower than anyone else (Table 9-4). Teachers generally described children to be more active during Maths Virtual Traveller sessions than English ones. For example, "*actions in the Maths ones* (sessions) *were more obvious and the kids got it more, like jumping a number of moves to an answer.. it just makes sense for them*" (Class 10). All teachers also described pupil behaviour to be worse when sessions were not very fun: "*they will tell you if the session isn't working well, they will moan if they think the moves are boring or they don't want to travel to another place*" (Class 7). Some specific examples of less effective sessions were given, such as "*an English one wasn't good where they all had to act out nouns for one pupil to guess* (E6: Noun reverse charades)*, it took a lot of time for them to get the idea and they got impatient… I don't think they learnt anything from that"* (Class 6). Conversely one teacher described one session exploring the London Olympic Park (M4: London 2012 Olympics and beyond) as particularly relevant to their class as they had visited recently on a school trip: "*it was great for them to re-live that experience... for some of them it was their first trip out of their local area"* (Class 10). This highlights the potential of VFTs to enable pupils to explore and interact with varied environments. Teachers all described positive attitudes towards integrating physical activity into teaching during the intervention, such as "*it creates an experience that they'll go home and tell their family about and compliments their wider learning*" (Class 7).

Table 9-4. Individual Virtual Traveller session ratings by class teacher

Class	M1	M2	M3	M4	M5	M6	M7	M8	M9	Teacher Maths overall rating
2	3	5	4	4	3	2	3	3		3.4/5 (0.92)
5		4	4	5		3			4	4.0/5 (0.71)
6	4	4	4	5	3	3	4	3	5	3.9/5 (0.78)
7		5		5	4				4	4.5/5 (0.58)
10	4	4	3	5	3		3	3	4	3.6/5 (0.74)
Average Session Rating	3.7/5 (0.58)	4.4/5 (0.55)	3.8/5 (0.50)	4.8/5 (0.45)	3.3/5 (0.50)	2.7/5 (0.58)	3.3/5 (0.58)	3.0/5 (0)	4.3/5 (0.50)	3.9/5 (0.42)

Class	E1	E2	E3	E4	E5	E6	E7	E8	E9	Teacher English overall rating
2	3	3	5	4	4	3				3.7/5 (0.82)
5	4		3	4					4	3.8/5 (0.50)
6	4	3	3	4	4	2	4	4	4	3.6/5 (0.73)
7	4	3					4			3.7/5 (0.58)
10	4	4		5	4	3		4	3	3.9/5 (0.69)
Average Session Rating	3.8/5 (0.45)	3.3/5 (0.50)	3.7/5 (1.15)	4.3/5 (0.5)	4.0/5 (0)	2.7/5 (0.58)	4.0/5 (0)	4.0/5 (0)	3.7/5 (0.58)	3.7/5 (0.11)

9.3.2.2 Perceived physical exertion in intervention sessions

Effectiveness was finally assessed in terms of perceived physical exertion in intervention pupils during VFT sessions. Quantitative assessment via the OMNI scale showed there was no significant difference in intervention pupils' perceived physical exertion ratings between T1 (M=2.4/11, SD=1.80) and T2 (M=2.8/11, SD=2.30; $t(90)=1.31$, $p=0.19$) (Q1: 'How tired did Virtual Traveller sessions make you?'; Table 9-2). There were no significant differences in perceived physical exertion ratings between intervention classes or demographics, suggesting ratings were relatively low and consistent across the sample.

Relatively low OMNI-observed physical exertion was also mirrored in qualitative evaluations within pupil focus groups. All focus groups contained comments about the exertion during VFTs but these were accompanied as part of a positive overall experience. For example: "*you sometimes get really out of breath but it's ok because it's fun and we're moving around*" (Class 2). However, teacher interviews identified alternative perceptions. Some (n=3, 75%) described some pupils to express negative comments on exertion during VFT sessions. For example: "*sometimes one or two kids just aren't up for moving that day and whinge* (complain) *a lot about being tired*" (Class 10) and "*some of them are quite unfit generally and find it difficult to stay active even for one of these short sessions… it's quite worrying*" (Class 5). These qualitative teacher findings seem to align with those of Study One (Section 5.3), where children reported exertion during VFT sessions.

9.3.3 Adoption

Adoption of the Virtual Traveller intervention was assessed in terms of the representativeness of participating school and class settings (399, 443). This includes the representativeness of teachers delivering the intervention and the contexts of participating schools in terms of physical activity provision. Although the intervention materials were delivered free of charge to classes in this study, the potential costs of the intervention if implemented outside of research settings was also estimated (399).

9.3.3.1 Representativeness of participating settings

Teacher and school demographics were reported earlier (Section 7.2) but are hereby analysed in greater detail to assess representativeness between intervention groups. The teacher and school demographics table (Table 7-2) is hereby re-tabulated to present intervention and control classes separately (Table 9-5). Classes mostly had lower levels of ethnic minority participants and higher poverty levels compared to borough, local and national averages (614) (Table 7-1), suggesting that participating classes may not be indicative of others in their local areas. Levels of ethnic minority participants were also much higher than the national average, showing that results cannot be extrapolated at national level. Most teacher and school demographics were similar between intervention groups (Section 7.2.3). For example, two schools in each intervention group had Healthy Schools status (600), indicative of healthy practice in physical activity, diet and wellbeing. However, teachers of intervention classes had a lower level of teaching experience than control teachers (34 years total in intervention vs 58 years in control). As intervention teachers were generally newer to teaching, this may have biased the sample. They may have been introduced to interactive whiteboards during their more recent teacher training and may have been more comfortable in adopting the Virtual Traveller technology.

Table 9-5: Teacher and school demographics by intervention group

Class	Intervention Group	School borough	Sex of teacher	Teacher ethnicity	Years teaching	Teacher self-reported health	PM Play	Healthy School status	PE hr/wk	Children get enough PA during school (out of 5)	How often integrate physical activity into teaching	How often use Brain Breaks	How often teach PE
2	Intervention	Ealing	Female	White	5	Excellent	Yes	No	2	3	Sometimes	Sometimes	Never
5	Intervention	Ealing	Female	Asian	5	Good	Yes	Yes	2	2	Most days	Not often	Never
6	Intervention	Windsor	Female	White	15	Excellent	Yes	No	2	4	Sometimes	Not often	Once in a while
7	Intervention	Ealing	Male	White	2	Excellent	Yes	No	2	3	Not often	Not often	Once in a while
10	Intervention	Hillingdon	Female	White	7	Excellent	Yes	Yes	2	3	Most days	Not often	Once in a while
1	Control	Slough	Female	Mixed	20	Good	Yes	No	2	4	Sometimes	Sometimes	Never
3	Control	Hillingdon	Female	Asian	8	Good	Yes	No	2	4	Sometimes	Sometimes	Once in a while
4	Control	Slough	Female	White	2	Excellent	No	Yes	2	2	Most days	Most days	Never
8	Control	Ealing	Female	White	20	Good	Yes	No	2	4	Most days	Sometimes	Never
9	Control	Windsor	Female	White	8	Good	Yes	Yes	2	4	Most days	Sometimes	Most sessions

9.3.3.2 Costs of intervention

As noted in the literature review (Section 2.7.2) the costing of physical activity interventions is rarely published, making it impossible for schools and researchers to fully appraise their potential (245). In this study; recruitment, teacher training and intervention materials were provided free of charge by the researcher. However, it is important to estimate the potential costs of replicating the Virtual Traveller intervention in real-world teaching. Estimated real-world costs for schools to implement the Virtual Traveller intervention in one class are provided in Table 9-6. These are informed from in-depth costings of other school-based physical activity interventions (261, 619) and costings of interactive whiteboard purchases (620).

Table 9-6. Estimated Virtual Traveller costs in real-world implementation for one class

Resources	Unit cost £	Units required	Total cost £
Teacher training			
Researcher-delivered teacher training	£30/hour	1	£30
Printing – teacher guide	£1/guide	1	£1
Teacher training total			*£1 - £31*
Technology			
Interactive whiteboard [a]	£1,600	1	£1,600
Warranty [a]	£200	1	£200
Projector [a]	£1,500	1	£1,500
Installation and cabling [a]	£340	1	£340
Audio system [a]	£250	1	£250
Technology total			*£3890*
Teacher training + technology total			***£3891-£3921***

Notes. [a] represents costings of interactive whiteboard purchases by (620)

There are different options for Virtual Traveller teacher training in real-world scenarios. Training could be delivered by an expert in the intervention (estimated at £30 an hour) as done in Study Two (Section 6.4.7). However, this would require an active trainer to be available after the completion of the Virtual Traveller research project, subject to additional funding. Alternatively and arguably more sustainably, developed teacher training resources (e.g Appendix 6P) could be made available via popular educational resource websites such as TES Resources (510) and Twinkl (511). This would allow teachers to access and share Virtual Traveller resources at times convenient to them, embedded within an existing and familiar website. However, this cheaper and more informal mode of teacher training may have consequences for intervention implementation. For example, without face-to-face discussion it may be difficult for the behaviour change techniques (BCTs) embedded within Virtual Traveller intervention training (Figure 6-4) to be successfully delivered. Although online training could present information based around BCTs to help increase intervention adoption, there would be no opportunity for discussion or clarification. Such training may hence have weaker impact than if delivered by a researcher in the field who could tailor discussion around the questions and concerns of the individual teacher. Without a scheduled timeslot for training, online resources may also not be fully completed by teachers due to time constraints (284). This may lead training to be incomplete and reduce the potential for full implementation.

As Virtual Traveller fundamentally requires interactive whiteboards and projectors, the predominant costs for schools would be based around whether they already have access to this equipment or not. Projected costs in purchasing and maintaining this equipment total £3890 based on projected costings for schools (620) (Table 9-6). However as previously shown in the rationale for VFT interventions (Section 2.9.1), over 70% of UK classes already have access to interactive whiteboard technology (336), making these purchases irrelevant for the majority of potential users. Given the high availability of required technology and potential for online resources, Virtual Traveller has the potential to be a free-to-access intervention available to all teachers and schools.

9.3.4 Implementation

The implementation of Virtual Traveller was evaluated in a variety of ways. Firstly, the extent the intervention was delivered as intended was assessed using teacher log records (Appendix 6O), teacher interviews and pupil focus groups. Secondly, the time delivered to deliver the Virtual Traveller intervention was assessed via teacher interviews and pupil focus groups. Identifying the factors influencing Virtual Traveller delivery will enable issues to be addressed and implementation to be maximised in future research (399, 443).

9.3.4.1 Extent the intervention is delivered as intended

9.3.4.1.1 Teacher log and pupil focus groups

The number of sessions actually delivered out of the eighteen provided Virtual Traveller sessions was firstly assessed using the intervention teacher log. As shown in Table 9-7, the number of unique sessions completed ranged from 38.9% (Class 7) to 100% (Class 6), with 70% of sessions delivered overall across all intervention classes. Individual teachers delivered between 44.4% (Class 7) to 100% (Class 6) of Maths sessions at least once during the intervention. Sessions M2: 'Maths Marching' and M4: 'London 2012 Olympics and Beyond' were the most frequently delivered (used in 5/5 (100%) of intervention classes) and sessions M1: 'Tens and Hundreds Challenge', M6: 'Sports Galore', M7: 'Rock around the Clock' and M8: 'Money, Money, Money!' were the least frequently delivered (used in 3/5 (60%) of intervention classes; Table 9-4). Teachers delivered between 33.3% (Class 7) to 100% (Class 6) of English sessions at least once during the intervention. Session E1: 'Kung Fu Punctuation 1' was the most frequently delivered (used in 5/5 (100%) of intervention classes) and E7: 'Persuasive Writing' and E8: 'Frozen Vocabulary' were used the least frequently (used in 2/5 (40%) of intervention classes; Table 9-4). Importantly, pupil focus groups identified that teacher logs may not truly reflect full session implementation. For example: "*I think our teacher stopped halfway once*" (Class 10). This highlights that although sessions may have been reported as delivered (Table 9-7), the extent of delivery cannot be fully ascertained. Teachers may have recorded sessions as completed but not actually delivered all activities.

Table 9.7 Virtual Traveller sessions delivered in intervention classes

Class	No. of sessions completed	Maths sessions completed	English sessions completed	Sessions repeated
2	n=14 / 18 (77.8%)	n=8 / 9 (88.9%)	n=6 / 9 (66.7%)	n=0 / 18 (0%)
5	n=9 / 18 (50%)	n=5 / 9 (55.6%)	n=4 / 9 (44.4%)	n=3 / 18 (16.7%)
6	n=18 / 18 (100%)	n=9 / 9 (100%)	n=9 / 9 (100%)	n=0 / 18 (0%)
7	n=7 / 18 (38.9%)	n=4 / 9 (44.4%)	n=3 / 9 (33.3%)	n=4 / 18 (25%)
10	n=15 / 18 (83.3%)	n=8 / 9 (88.9%)	n=7 / 9 (77.8%)	n=1 / 18 (5.6%)
Overall	63/90 (70%)	34/45 (75.6%)	29/45 (64.4%)	8/90 (9%)

Teacher training recommended that each Virtual Traveller session should be delivered once during the six-week intervention period. However three out of five (60%) intervention teachers reported repeating sessions during the intervention period, with up to four Virtual Traveller sessions repeated (Class 7; Table 9-7). All repeated sessions were Maths sessions, including M2: 'Maths Marching' and M4: 'London 2012 Olympics and Beyond' which were both also the most frequently delivered sessions across all intervention classes. This repetition of sessions was also identified in pupil focus groups: "*We did the Queen Marching one* (M2: 'Maths Marching) *two times but Miss changed the times tables that we marched to*" (Class 7). These findings consistently indicate Maths Virtual Traveller sessions as being more implemented than English sessions (Table 9-7), with effectiveness findings also showing Maths sessions to be rated higher by teachers (Table 9-4).

Comparing the intervention log session ratings (Table 9-7) and teacher evaluation questionnaires (Table 9-3) provides some insight into patterns of perceptions in this small sample. For example, 100% of the eighteen Virtual Traveller sessions were implemented by teachers in Class 6 (Table 9-7), with this teacher also rating sessions as maximally easy-to-use, showing maximal interest in continuing to integrate activity into their teaching and being most positive about recommending the programme to other teachers (Table 9-3). In contrast, the teacher of Class 7 who implemented the lowest number of Virtual Traveller sessions (38.88%; Table 9-7) perceived themselves as the least likely to continue integrating physical activity into their teaching (3/5 at both time-points; Table 9-3).

9.3.4.1.2 Teacher interviews

Reasons for implementation rates were assessed further via teacher interviews. Various facilitators that helped aid implementation were described by teachers. Importantly, all teachers described the PowerPoint sessions as easy to use: "*You just click and go which saves a lot of time.. no fiddling with the internet or anything*" (Class 5). As per the Technology Acceptance Model (Section 5.2.3), this is an important facilitator for prolonged technological use. Some teachers described appreciating the flexibility of where Virtual Traveller sessions could be run: "*I liked that the sessions were quick and ready-to-go.. they were flexible as well so good to pop in as a plenary if the kids are flagging a bit*" (Class 10). Teachers also described strategies that helped aid implementation rates. For example, the teacher of Class 6 who had 100% implementation rate (Table 9-7) described how "*I sometimes split the class into two,* *just left and right (of the class) or girls and boys to get some competition going… they put a lot more energy in and it just changed the dynamics around a bit*". As found in feasibility qualitative work (Section 5.3.5.1.3), the use of ad hoc competition between pupils seemed to encourage extra activity and variety in the intervention. Teachers also described using the sessions as a reward for good behaviour: "*I used them a few times as rewards in class.. like they worked really well in an English lesson so we did an English one as a treat so they can let off some steam*" (Class 10). Teachers also praised the Virtual Traveller intervention for its quick set up time: "*It takes two seconds to start one of these, just tuck chairs in and off you go!*" (Class 5). They also appreciated the ability to integrate activity within the physical constraints of classrooms: "*I've really enjoyed getting pupils moving in the classroom... we've done outside lessons before but they take so much time to plan and organise. These give us study breaks and time to stand without any extra planning which is great*" (Class 7).

Reasons for repeated sessions by some teachers (Table 9-7) were explored with teacher interviews. For example, some teachers described how they repeated sessions to recap content: "*We did the metric unit one* (M5: Metric Movements) *before and after we covered that content.. the questions were the same but the gap was long enough for them to have forgotten the answers!*" (Class 7) and *"I used a couple for revision and did the same Maths one before and after"* (Class 5). Others described how some sessions were adapted and repeated to meet class objectives: "*I ran the marching one* (M2: Maths Marching) *a few times with different times tables*" (Class 10).

Barriers to implementing the Virtual Traveller intervention as intended were also discussed in teacher interviews. Firstly, some teachers described not running specific sessions as they did not match with currently taught curriculum content: "*There was one on persuasive writing* (E7: Persuasive Writing) *but we did that last term so I didn't want to backtrack and cover it again*" (Class 5). Evidently although the intervention was developed with teacher support tailored around Year 4 teaching objectives (Section 6.4.5), this still did not guarantee that these objectives would be taught at the same time as the associated VFT session. Secondly, some teachers described the Maths sessions to enable physical activity in a more intuitive way than English sessions "*I felt like the activity links in the English ones were more tenuous.. the Maths ones with counting and numbers seemed to make a lot more sense*"

(Class 5) . These findings align with previous physically active lesson interventions which predominantly feature Maths content (Section 4.5.4).

Thirdly, various barriers were identified surrounding the use of technology in the intervention. Some teachers commented that although the PowerPoint sessions were easy to use, they were somewhat inconvenient for practical reasons: "*You* (the teacher) *have to stay quite close to the computer to move the presentation along if you don't have a clicker.. it kind of limits you to how active you can be*" (Class 7). As seen in feasibility qualitative work (Section 5.3.5.1.2), one teacher commented that the success of the intervention would depend on the teachers' technological confidence: "*It was fine for me but I can think of colleagues who wouldn't want to use their whiteboard even for these easy sessions*" (Class 10). As also previously seen (Section 5.3.5.1.2), some teachers commented that they'd prefer to have more freedom in integrating activity without necessarily using technology. For example, "*It's great to have that active time ready and prepared.. but equally it would be nice to do things like this outside more without their eyes on the screen*" (Class 7). Also, some teachers commented that a session that ran quite poorly had put them off running other Virtual Traveller sessions: "*One English one went really badly.. the sound wasn't working and the kids were restless.. it put me off running another one for a while*" (Class 7). This highlights how experiences implementing such novel programmes must be successful to maximise teacher implementation.

9.3.4.2 Time required to deliver intervention

As described in the Study 2 protocol (Section 6.4.5), Virtual Traveller sessions were designed to be 10 minutes in length. Teacher interviews and pupil focus groups provided insight into the suitability of this intended session length and how long sessions were actually run for. Some pupils described how their overt reactions to a session altered the teacher's choice of session length: "*Some days we were tired and didn't want to stand up and so our teacher stopped it early*" (Class 7). This ad hoc adjustment to session delivery was also reported by some teachers: "*You can tell some days that they're just not ready for it, so I'd either move it to another day or just run a shorter version and cut bits out*" (Class 10). Conversely, one teacher reported extending Virtual Traveller sessions based on pupil reactions: "*The marching one* (M2: Maths Marching) *they really enjoyed so I replayed some of the slides but* *used different times tables*" (Class 7). Overall it seems that the 10 minute length of sessions was appropriate, with no teachers asking for longer or shorter sessions.

9.3.5 Maintenance

As shown in Chapters 7 & 8, there was no effect of the Virtual Traveller programme on physical activity and student engagement outcomes at three month follow-up. Maintenance of the Virtual Traveller intervention beyond the six-week intervention period was assessed to measure any prolonged usage. Individual-level maintenance (399) was assessed by analysing the impact of pupil attrition on outcomes, comparing outcomes in pupils who remained in the study throughout with those who did not. Class-level maintenance was assessed by teacher reports of continued or modified intervention use beyond the intervention periods from teacher interviews.

9.3.5.1 Impact of attrition on outcomes

No schools were lost to follow-up during Study Two. Of participants in the analytic sample, 72% (n=157/219) were 'remainers': providing study data all time-points, 11% (n=23/219) were lost to attrition and 18% (n=39/219) were 'returners': providing data intermittently during the study (Section 7.2). Although there were no demographic differences between those who were lost to attrition and who remained (Section 7.2), it is important to assess if there are any effects of attrition on outcome measures. The outcomes observed in 'remainers' and those lost to attrition were hence compared to understand any potential effect of attrition. One-way ANOVAs with post-hoc Bonferroni analysis found that at T0 (baseline), 'remainers' demonstrated significantly higher average school day accelerometer-assessed SB than those later lost to follow-up (655.55 minutes (SD=38.22) vs 634.55 minutes (SD=35.72); $F(202)=3.60$, $p<0.05$). There were no significant differences in any other outcomes at any other time-point. This suggests that there was unlikely to be any effect of attrition on outcomes during the Virtual Traveller study.

9.3.5.2 Continuation or modification of intervention beyond intervention period

Teacher interviews identified that no teachers had continued to use Virtual Traveller sessions beyond the intervention period. Reasons for this lack of continuation firstly included wanting to use sessions in subsequent years: "*I've taught these enough with these pupils but I will teach them with the next lot next year*" (Class 5). One teacher also reported not continuing to run sessions to prevent confusing the research findings: "*I thought it would be best for your research if we went back to normal so you could compare better*". This identifies a potential flaw in researcher-teacher communication, as continued use could have been adjusted for in analysis. All teachers commented that although they were not using Virtual Traveller at the moment, the intervention had made them consider integrating physical activity into their teaching more in the future. For example, "*I definitely noticed an improvement in their behaviour and happiness in class.. I wouldn't necessarily use this programme again because of the whiteboard-use, but I will definitely plan more activity into my planning for next year*" (Class 7). Hence although the Virtual Traveller sessions were not used beyond the intervention period, they do seem to be associated with increased intentions to teach in more active ways.

9.4 Discussion

This chapter presented a process evaluation of Study Two's Virtual Traveller intervention to understand how the intervention was delivered and identify teacher and pupil experiences. Mixed methods were used, with quantitative teacher record logs and teacher and pupil evaluation questionnaires used alongside qualitative teacher interviews and pupil focus groups (Section 6.4.9.5) These findings were assessed and presented according to the RE-AIM framework criteria of Reach, Efficacy, Adoption, Implementation and Maintenance (399, 569). Findings from these criteria are hereby collated to discuss elements that worked well in this iteration of the intervention and elements that could be improved for future iterations. This chapter hence addressed thesis question 7) to what extent will a physically active Virtual Field Trips intervention be implemented in primary-school teaching? (Chapter 3) and study question 4) what is the fidelity of a longitudinal physically active Virtual Field Trips intervention? (Section 6.1.1).

9.4.1 What worked well in the Virtual Traveller intervention

9.4.1.1 High participation and low attrition rates

Reach was shown to be high in this intervention. Firstly, high participation rates were observed from schools invited to participate in the intervention. Ten out of twelve (83.3%) contacted schools agreed to participate in the study (Section 7.2.1), much higher than the median rate of 44.5% (range 12%-100%) seen in a recent review of children's physical activity interventions evaluated using the RE-AIM framework (443). This suggests that the information supplied to schools during the recruitment process was of sufficient detail and interest to attract schools to participate. Secondly, high participation rates were observed in pupils, with 87% of those invited consenting. This is much higher than the median pupil participation rate of 76.7% (range 4.3%-100%) in the aforementioned review of children's physical activity interventions (443). High participation rates may also be indicative of a more targeted recruitment strategy used in Study Two. Schools were contacted via recommendations from Public Health and School Sports organisations, rather than contacting individual schools as done in the Masters pilot study (Section 6.4.3). This may have produced a biased sample as schools contacted to participate will likely have had more of a vested interest in physical activity at the outset.

Pupil attrition during the intervention was also low, with 11% of participants being lost to follow-up (Section 7.2) indicating positive Maintenance of pupils throughout the intervention. This is lower than the median rate of 14% participant attrition observed across children's physical activity interventions (443). Apart from having lower SB at T0, participants lost to follow-up were found to have outcomes not significantly different to those remaining in the study. Low observed attrition may be the result of a range of factors, including the ongoing pupil competition for accelerometer wear time (Section 6.4.3) or positive perceptions of the intervention in teachers and pupils (Section 9.3.2).

9.4.1.2 Consistently positive evaluations during intervention

Evident across all forms of Effectiveness evaluation was consistently positive perceptions of the Virtual Traveller programme. Positive quantitative ratings from both pupils (Table 9-2) and teachers (Table 9-3) measured during the intervention were shown to remain largely stable within classes over time. There were slight increases in teachers' perceived session ease-of-use in T2 than T1: a key component of the Technology Acceptance Model (451, 452) and important for prolonged technology use (Section 5.2.3). These findings suggest that repeated exposure to sessions with relatively similar physical appearance remains appealing over the course of a 6-week intervention. This seems to contradict teacher concerns in Study One (Section 5.3.5.1.2) of a potential limited novelty factor for the intervention. It seems from this evaluation that Virtual Traveller may be implemented with repeated exposures of at least 6-weeks without the formation of negative user perceptions.

9.4.1.3 Examples of highly rated Virtual Traveller sessions

Evaluation of the intervention against Effectiveness and Implementation criteria highlighted some sessions to be particularly well received by teachers and pupils. For example, 'M2: Maths Marching' which required classes to complete physical activities while reciting times tables, was rated an average of 4.4/5 on teacher log sheets and also described with enthusiasm in qualitative work. Teachers interviews also found that some sessions were repeated during the intervention, due to their positive reception by pupils and to allow content to be revised (Section 9.3.2.1.2). Teachers also described sessions as best received when featured content was relevant to current teaching. Virtual Traveller was developed with support from Year 4 teachers to ensure content was as relevant as possible (Section 6.4.5). However this could not guarantee that teaching at the time of the 6-week intervention was all relevant to Virtual Traveller content. Although core abilities such as times tables (e.g 'M2: Maths Marching') and punctuation (e.g 'E1: Kung Fu Punctuation 1') were described to be regularly revisited, more specific content such as monetary values (e.g 'M8: Money, Money, Money') and persuasive writing (e.g 'E7: Persuasive Writing') were of less interest to teachers beyond their allocated teaching periods. Virtual Traveller sessions were hence best received by teachers when content was aligned with current teaching objectives.

9.4.1.4 Potential as a low-cost intervention

As part of assessment for the Adoption criterion, costing analysis found promising implications for real-world implementation of the Virtual Traveller intervention (Section 9.3.3.2). With the majority of UK classrooms already having interactive whiteboards (336), the initial costs of equipment purchasing can be avoided. The familiar PowerPoint basis of sessions means that little training will be required and sessions could potentially be provided for free using existing teaching resource websites (510). By promoting the positive lesson time physical activity and on-task behaviour effects observed in this thesis (Chapters 7 & 8) and minimal preparation time, this extremely low-cost intervention should have both outcome-related and financial appeal to schools and Year 4 teachers in particular.

9.4.2 What could be improved in the Virtual Traveller intervention

9.4.2.1 Suitability of English sessions

Assessment of intervention Effectiveness found that English sessions were commonly rated less positively than Maths sessions across evaluation methods (Section 9.3.2). Teacher log ratings showed less positive perceptions of English sessions, with English sessions also being implemented less often. Teacher interviews described physical activity prompts in English sessions as more tenuous; whereas movement in Maths were viewed to align more naturally to concepts of number, such as moving a number of times to answer a numerical question. As identified in the systematic review (Section 4.5.4) (3), physically active lessons to date have most commonly implemented in Maths with reasons for this subject choice not explicitly reported. English and Maths were chosen as the basis for the Virtual Traveller intervention as these subjects represent the greatest proportion of primary school teaching time (508) (Section 5.4.2). Teacher interviews in Study One reported great potential for VFT use across curriculum subjects (Section 5.3.5.1.3) (4), however it is apparent here that English may not be as immediately suitable to VFT use. More work is needed to better integrate activity into English sessions before Virtual Traveller is more widely distributed.

9.4.2.2 Fixed technological format of sessions

Although teacher evaluations were largely positive, analysis of interviews for the Adoption criterion revealed that the enforced technological provision of Virtual Traveller sessions could be problematic. Firstly and as noted in Study 1 (Section 5.3.5.1.3) (4), some teachers thought that peers less confident in technology may not choose to implement these sessions or may require additional training. As seen in the Technology Acceptance Model (451, 452) (Section 5.2.3), perceptions of ease-of-use and usefulness are key in predicting prolonged use of technologies, such as classroom technologies in this case. Intervention teachers in Study Two were generally newer to teaching than control teachers (Section 7.2.3), and would hence have more likely had classroom interactive technologies introduced as part of their Initial Teacher Training. This may have produced a biased sample of evaluations, whereby intervention teachers may have rated sessions as more easy-to-use or more enjoyable than teachers with less technological experience. However, it must be noted that existing use of classroom technologies was not assessed in this study. Secondly, some teachers felt limited by the technological basis of the intervention, describing a desire to combine Virtual Traveller sessions with non-technological or outdoor-based activities (Section 9.3.4.1.2). A greater variety of sessions beyond PowerPoint alone could appeal to a greater range of teachers and maintain interest in the intervention if extended beyond the 6-week implementation of Study Two.

9.4.3 Strengths and weaknesses of process evaluation

A major strength of this process evaluation is its use of mixed methods (464), featuring quantitative teacher logs and teacher and pupil questionnaires as well as qualitative teacher interviews and pupil focus groups. As shown in the physically active lesson systematic review (3, 450), the use of in-depth qualitative user evaluation of such interventions is currently rare (325, 373, 374, 383) (Section 4.5.6). This range of evaluation from key stakeholders enabled analysis of intervention experiences, as well as providing ideas for potential improvements.

A weakness of this process evaluation is its focus on stakeholders receiving a particular physically active lesson intervention in a particular geographical location of Greater London. This means there is limited potential to extrapolate findings from this context to other school-based interventions elsewhere. Also, there was a lack of teacher training evaluation (621), providing no insight into whether the objectives of the intervention were understood. Another weakness is a potential researcher-participant relationship effect present in pupil evaluations. The repeated measures design of this study necessitated that the lead researcher met all participating classes on many occasions, for data collection, consent and debriefing. Although pupil anonymity was maintained throughout the intervention, these repeated sessions may have led to the development of a researcher-participant relationship (466). This relationship may be indicated in overly positive pupil evaluation questionnaires and focus groups. For example, teachers reported greater exertion in their pupils than pupils self-reported themselves (Section 9.3.2.2), with such discrepancies similarly shown in other school-based physical activity work with similar repeated measures designs (488). Although pupils may have demonstrated exertion to teachers during the intervention itself, they may not have wished to describe this to the researcher in order to please them (466). Another weakness is the evaluation's large reliance on teacher self-report for implementation measures. Although the provided teacher log was completed by all teachers, it is unclear to what extent it was completed correctly. For example, although pupils from one class reported the teacher to cut some sessions short (Section 9.3.4.1) it is unclear if this is reflected in teachers' log records. The teacher may have marked the session as completed, although all content was not delivered. Additionally, there may have been unmeasured factors influencing intervention processes and outcomes, such as the degree of activity in non-participating pupils (443).

9.5 Conclusion

This process evaluation of the Virtual Traveller study assessed how the intervention was delivered and perceived by teachers and pupils. Results were analysed and presented according to the RE-AIM framework criteria of Reach, Effectiveness, Adoption, Implementation and Maintenance (399). Quantitative evaluation questionnaires and teacher log sheets were combined with qualitative teacher interviews and pupil focus groups to enable deeper assessment of the underlying processes of intervention implementation. Evaluation work identified various strengths of Virtual Traveller provision, including high participation and low attrition rates, examples of highly rated sessions and its potential as a low-cost intervention. Potential intervention improvements were also highlighted, with revisions needed to make English session physical activity links more relevant and potential for a broader range of sessions beyond technology-based activities.

Chapter 10 Discussion

This thesis has presented the development, testing and evaluation of Virtual Field Trips as physically active lessons for children. This chapter summarises the empirical findings described in this thesis, its contribution to the wider literature and its implications for public health and education. Recommendations for physical activity and educational policy are provided: both in terms of how existing policies could be improved and how new policies could be introduced. Reflections on working on this multidisciplinary PhD are discussed, leading to a critique of the thesis as a whole. Finally, ideas for future research building on the findings of this thesis are described.

10.1 Summary of findings

This thesis took a novel approach to integrate physical activity into teaching practice using readily available interactive whiteboards and PowerPoint software. The literature review (Chapter 2) is comprehensive in its consideration of research across epidemiological, public health, information science and educational backgrounds. Of particular note is the increasing body of evidence linking physical activity to increased educational and cognitive outcomes in children (Section 2.3.4.2) and subsequent research interest in pedagogic movement integration (Section 2.8). A discussion of the ubiquity of interactive whiteboards as classroom technologies suggested them as readily-available potential facilitators for active learning (Section 2.9.1). Virtual Field Trips (VFTs) were proposed as a teaching tool to potentially integrate physical activity into primary school lessons using interactive whiteboard facilities (Section 2.9). This synthesis of multidisciplinary literatures proposed VFTs as a novel intervention with potential to improve both physical activity and educational outcomes.

The remaining review and empirical chapters of this thesis charted the iterative development and evaluation of Virtual Field Trips as physically active lessons. The systematic review organised the related and burgeoning area of physically active lesson research (Chapter 4), providing a clear picture of methods used and results found. Notably, the number of identified studies increased from eleven in the first iteration of the review in Spring 2014 (3) to twenty eight in Spring 2016. The published review was cited in recent Public Health

England guidance (234), recommending movement integration as a target area for school-based physical activity interventions. The relatively low quality of most identified papers (Section 4.5.12) and non-diverse, poorly described samples (436) provided a range of improvement areas for following VFT work (Section 4.7). Previous Masters pilot VFT work (2, 450) also provided ideas for practical improvements in technology use and physical activity measurement (Chapter 5A).

Chapter 5 presented a qualitative extension (4) of feasibility work previously done for the Masters thesis (2, 450) (Chapter 5B). Teacher interviews and pupil focus groups provided perceptions of using a sample VFT session. Physically active lessons generally were described as memorable learning experiences by both teachers and pupils; however the frequency of such sessions varied. The potential of VFTs as a flexible and inclusive teaching tool was praised. However, teachers highlighted a potential novelty effect in running sessions over time and stressed that sessions must be pre-prepared to minimise time concerns (Section 5.3.5.1.2). They also warned that other teachers may be resistant to using interactive whiteboards to facilitate activity.

Chapter 5 also charted the action of improvements for Study Two, generated from ideas of Study One, Chapter 4 and previous pilot work (Chapter 5C). Firstly, theory was applied to VFT intervention work via the popular COM-B model (282), with intervention and training components explicitly described using the Behaviour Change Techniques Taxonomy (495). These additions aimed to allow replication of the resulting VFT intervention. Secondly, software problems during feasibility testing alongside 3D functionality changes by Google led to iterative reformulation of VFTs from Google Earth to Google Tour Builder, to PowerPoint sessions with embedded Google Earth pictures and video (Section 5.4.3). Additionally, low accelerometer-assessed activity levels during VFTs in the Masters pilot study (2, 450) were addressed in two ways. A review of the child accelerometer literature found no published cut-points had been calibrated specifically for on-the-spot movements. This means that accelerometer-assessed research such as VFTs and Active Video Games (256) are not using cut-points calibrated for the types of actions being measured (further discussed in Section 10.3). Pulsford cut-points (536) were identified from this review as being sufficiently validated and having slightly lower sedentary cut-offs to facilitate more accurate sedentary behaviour assessment (Section 5.4.4). To combat potential issues with not using on-the-spot calibrated cut-points, the triangulation of accelerometers with other activity measurement tools was also considered. The Children's Activity Rating Scale (CARS) (31) observation tool was selected for its strong validation, low manpower and cost (Section 5.4.5). Additional improvements included featuring a measurement of perceived exertion within process evaluation and ensuring VFT content was specifically relevant to curriculum content and developed with teachers.

Chapter 6 went on to apply these improvements in a detailed protocol for Study Two: a six-week pilot randomised controlled trial VFT intervention called 'Virtual Traveller' (1). The physical activity results from this trial were reported in Chapter 7. The intervention was shown to produce no changes to overall, school or weekend day activity at any intensity. However, lesson time physical activity was found by accelerometer measurements and CARS observations to be significantly higher in intervention pupils during Virtual Traveller sessions. Levels of light intensity activity were more than doubled in intervention lessons compared to control sessions (Section 7.6), although the majority of time was still recorded as sedentary by accelerometry. No differences in Virtual Traveller session activity was seen by sex, although there was some suggestion of less MVPA in ethnic minority pupils. These positive lesson time effects were not seen at three month follow-up, suggesting the need for prolonged VFT provision for sustained increases to lesson time activity. The absence of effects beyond the classroom may be related to intervention dose. 10-minute sessions three times a week may not have produced sufficient extra activity to equate to greater activity across overall days (Section 10.7). VFTs or other forms of physically active teaching may need to be provided more regularly across the school day or week to have meaningful effects on children's overall activity levels.

Chapter 8 reported the effects of Virtual Traveller on educational outcomes. On-task behaviour was significantly improved during intervention sessions, as observed with the Observing Pupils and Teachers in the Classroom (OPTIC) (593) tool. No prolonged effects were seen in follow-up assessments. No aspects of student engagement were found to be significantly changed by the intervention, as assessed with the Student Engagement Instrument – Elementary version (SEI-E) (583) questionnaire. These findings collectively suggest that physical activity can be integrated into teaching via VFTs with positive effects on on-task behaviour and without detriment to student engagement. Further research could assess if other educational outcomes such as academic achievement can also be improved with the provision of active VFTs (Section 10.7)

Finally, Chapter 9 reported mixed method process evaluation findings collected during Study 2. The selection and reporting of evaluation elements was framed around the RE-AIM framework criteria of Reach, Efficacy, Adoption, Implementation and Maintenance (399). In summary, high participation and low attrition rates were found throughout the study. 70% of Virtual Traveller sessions were reported as delivered by teachers. Consistently positive evaluations were given by teachers and pupils, showing no evidence for decreased enjoyment during the intervention. Virtual Traveller was also shown to be a very low-cost intervention for classes possessing interactive whiteboards in real-world settings (Section 9.3.3.2). Teacher ratings identified that the content of English VFT sessions could be improved. Also as seen in Study 1, some teachers queried the use of technology to improve children's physical activity (Section 9.3.4.1.2). Despite maximum efforts to ensure content was as relevant and easy-to-use as possible, it appears that the use of classroom technologies will not be acceptable to all teachers. This will likely limit the acceptability and use of VFTs in real-world settings.

This thesis has shown that Virtual Field Trips can be used to integrate physical activity and improve on-task behaviour in primary school teaching. Although the effects of VFTs on lesson time physical activity were statistically significant, they were too small to have any evident effects on children's overall activity levels. No detriment to student engagement outcomes suggests that VFTs as physically active lessons can be added to teaching schedules without negative educational effects. Strong evaluations were seen for the Virtual Traveller intervention, showing maintained interest and implementation throughout the six-week programme. However, the potential for VFTs in real-world applications may be limited by some teachers' acceptability of classroom technology. How these findings can be used to inform practice in public health and education, as well as policy implications, are discussed in Sections 10.3 and 10.4 respectively. However the limitations presented in the discussion section of each chapter and the overall thesis (Section 10.6.2) should be appraised when considering any future research or policy recommendations arising from this research.

10.2 Contributions to the literature

This thesis has added new publications and insight into physically active lesson research, as well as school-based physical activity interventions more generally. Firstly, the systematic review of physically active lessons provided the first synthesis of methods and findings in this area. In the two years since undertaking the original systematic review (3) (Appendix 4A) seventeen more studies have been identified (Chapter 4). This reflects a growing interest in the assessment of active teaching practice within academia. However, the extent to which these practices are installed in real-world teaching practice has yet to be explored (Section 10.7). Secondly, at the time of thesis write-up, the feasibility papers (2, 4) (Appendices 5A & 5C) stemming from this work are the only examples of UK physically active lesson research currently published in peer-reviewed journals. One other UK study exists (325) (Section 4.5), however this is published in grey literature as a report by the Education Endowment Foundation. Forthcoming publications from Virtual Traveller (Chapters 7-9) will add key evidence of the benefits and ease-of-implementation of physically active lessons within UK teaching practice.

Thirdly, this thesis provides an example of adapting existing classroom technologies to integrate physical activity into classroom teaching. Where other interventions have charged schools (389) or brought additional equipment into the classroom (373, 375, 389, 391) to facilitate active teaching (Section 4.5.4), the Virtual Traveller programme utilises readily available interactive whiteboards. This gives huge potential for the programme to be delivered free-of-charge (Section 9.3.3.2), limiting cost-related barriers for teachers and schools (284). Recent studies have described sessions to be provided as PowerPoint slides in a similar way to Virtual Traveller (379, 380-382) (Section 4.5.4), however they do not provide samples to show their layout or structure. For the first time in the reporting of physically active lesson interventions, publications from this thesis have provided clear examples (1), including step-by-step development (2). This allows reporting of the multimodal nature of VFTs to be as in-depth as possible, adding insight for potential users and benefitting replication. Also, the Virtual Traveller study is one of a limited number of physically active lesson interventions to consider theory (282) and report behaviour change techniques (495) in its development and reporting (1).

Additionally, Virtual Traveller is the first physically active lesson intervention to explore student engagement as an outcome (Chapter 8). This involved the use of the Student Engagement Instrument – Elementary Version (SEI-E) for the first time in a UK sample. Although none of the SEI-E sub-scales were found to be effected by the intervention, its assessment provided exploration of educational outcomes beyond those previously used in the field (Section 4.5.11). Finally, the publication of feasibility work (2, 4) and protocol papers (1) in open access journals is intended to allow as maximal awareness and replication of this thesis' work as possible. Most other physically active lesson research is published in subscription journals (376, 379, 382), preventing access from target users of teachers and schools. It is intended that Virtual Traveller outcome and process evaluation findings (Chapters 7-9) will be published in open access formats to continue this accessibility.

This intervention is in no way a standalone fix to increase child physical activity levels: arguably no intervention can be. This body of work does show that lesson time activity can be statistically significantly improved with the use of physically active VFTs. However, these changes are small and may be due to chance or a potential Hawthorne effect from accelerometer measurement. This research also show that key educational outcomes can be improved (on-task behaviour) or maintained (student engagement) with VFT provision.

10.3 Public health and educational implications

This thesis has implications for public health and educational practice in England, which may also be applicable in other countries. In terms of public health implications, Chapter 4 has shown consistent benefits of physically active lessons to significantly improve activity levels. However, this evidence is largely based on school-time activity measurement only and relatively weak study designs. Although physically active lessons have recently been recommended by the government (235) and Public Health England (234), it is clear from this review that some caution should be given to these early findings. A lack of evident theoretical considerations was also identified in Chapter 4, with the exact features and 'active ingredients' (489) of interventions often unclear. Chapter 5 hence explicitly linked the VFT intervention to the well-established COM-B model of behaviour change (282): describing how VFTs address teachers' and pupil's Capability, Opportunity and Motivation to be active in the classroom and improve overall Behaviour. Additionally, the explicit identification of both training and intervention components as specific techniques via the Behaviour Change

Technique Taxonomy (BCTT; Section 5.4.1) (495) is intended to aid replicability and understanding of the Virtual Traveller intervention (1). There is a huge drive towards increasing replicability of public health interventions through methods such as BCTT (279), to maximise the usefulness of effective programmes and prevent duplication. Only one other physically active lesson study has reported their intervention in such a way to date (374) (Section 4.5.4). Given that physically active lessons would be implemented by teachers in the real-world, it is important that these novel interventions are well described to facilitate replication.

Feasibility work of Chapter 5 and the Masters pilot study found a lack of existing calibrated accelerometer cut-points for on-the-spot activities such as VFTs. The Masters pilot found existing cut-points to record VFT activity as more sedentary compared to that informally observed by the researcher (2) (Section 5.4.4). Although many studies have used accelerometers alone to assess such non-ambulatory movements including Active Video Games (256), this work indicates that this may not be sufficient to accurately capture activity estimates. Subsequent triangulation of accelerometer cut-points with validated observational measures (Section 7.6) provided a more accurate estimation of VFT activity given available resources.

Chapter 7 has shown that although VFTs may improve in-class activity, they do not have such effects beyond the classroom. Unlike the majority of other similar interventions, Study Two assessed full school and weekend day activity, not restricted to school hours only (Section 4.5.9.1). Public health guidance should clarify that the evidence for physically active lessons to increase evidence beyond the classroom is still relatively unclear. Additionally, the potential varying associations between demographics and lesson time physical activity seen in multilevel modelling should be noted. No significant differences were seen in lesson time activity by sex (Section 7.6), suggesting that Virtual Traveller may be as effective for both boys and girls. As girls are consistently less active than boys (Section 2.3.3); VFTs may be a useful intervention to provide relatively equal activity benefits across sexes. However, differing effects were seen in multilevel modelling for lesson time activity by ethnicity, with white pupils demonstrating more MVPA and CARS-assessed activity than non-white pupils (Section 7.6). With limited previous research suggesting ethnic minority children to be less active (Section 2.3.3), this suggests that Virtual Traveller may not be as effective for ethnic groups who may be at need of targeted activity interventions.

Educational implications can also be seen in this thesis. Chapter 4 showed that the building evidence for physically active lesson interventions shows consistent improvement or at least no change to educational outcomes, such as on-task behaviour and assessment scores (Section 4.5.11). This has extremely important implications for educational practice. With ever-increasing academic targets leading to active break times being replaced by additional lesson time (84, 85) (Section 2.3.3.1), this collective work suggests that the addition of physical activity in taught content is not detrimental to reaching these key outcomes. The systematic review also identified a wide range of movement integration approaches across curriculum topics and age-groups (Section 4.5.4), providing a broad range of potential ideas for physically active lessons. Qualitative findings in Chapter 5 showed a readiness to incorporate physical activity into teaching. Pupils and teachers alike reflected on memorable and successful experiences of physically active teaching, with a common desire for more active lessons (Section 5.3.5). These findings show a real appetite for active learning, although actual practice was reported as inhibited by time restrictions and reaching academic targets (4, 284). In the same light as the systematic review, Chapter 8 found VFTs to either improve (on-task behaviour) or not be detrimental (student engagement) to educational outcomes. This provides further evidence for physically active lessons as effective health and educational tools.

Chapter 9 showed that VFTs were well implemented and rated by teachers, reflecting iterative development of the intervention with teacher support. This highlights that educational and public health interventions should strive to be driven by teacher ideas and recommendations. Without teacher support and input, it is unlikely that educational elements will be perceived as relevant. The most commonly recorded barrier to physically active interventions is a lack of teacher time (4, 284) (Section 2.7.3), however this evaluation work found that Virtual Traveller's provision as a ready-made programme did not incur additional preparation time. Chapter 9 also showed Virtual Traveller as an intervention with little-to-no cost for schools. Unlike other subscription active lesson interventions such as 'Take 10!' (295) and 'EduMove' (299) (Section 2.8), Virtual Traveller is free, curriculum-focused and evidence-based with clear public health and educational effectiveness.

Additionally, the innovative use of interactive whiteboards to initiate activity during this work shows that school's investment in such technology can have multi-faceted benefits: addressing both educational and activity outcomes for their pupils.

10.4 Policy recommendations

Increasing children's physical activity is of public health and educational importance. The evidence in this thesis has shown the potential for VFTs and other physically active lessons as effective interventions to increase children's lesson time activity levels. Existing school-specific policy has been largely focused on sport provision. For example, the Primary PE and Sport Premium was established to devote an extra £150 million per year into school sports funding until 2020 (231) (Section 2.6). The recent government outline for childhood obesity policy has outlined that funds generated from the upcoming 'Soft Drinks Industry Levy' will be pledged to supplement this premium from 2018 (235). However, the evident current low levels of PA within PE and children's general day-to-day living (Section 2.3.3) show these techniques alone are insufficient. Other non-sport strategies are also needed to ensure the broadest range of pupils enjoy and maintain a physically active lifestyle (85). Recent recommendations from the National Institute for Health and Care Excellence (233) and Public Health England (234) have accordingly argued for comprehensive and varied school physical activity strategies. The new childhood obesity policy has also identified physically active lessons as an effective method to integrate activity (235) and help meet the recommended daily sixty minutes of activity (17). There is hence a growing policy movement towards more inclusive activity promotion, incorporating the growing movement integration literature contributed to and seen in this thesis (2, 3).

The new childhood obesity policy has outlined that Office for Standards in Education, Children's Services and Skills (OFSTED) inspections will assess schools for physical activity opportunities from September 2017 (235) showing a need for schools to address activity provision in a relatively short time. This additional facet of scrutiny now gives extra incentive for teachers and schools to integrate physically active teaching across their curriculum. The findings of this thesis and wider physically active lesson research could provide suggestions for schools to address this new physical activity OFSTED component. Continuing Professional Development courses must be developed to train existing teachers on the fundamentals of physically active learning, as well as overall benefits of physical activity for child health and learning. Initial Teacher Training should also teach the benefits and practical considerations of movement integration as standard, showing new teachers that active learning can easily be part of typical teaching.

10.5 Reflections on multi-disciplinary nature of thesis

This thesis was funded by UCL Crucible: a funding scheme designed to promote multi-disciplinary doctoral scholarship. With a growing interest in multidisciplinary research by funding bodies such as the Economic Social Research Council (622) and the Medical Research Council (623), there is a clear wider trend towards multidisciplinary working to address complex problems such as childhood physical inactivity. Following the definition of multidisciplinary as 'drawing on knowledge from different disciplines' (624), this project hence synthesised knowledge from different backgrounds to address the complex problem of child inactivity. As a PhD student with a primary background in health psychology, this involved me familiarising myself with the backgrounds of my four respective supervisors. In practice, this firstly led me to examine epidemiological research to understand the health impacts and measurements of physical activity and sedentary behaviour (e.g Chapter 2). Public health and health psychology fields informed the steps I took to develop and report the VFT intervention (e.g Chapters 5-9). Educational psychology texts informed my understanding of relevant educational outcomes to explore and how best to carry out school-based research (e.g Chapters 5-9). Finally, literatures from information studies and wider human computer interaction fields enforced the need for both simple VFT technology and iterative session development (e.g Chapter 5). These approaches and literatures were combined with an over-arching mixed methods approach to the project: ensuring that the concerns of teachers and pupils as target users were accounted for at all stages of intervention development and evaluation.

Some practical issues emerged when negotiating this multidisciplinary work. Firstly although creative, the use of technology for the Virtual Traveller intervention generated some difficulties. Early VFT iterations did not consistently display on different computers within- or between-schools (Section 5.4.3), highlighting issues with school firewalls and privacy settings. Also, although the use of Google Earth-affiliated programmes allowed higher-quality sessions with less effort, this meant the project was at the mercy of Google's adjustments. As shown during intervention development, this led to the need for all sessions to be redeveloped at short notice after Google removed 3D functionality from their beta Google Tour Builder website (Section 5.4.4.2). Additionally, a minority of teachers voiced concern over a potentially circular argument: using technology to address an issue (inactivity) caused in part by technology itself (Section 5.3.5.1.2). These challenges would have been avoided if a non-technological approach was used. Secondly and as discussed in various reflective papers (624, 625), there were also some minor difficulties in negotiating the direction of this multidisciplinary work. The PhD involved negotiating supervisors' different views on methods to use and how to best report findings based on their backgrounds. Also, synthesising and summarising the wide range of literature read for the basis of the thesis was challenging.

Understandably the various components of this PhD made for an interesting yet difficult project. I am proud that leading work supported by my varied supervisory panel has produced a high-quality and well-received intervention, which has real scope to be integrated into teaching very easily and cheaply. As also reported by teachers themselves in process evaluation work, I believe that the Virtual Traveller intervention helps teachers utilise their interactive whiteboards to educate and facilitate activity in an effective and novel way.

Arguably, numerous alternative intervention ideas could have arisen if children's inactivity during lesson time was addressed by lone disciplines. For example, addressing the issue from a purely information science or technological perspective would likely have involved focus towards more complex utilisation of interactive whiteboard technology or peripheral equipment. It was clear from feasibility work that such complicated technology would likely not work given school internet and security restrictions (Section 5.4.3) and would unlikely be acceptable by teachers. Given teachers' already busy workload; it was important to ensure the resulting intervention used software that was as familiar to them as possible. I am pleased with the innovative use of PowerPoint with embedded Google Earth pictures and videos for this purpose. Past physically active lesson interventions were developed from largely single discipline teams, largely in public health departments (Chapter 4). They did not attempt to utilise existing facilities such as interactive whiteboards, providing an additional range of resources to add to teachers' workloads. I believe that the creative use of existing classroom technologies to address the complex problem of lesson inactivity would not have been imagined without the multidisciplinary background of this project.

10.6 Strengths and limitations of this thesis

Although strengths and weaknesses have already been presented for each empirical chapter, it is important to fully assess the strengths and weaknesses of the thesis as a whole. This critical evaluation will have important implications for both future physically active lesson research and real-world teaching practice.

10.6.1 Strengths

A strength of this thesis is its multidisciplinary grounding. Combining the literatures and supervisor expertise across epidemiology, public health, educational psychology, geography and information science has provided development of a truly novel, feasible and effective intervention. There is currently a drive by academic funding sources (622, 623) and evaluation bodies towards multidisciplinary collaboration, to maximise the potential of research funds and pool expertise. For example, over 80% of impact case studies submitted by universities as high-impact research to the Research Excellence Framework (REF) assessment in 2014 were multidisciplinary in nature (626). The support from supervisors within this UCL Crucible multidisciplinary PhD funding has arguably led to development of an inventive intervention that would not be possible with thought from one field alone.

Another strength is the use of mixed methods feasibility work in intervention development (Chapter 5) (2, 4), adhering to the MRC framework for the evaluation of complex behavioural interventions (279). This allowed both first-hand trialling of experimental software in the target population, as well as providing qualitative opinions from teachers and pupils to influence iterative development of VFT sessions. This feasibility work also provided links with teachers who supported development of the Virtual Traveller intervention. As identified in Chapter 4, previously there has been very little teacher involvement in physically active lesson interventions. Given that these interventions are fundamentally designed to integrate academic content, it seems highly counter-intuitive for researchers to ignore teachers as experts in curriculum content and provision. With this support, it was ensured that the Virtual Traveller curriculum was optimally suited to the current Maths and English National Curriculum for Year 4 pupils.

The development of a novel intervention specifically utilising existing classroom equipment is another strength of this thesis. Virtual Traveller's adaptation of ubiquitous interactive whiteboards (336) and PowerPoint software means that the intervention has potential to be distributed with minimal cost. With ever-tightening budget constraints for UK schools, schools have to carefully allocate funds for health and educational programmes (627). Compared to more expensive interventions such as standing desks (266) and facilitator-supported programmes (110), Virtual Traveller has scope to be made freely available online via existing resource websites (510). It could alternatively be further developed into a larger commercial package and brand, still costing relatively little.

Other strengths of this research include using an easy-to-implement and cheap pupil competition (Section 6.4.3) to produce relatively high accelerometer wear time and adherence during the Virtual Traveller intervention. Also, the publication of the Virtual Traveller protocol (Chapter 6; Appendix 6A) (1) which provides full details on the interventions' content and design will hopefully facilitate replication in both researchers and education professionals. Finally and importantly, the Virtual Traveller intervention featured a diverse population with high levels of participants of ethnic minorities and from families experiencing poverty. This is in great contrast to the majority of physically active lesson research which tends to recruit white and relatively privileged populations (436). The observed positive effects of the Virtual Traveller on lesson time physical activity and on-task behaviour show great potential for the benefits of physically active lessons in diverse primary school populations.

10.6.2 Limitations

Blinding of participating pupils and teachers was not possible during Study Two. The purpose of the intervention had to be described to schools during recruitment, with intervention teachers also trained to make them aware of the interventions' content. Pupils were also aware of their allocated intervention due to the inherent difference of VFT sessions. This impossibility of blinding has been noted in wider school-based physical activity research (256, 274) (Section 2.7.2) and physically active lesson research (Section 4.5.12) (3). Also, there would ideally have been simultaneous data collection in all participating classes during Study Two. This would have minimised bias associated with weather, school exam periods or special occasion days (such as Christmas or sports days) (435). However it was not possible for the researcher to organise this given the resources available.

Methods of recruitment used in this thesis could be criticised. Convenience sampling was used to recruit teachers in Study One, with pre-existing relationships between interviewer and interviewee present in some interviews (Section 5.3.4). This existing personal connection may have led participants to withhold negative feelings about the presented sample VFT (481) and may hence have limited following revisions to the intervention. Study Two featured recruitment via school sports and Personal, Social and Health Education (PSHE) networks, who contacted schools they believed may be interested in the Virtual Traveller programme (Section 6.4.3). This may have produced a biased sample, with participating classes being more interested or invested in physical activity promotion than other schools. Previous physically active lesson interventions provided poor detail on recruitment and retention strategies (3), giving little indication of best practice. In terms of retention strategies, the ongoing competition for pupils' accelerometer wear-time could also have been accompanied by teacher incentives. As teachers were key in allowing continued data collection and delivering the sessions, they could have been incentivised by rewards. Although no schools withdrew during Study Two (Section 7.2.1), the establishment of teacher incentives may have increased teacher enjoyment and enthusiasm for participation. Teacher incentives have been used in other physically active lesson interventions (376, 391), with low levels of attrition seen (Section 4.5.12).

The efficacy of smaller-scale school interventions such as classroom-based physically active lessons has been debated in physical activity literature. With a recent systematic review finding no effects of school-based physical activity interventions at six month follow-up (274), there is an evident paucity of effective longer-term programmes (Section 2.7.2). Although clear effects have not been consistently found in published work to date, this does not mean we should abandon research in this area. Conversely, this should act as a call to action for effective child physical activity interventions to be formulated and tested (172). Under the Social Ecological Model, (215, 397), successful physical activity interventions for children should encompass individual, interpersonal, organisational, community and public policy levels (Section 2.5.4). VFTs in this thesis incorporate the individual child-level as they are developed for pupils' specific curriculum age, the interpersonal level as they involve the involvement of classroom teachers and peers and to some extent the organizational level as they involve adapting teaching practices. However, given the relatively short length of the Virtual Traveller intervention and its use in only one class per school, it is unlikely that community-level changes were possible. Public policy changes were also beyond the scope of this thesis. Whole-school approach interventions incorporating a range of elements across a given school setting have been proposed to better encapsulate the broader aspects of community and policy (270, 271) (Section 2.7). Although not possible within this thesis, there is scope for VFTs as physically active lessons to be integrated to a greater extent across schools to address these larger-scale factors.

10.7 Future research directions

This thesis provides a novel insight into the use of existing classroom technology to integrate physical activity into teaching content. There are many potential avenues that could now be explored to extend the methods and findings outlined in this thesis. Firstly, the effects of VFTs on many other outcomes could be tested. Howie & Pate's (2012) model of the relationship between physical activity, cognitive function and academic achievement (Section 2.3.4.1) provides a range of potential options to explore. For example, changes to academic achievement could be assessed in the form of standardised testing or teacher reports. This was not done in this thesis due to the extra researcher burden required and as it was felt that the relatively short intervention period possible within PhD time was too short for any clear change to be made. Cognitive skills were also not assessed in this work due to time and monetary constraints (Section 6.1). However use of the free, recently developed Psychology Experiment Building Language (PEBL) cognitive assessment battery would greatly reduce financial costs (628). Potential changes to physical fitness could also be assessed, to date only done in one physically active lesson intervention (379).

Secondly, different methods of VFT physical activity assessment could be trialed. For example, the recently published System for Observing Student Movement in Academic Routines and Transitions (SOSMART) observation tool (629) has been developed to specifically assess movement integration in the classroom. This assesses the type (academic or non-academic), context (e.g teacher or technology-directed) and extent (e.g upper, lower or full body movement) of movement. It has been rigorously developed by videotape analysis of classroom teaching and Delphi survey: involving the revision of observation criteria from experts (629). Also, as no cut-points have been developed for on-the-spot movements specifically (3) (Section 5.4.4), calibration would be beneficial for interventions such as VFTs and other physically active lesson interventions as well as Active Video Games (256).

Thirdly, the effects of VFTs on different populations could be explored. As mentioned by some teachers in Study One (Section 5.3.5.1.3), the integration of movement into taught content with VFTs may be appropriate in Special Educational Needs (SEN) pupils to help improve their attention and behaviour. These associations have also been identified in wider research, with increased on-task behaviour (135), sleep (630) and physical activity (630, 631), as well as reduced aggression (135), illness and hospital admissions (631) found with physical activity interventions in children with autism and intellectual disabilities. VFTs could be tested within SEN provision in mainstream schools or in SEN schools specifically. Additionally, VFTs could be tested within secondary school teaching (ages 11-18). As identified in the thesis' systematic review (Chapter 4), physically active lesson research has focused almost exclusively on younger primary-school settings (3). As physical activity levels have been found to decrease during adolescence (60), physically active lessons such as VFTs could be a novel way of integrating activity into teaching time for this older age-group. The feasibility of physically active VFTs according to secondary school curriculum content and social contexts would need to be evaluated prior to intervention piloting.

As no effects were observed on overall school or weekend day activity, the structure of VFT intervention provision could be varied in future research. The intervention dose could be increased by making sessions longer than the ten minutes sessions of Virtual Traveller. Ten studies identified in the systematic review featured sessions of thirty minutes or more (Section 4.5.3), finding overly positive effects on outcomes. If session length was to be extended, the number of sessions delivered per week would likely need to be decreased to fit around wider school activities. Alternatively, the session length could be maintained but run on a daily basis rather than three times per week as in the Virtual Traveller intervention (Section 6.4.5). Other physically active lesson interventions have similarly tested this, with the systematic review identifying ten out of twenty-eight studies to run their interventions on a daily basis. The feasibility of this more regular VFT provision would need to be assessed; would pupils and teachers become tired by this daily use of familiar software and on-the-spot activity? The overall length of the VFT intervention period could also be extended beyond the six weeks tested in the Virtual Traveller intervention. For example, studies identified in the systematic review (Section 4.5.3) ran physically active lesson programmes for up to three academic years (383). A longer intervention period would allow greater assessment of potential habitual behaviour- and attitude-change over time. Alternatively, VFTs could be integrated within a complex intervention, with other components addressing activity beyond lesson time.

During the latter stages of this PhD, new VFT-related technologies have emerged. Google recently launched a scheme integrating technology into classrooms around the world called Google Expeditions (632). This is a software platform using cheap 'Google Cardboard' headsets (633) which fasten to smartphones to create an in-class virtual reality experience. Sessions are run via an Android app on a teacher-operated tablet. Currently in beta testing, there are plans for the full app to be publicly launched shortly (632). Google Expeditions has not been described to integrate physical activity; however this could potentially be explored by providing additional teacher training to include movement prompts. A critique of Google Expeditions is that sessions require all participating children to have their own smartphones and headsets, which arguably limits potential adoption.

Finally, there is potential for more investigation into current physically active teaching practice in the UK. In Study One (Section 5.3.5.1.1), some teachers described physically active lessons to be used regularly and to have been featured in their initial teacher training. However, the extent that movement integration is incorporated into teacher training nationally has not been audited to date. This could be investigated by approaching universities providing undergraduate and postgraduate teaching programmes. There has also been no research into the extent and experiences of physically active lesson teaching in qualified, practicing teachers at a national level. A national-level survey could be administered to teachers to assess this, with recruitment via teaching websites such as TES Resources (510) and Twinkl (511). It is clear that a whole range of research could subsequently emerge from the work of this thesis. Outlined potential work would extend the evidence base for VFTs, as well as giving wider support for the extent and benefits of physically active teaching practice.

10.8 Conclusion

Low levels of child physical activity are seen in the majority of UK children. This thesis has shown that physical activity can be integrated into taught primary school lessons using Virtual Field Trips (VFTs). VFTs were not associated with increased physical activity across overall assessment periods, nor school days or weekends. However, they were associated with consistent and significant increases to lesson time physical activity. VFTs were also shown to improve on-task behaviour and to be integrated without detriment to student engagement. Virtual Traveller was well implemented and assessed as easy-to-use, acceptable and enjoyable by teachers and pupils.

The mixed methods, iterative development of the Virtual Traveller package in this thesis ensured that the intervention was as relevant to teachers as possible. The original contributions that this thesis provides are its synthesis of arising physically active lesson studies and its use of existing interactive whiteboard technology to effectively facilitate physically active teaching. This work shows that cheap-to-run interventions utilising existing classroom technologies have potential to increase lesson time activity. Combining physically active VFTs as part of more complex interventions may see increased effects on overall activity levels.

VFTs as physically active lessons could be recommended in future public health guidance and health policy to partially address low levels of physical activity in children. Future research could assess the effects of different VFT doses on outcomes and assess their suitability in secondary school or special educational need populations.

10.9 Lay summary of thesis

This thesis has investigated if Virtual Field Trips (VFTs) in school lessons can increase children's physical activity. VFTs use classroom interactive whiteboards to allow children to explore the world, using movements to simulate travel to and interact with different locations. VFTs are a type of 'physically active lesson': combining educational content with physical movements. Around three quarters of children in the UK do not meet recommended physical activity levels of 60 minutes each day. As physical activity is important for health, it is important that programmes (or 'interventions') are developed to help improve children's activity levels.

A review of published literature found that greater levels of physical activity are associated with benefits to children's education. A structured (or 'systematic') review of twenty eight studies investigating physically active lessons found these interventions to be effective at improving physical activity and learning. Accordingly and in addition to physical activity, this thesis also examined the effect of VFTs on children's attention in-class ('on-task behaviour') and their interest in learning and school generally ('student engagement'). Opinions of teachers and pupils towards a sample active VFT were used to understand potential changes to be made.

From this work, a six-week programme of VFTs for Year 4 (8-9 year old) classes was developed called 'Virtual Traveller'. This featured a package of eighteen 10-minute sessions to be delivered by teachers three times a week within Maths and English lessons. The programme was run in five classes, with five other classes not receiving Virtual Traveller also assessed for comparisons. Physical activity was measured before, during and after the programme. Physical activity was measured using activity monitors and observations, on-task behaviour was measured using observations and student engagement was measured with pupil questionnaires. Data from 219 pupils was analysed.

Virtual Traveller did not have any effect on children's activity outside of the classroom or on student engagement. However, children were over 2.5 times more active during Virtual Traveller sessions compared to typical seated lessons. They also showed greater on-task behaviour during Virtual Traveller sessions compared to typical lessons. Evaluation surveys and interviews found that teachers delivered 70% of sessions overall and also showed that teachers and pupils both enjoyed Virtual Traveller.

This thesis showed that VFTs integrated into primary school teaching may increase children's lesson time physical activity and on-task behaviour. Physically active lessons such as this should be used in wider teaching practice and future public health policies. This will help to increase activity during lessons and may help improve child health in combination with other interventions.

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Appendices

Appendix 4B. Search strategies for physically active lesson systematic review

ERIC search strategy

Search term number	Search term	No. of search hits
1	physical activity or exercis* or movement* (abstract)	61221
2	class* or lesson* or learn* (abstract)	494713
3	child* or young* or pupil* (abstract)	298915
	1 and 2 and 3	6187

PubMed search strategy

Search term number	Search term	No. of search hits
1	physical activity or exercis* or movement* (title and abstract)	523285
2	class* or lesson* or learn* (title and abstract)	1302476
3	child* or young* or pupil* (title and abstract)	1566223
	1 and 2 and 3	6224

PsycINFO search strategy

Search term number	Search term	No. of search hits
1	physical activity or exercis* or movement* (abstract)	172049
2	class* or lesson* or learn* (abstract)	587209
3	child* or young* or pupil* (abstract)	667510
	1 and 2 and 3	5531

Web of Science search strategy

Search term number	Search term	No. of search hits
1	physical activity or exercis* or movement* (title)	1037946
2	class* or lesson* or learn* (title)	1700557
3	child* or young* or pupil* (topic)	7431635
	1 and 2 and 3	756

Appendix 5A. BMC Public Health paper of Masters VFT Pilot project

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BMC Public Health

RESEARCH ARTICLE Open Access

Virtual field trips as physically active lessons for children: a pilot study

Emma Norris[1*], Nicola Shelton[1], Sandra Dunsmuir[2], Oliver Duke-Williams[3] and Emmanuel Stamatakis[1,4,5]

Abstract

Background: The modern classroom is an inherently sedentary environment. Virtual Field Trips (VFTs) using interactive whiteboards to explore virtual scenes are a potential method of converting sedentary class-time into physically active teaching. This pilot aimed to assess the effects of a developed VFT on physical activity and learning in primary-school children.

Methods: Participants (n = 85) were randomly assigned to a) a 30-minute physically active London 2012 Olympics-themed VFT, or b) a 30-minute sedentary version of the same VFT. Activity was measured using GT1M Actigraphs, content recall was assessed with a quiz and user evaluations were gained from teacher and pupil questionnaires.

Results: Pupils in the active VFT displayed significantly less sedentary time ($p < 0.001$), and significantly more light ($p < 0.001$), moderate ($p = 0.01$) and vigorous physical activity ($p < 0.001$) than sedentary VFT pupils. No differences in content recall were found between intervention groups: suggesting that adding physical activity into classroom teaching may not compromise attainment. High acceptability was found in teachers and active VFT students rated their session significantly higher than sedentary pupils ($p < 0.002$).

Conclusions: This one-day pilot provides early evidence of the ability of VFTs to convert sedentary academic time into active time. Longitudinal research is needed to assess prolonged effects of active VFTs in reducing sedentary time.

Keywords: Virtual Field Trips, Physically active lessons, Physical activity, Schools

Background

Children currently spend 7–8 hours a day being sedentary [1], with most of this time spent in obligatory seated school lessons [2]. Children additionally do not perform more activity outside school hours to compensate for this inactivity [3], leading to an inherently inactive lifestyle and children unable to reach the recommended 60 minutes of moderate to vigorous exercise (MVPA) a day [4]. Current school inactivity is also undoubtedly a contributor to high rates in childhood obesity: with 33.3% of children currently overweight or obese [5]. Urgent action is needed to make school-time more active.

Schools are an important setting to promote physical activity (PA), allowing a large number of children to be exposed to interventions over a long period of time [6]. Although found to be largely effective in increasing active time [6,7], school PA interventions are often difficult to implement. They frequently involve securing time for PA outside of academic lessons, making them difficult for teachers to implement around academic priorities [8]. Integrating physical activity into educational time within classroom environments is one potential way of minimising such barriers for teachers and schools [9].

Physically active lessons are one way of doing this: promoting understanding of curriculum concepts via physical actions [10,11]. Such interventions emerge from the Social Ecological model, which recognises health behaviours such as physical activity as determined by both intrapersonal behavioural factors and interrelationships between individuals and wider social, physical and policy

* Correspondence: e.norris.11@ucl.ac.uk
[1]Department of Epidemiology & Public Health, University College London, 1-19 Torrington Place, London WC1E 7HB, UK
Full list of author information is available at the end of the article

environments such as school peer-groups [12,13]. Projects such as Take 10! [14] and Physical Activity Across the Curriculum (PAAC) [15,16] integrate activity into short sessions of Maths, English and Social Sciences [17]. An example activity would be recalling multiplication tables whilst skipping or running [18]. Significantly improved PA levels have been found following physically active lessons [16,19], with corresponding improvements in educational outcomes [16,20,21]. These findings are supported by a wealth of other research finding physical activity to improve cognitive outcomes [22,23], on-task behaviour [24] and wellbeing [25] in children.

Classroom technology has untapped potential as a source of physical activity. With over 70% of classrooms now featuring interactive whiteboards [26], Virtual Field Trips (VFTs) using these multi-modal devices may be viable as a physically active lesson format. VFTs allow pupils to interact with virtual maps, landmarks and objects to gain multi-modal information and facilitate multiple learning styles [27]. Until now VFTs have been entirely sedentary and mostly restricted to development for university-level study [28,29]. However, given the inherently explorative and geographical nature of VFTs, they seem prime candidates as physically active lessons for school-aged children. Children could 'cycle', 'run' or 'fly' on-the-spot through virtual scenes embedded with educational elements whilst still being in their classroom. No research has yet assessed the potential of school-based VFTs to improve children's physical activity levels.

This pilot study investigated the effects of a one-off Olympic-themed VFT on pupil's physical activity. The study aimed to:

1) Objectively measure children's physical activity during the VFT lesson and the school day
2) Assess VFT content recall
3) Assess user evaluations after physically active VFT sessions

Methods

Participants and study design

Pupils (n = 85) from four Year 5 classes (aged 9 to 10) from two London state-funded primary schools participated in the study. A 2×2 between subjects experimental design was used.

Cluster randomisation was performed at class level in each school, with one class randomly allocated to the 'active' intervention VFT condition, and the other to the 'sedentary' control condition.

Instrumentation

A teacher-operated VFT was created using Google Earth: a free, widely available virtual globe [30], already available in the local software systems of participating schools. A London 2012 Olympics theme was chosen for the trip, due to the event's recent and inherently active nature. Using the Interactive Whiteboard, the session involved navigating through various Olympic venues to discover more about their associated sporting events and was developed by the principal researcher (Figure 1). Existing 3D models of Olympic buildings made by other Google Earth users were used, with place marks, facts and multimedia content added using HTML. Questions related to sports hosted at each site were indicated with bold font. Both groups completed the session instead of a Topic (geography or history) lesson. Both VFTs featured the same building-specific information; however the intervention trip also included activity prompts in bold font to promote simulated exercises relating to each location. Intervention pupils stood throughout the 30-minute session, completing prompted activities such as running the 100 m finals on-the-spot in the Olympic Stadium or flapping their arms when 'flying' to the next location. Sedentary VFT participants were seated throughout the session and completed no related activities.

Demographics

A questionnaire pack was sent to parents requesting their child's gender, ethnicity [31] and whether they had watched the London Olympics at a venue or on television.

Anthropometry

Weight was assessed by the lead researcher to the nearest 0.1 kg (Weight Watchers 8961U electronic scales, Milton Keynes, UK) and height to the nearest mm (2 metre tape measure). Body Mass Index (BMI; kg÷ m^2) was then produced from these measurements. Underweight, overweight and obesity prevalence was estimated using the 2^{nd}, 85^{th} and 95^{th} percentiles of the 1990 UK reference curves [32].

Physical activity

Physical activity was measured from 9:00 AM to 3:00 AM during the study day using bi-axial Actigraph GT1M accelerometers (CSA, Shalimar, FL) worn on pupils' waist above the right hip. Data was recorded using 15 second epochs, with this interval validated to measure bursts of activity typical in children [33].

Learning

A ten-item quiz on content recalled from the Olympic VFT was issued to participants following the session. Four multiple choice questions were included, such as "When did the Olympic flame stay lit until? A: The Olympic Games closing ceremony, B: The end of 2012, C: The end of the men's 100 m sprint final". Six open-

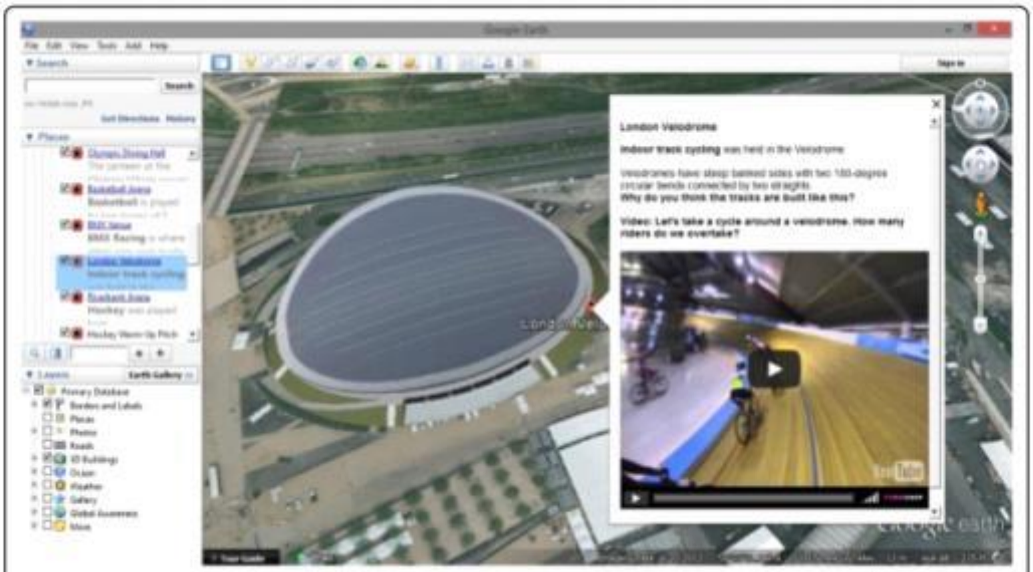

Figure 1 Example of developed Olympic-themed Virtual Field Trip with activity prompt.

response questions were included, such as "What type of sport was held at the Velodrome?"

Process evaluation

Evaluations sheets were supplied to participants and teachers after the VFT. This asked for their overall liking of the session (out of 5), whether they would like to take another VFT in the future (yes/no) and for positive and negative comments about the session. Difficulties in the provision of VFTs or outcome measurement were noted by the principal researcher.

Procedure

The study was conducted during May and June 2013, with the pilot intervention run for one day in each class. Participants had anthropometric measurements taken on the morning of the study. The 30-minute VFT was delivered after the school lunch break, allowing one hour of post-VFT activity measurement time for this pilot. Post-VFT content recall and process evaluation forms were provided after the session. The session was delivered by the class teacher following a short briefing from the researcher. Pupils were blinded to their study condition but teachers were not to allow them to deliver their allocated session effectively. Ethical approval was granted from University College London. Consent was obtained from participating children and their parents, as well as teachers.

Statistical analysis

Actigraph data was downloaded immediately after each study day using ActiLife software version 6.0 (Actigraph, LLC, Fort Walton Beach, Florida). Pulsford cut-points [34] were applied to assess activity intensity (Sedentary: <100 counts per minute (CPM), light: 100–2240 CPM, moderate: 2241–3840 CPM, vigorous: ≥3841 CPM). Pulsford cut-points are calibrated from free-living as opposed to treadmill activities in children: reflecting the sporadic movements initiated by children and targeted to be elicited during VFT participation [33,34]. Accelerometer data was then extracted to SPSS (version 19; Chicago, SPSS Inc.) for analysis.

Missing demographic data was evident in parent questionnaires ($n = 6$, 5.1%) and missing pupil VFT evaluations ($n = 5$, 4.25%). Pairwise deletion of missing activity was hence used to retain maximal data. Descriptive statistics of demographics, activity levels, post-VFT quiz learning outcome and VFT teachers and pupil evaluations were performed. Pearson chi-squared tests were used to assess demographic differences. One-way ANOVAs were used to assess differences in outcomes between intervention, school and demographic groups. Independent *t* tests were used to assess axes recordings across VFT groups. Multiple regressions were completed for post-VFT quiz learning outcome and sedentary, light, moderate and vigorous activities during the VFT period. Activity intensities of school day activity outside of VFT sessions were used in the VFT activity regression analysis. Dummy coding was used for categorical variables of ethnicity, BMI category and teacher. Backward stepwise entry was used, with all variables entered first before removing those non-significant. Models producing the greatest amount of explained variance from adjusted R^2 were reported.

Results

Participants

Of the eighty five participants, 47.1% (n = 40) were allocated to the active, intervention VFT condition. 58.8% (n = 50) were male, 56.5% (n = 48) were white, 25.9% (n = 22) were Asian or Asian British and 5.9% (n = 5) were Black or Black British. 20% (n = 17) were obese and 8.2% (n = 7) were overweight. 8.6% (n = 7) had attended a London 2012 Olympics event at an official venue and 87.7% (n = 71) had watched the Olympics on television. Significantly more pupils watched the Olympics on television in the sedentary compared to the active condition groups ($\chi^2(1) = 4.28$, $p < 0.05$). There were no other significant differences in demographics between intervention groups and schools (Table 1).

Physical activity during VFT sessions

97.6% (n = 83) of participants had available accelerometer data. There were significant differences in physical activity during the VFT between intervention groups (Table 2). Active intervention pupils had significantly fewer sedentary bouts (M = 0.11, SD = 0.31) during the VFT than sedentary group pupils (M = 0.56, SD = 0.62) ($F(1,82) = 16.35$, $p < 0.001$) and completed less sedentary time (M = 28.90 mins, SD = 5.12) than the sedentary group (M = 34.88 mins, SD = 7.80) ($F(1,82) = 16.35$, $p < 0.001$). The majority of time in both groups was recorded as sedentary by accelerometers (active 63.9%; sedentary 76.3%), despite active VFT participants standing and moving throughout the session. Active intervention pupils engaged in significantly more light activity (M = 14.97 mins, SD = 6.18) than the sedentary group (M = 9.92 mins, SD = 6.11) ($F(1,82) = 13.92$, $p < 0.001$), more moderate activity (M = 1.07 mins, SD = 0.81) than the sedentary group (M = 0.61 mins, SD = 0.80) ($F(1,82) = 6.89$, $p = 0.01$) and more vigorous activity (M = 0.79 mins, SD = 0.65) than the sedentary group (M = 0.27 mins, SD = 0.64) ($F(1,82) = 13.62$, $p < 0.001$). There were no significant differences in VFT activity between gender, BMI or ethnicity groups.

Multiple regression analyses were performed for activity intensities during the VFT (Table 3). 58.4% of sedentary VFT time was explained ($F(9,75) = 39.33$, $p < 0.001$), with sedentary VFT condition ($p < 0.001$) and more sedentary time during the day ($p < 0.001$) significantly associated with increased VFT sedentary time. 63.2% of light VFT activity was explained ($F(6,82) = 24.46$, $p < 0.001$), with school ($p < 0.001$), active condition ($p < 0.001$) and less sedentary time during the day ($p < 0.001$) significantly associated with more light VFT time. 7.8% of moderate VFT time was explained ($F(2,77) = 4.25$, $p < 0.05$). No included factors in the model were significantly associated with moderate VFT time, although active VFT condition

Table 1 Descriptive characteristics of 85 participants

Demographics	All (N = 85)	Active VFT (N = 40)	Sedentary VFT (N = 45)	p
Gender				
Male	58.8% (n = 50)	57.5% (n = 23)	60% (n = 27)	0.82
Female	42.2% (n = 35)	42.5% (n = 17)	40% (n = 18)	
Ethnicity				
White	56.5% (n = 48)	55% (n = 22)	57.8% (n = 26)	0.92
Asian	25.9% (n = 22)	30% (n = 12)	22.2% (n = 10)	
Black	5.9% (n = 5)	5% (n = 2)	6.7% (n = 3)	
Arab	2.4% (n = 2)	2.5% (n = 1)	2.2% (n = 1)	
Mixed	4.7% (n = 4)	2.5% (n = 1)	6.7% (n = 3)	
Other	2.4% (n = 2)	2.5% (n = 1)	2.2% (n = 1)	
Missing	2.4% (n = 2)	2.5% (n = 1)	2.2% (n = 1)	
BMI (kg÷ m^2) Mean (SD)	18.37 (3.42)	18.27 (3.77)	18.46 (3.13)	*t(83) = −0.25, n.s
BMI Category				
Normal	71.8% (n = 61)	70% (n = 28)	73.3% (n = 33)	0.85
Overweight	8.2% (n = 7)	7.5% (n = 3)	8.9% (n = 4)	
Obese	20% (n = 17)	22.5% (n = 9)	17.8% (n = 8)	
Watched Olympics at official venue	8.6% (n = 7)	2.5% (n = 1)	13.3% (n = 6)	0.052
Watched Olympics on TV	83.5% (n = 71)	80% (n = 32)	86.7% (n = 39)	0.04

Note: Pearson chi-squared tests used to assess VFT condition differences, *indicates independent samples t-tests.

Table 2 One-way ANOVAs of physical activity during VFT

Physical activity level	All (N = 83)	Active VFT (N = 38)	Sedentary VFT (N = 45)	p
Sedentary Bouts	0.35 (0.55)	0.11 (0.31)	0.56 (0.62)	<0.001
Sedentary Time (mins)	32.14 (7.31)	28.90 (5.12)	34.88 (7.80)	<0.001
Light Time (mins)	12.23 (6.61)	14.97 (6.18)	9.92 (6.11)	<0.001
Moderate Time (mins)	0.82 (0.84)	1.07 (0.81)	0.61 (0.80)	0.01
Vigorous Time (mins)	0.51 (0.69)	0.79 (0.646)	0.27 (0.64)	<0.001

Note: Mean in minutes (SD).

approached significance ($p = 0.053$). 22.4% of vigorous VFT activity was explained ($F(6,77) = 4.70$, $p < 0.001$), with school ($p < 0.05$), active VFT condition ($p < 0.001$), girls ($p < 0.05$) and sedentary time during the ($p < 0.01$) significantly associated with increased VFT vigorous activity.

Post-VFT physical activity

Post-VFT activity between intervention groups was analysed to assess the potential effects of active class sessions on subsequent school activity. VFT sessions were held following lunch breaks allowing only an hour of post-VFT measurement in this pilot study. Two classes (one intervention and one control) were permitted extended afternoon play after the VFT by their teachers due to good weather. To allow realistic assessment of the provisional effects of VFT on subsequent typical teaching, these two classes were removed from post-VFT physical activity analysis.

Following the VFT, the remaining active class demonstrated more moderate time (M = 0.88 mins, SD = 0.81) han the sedentary class (M = 0.55 mins, SD = 0.48) ($F(1,38) = 9.19$, $p < 0.01$). Conversely, significantly more vigorous time was found post-VFT in the sedentary class (M = 0.71 mins, SD = 0.46) compared to the active class (M = 0.15 mins, SD = 0.33) ($F(1,38) = 18.30$, $p < 0.001$). However these rates were extremely small in both groups and drawn from a reduced sample due to aforementioned external factors (Table 4).

Physical activity during the school day

Eight (9.6%) of participants with accelerometer data achieved ≥60 minutes MVPA during the school day. However these were exclusively from the two classes with teacher-permitted extended play post-VFT, hence not reflecting typical teaching. Forty five (54.2%) performed over 30 minutes MVPA, with thirty five of these (77.8%) from classes with extended post-VFT play. There

Table 3 Backward multiple regression models of activity intensities during VFT with greatest adjusted R^2

DV	Step/predictor	B	β	DV	Step/predictor	B	β
Sedentary Time	Condition	6.30	0.43***	Light Time	School	8.20	0.62***
	Sex	−1.65	−0.11		Condition	−5.16	−0.39***
	Sedentary Time during day	0.16	0.65***		Sedentary Time during day	−0.17	−0.77***
					Moderate Time during day	−0.16	−0.23
					Vigorous activity during day	0.08	0.11
F	39.33***			F	29.19***		
Adjusted R^2	0.584			Adjusted R^2	0.632		
DV	**Step/Predictor**	**B**	**β**	**DV**	**Step/Predictor**	**B**	**β**
Moderate Time	Condition	−0.37	−0.22*	Vigorous Time	School	0.39	0.28*
	Watched Olympics at venue	0.62	0.20		Condition	−0.49	−0.35***
					Sex	0.36	0.26*
					Watched Olympics on TV	−0.22	−0.11
					Watched Olympics at venue	0.40	0.15
					Sedentary time during day	−0.01	−0.33**
F	4.25*			F	4.70***		
Adjusted R^2	0.078			Adjusted R^2	0.224		

Note: Day activity intensities include all recorded time outside of VFT sessions; *$p < 0.05$; **$p \leq 0.01$, ***$p \leq 0.001$.

Table 4 One-way ANOVAs of physical activity after VFT in classes without extended afternoon play

Physical activity level	All N = 39	Active VFT N = 18	Sedentary VFT N = 21	p
Sedentary Bouts	0.54 (0.64)	0.50 (0.62)	0.57 (0.68)	0.73
Sedentary Time (mins)	43.28 (5.56)	41.69 (5.74)	44.63 (5.16)	0.10
Light Time (mins)	14.42 (5.31)	15.89 (5.42)	13.15 (4.99)	0.11
Moderate Time (mins)	1.14 (0.69)	0.88 (0.81)	0.55 (0.48)	0.004
Vigorous Time (mins)	0.46 (0.49)	0.15 (0.33)	0.71 (0.46)	<0.001

Note: Mean (SD).

were no differences in physical activity across the school day between intervention groups (Table 5).

Accelerometer counts

Total accelerometer axes counts recorded during the VFT were analysed to assess the types of movement elicited. The bi-axial GT1M model used detects axis 1 (Y-axis): reflecting accelerating, ambulatory movement such as running and axis 2 (X/ anteroposterior axis) reflecting vertical movements such as jumping [35]. Significantly more Y-axis counts were recorded from the active VFT group (16804.21 counts, SD = 9684.87) compared to sedentary group (8826.29 counts, SD = 7578.59) ($t(81) = 4.21$, $p < 0.001$). There were also significantly more X/A-P axis counts in the active (22308.53 counts, SD = 8635.34) compared to the sedentary group (11754.42 counts, SD = 7742.71) ($t(81) = 5.87$, $p < 0.001$). More counts were recorded on the X/ A-P axis than the Y axis by the active group, suggesting VFT-prompted activity produced more on-the-spot rather than ambulatory movement.

VFT content recall

A mean score of 7.55 out of 10 (SD = 1.90) was attained across all participants for the post-VFT quiz. There were no significant differences in post-VFT quiz marks between intervention groups. This suggests there was no detrimental effect of physically active versus sedentary VFTs on learning in this pilot sample. Scores were fairly high across participants (M = 7.55 out of 10; SD = 1.90), which may suggest a potential ceiling effect. There were also no significant post-VFT quiz mark differences between genders, ethnicities, BMI categories and Olympic venue attendance. This suggests that learning via VFT may be beneficial for a diverse range of pupils. Participants who had watched the Olympics on television scored significantly higher (M = 7.71, SD = 1.78) than those who had not (M = 6.20, SD = 2.25) ($F(1,79) = 5.98$, $p < 0.02$).

A multiple regression analysis was performed for the post-VFT learning outcome using backwards stepwise entry (Table 6). 12.2% of variance in learning outcomes results was explained. This is a low degree of explained variance, suggesting unmeasured factors are also important. Pupils who watched the Olympics on television ($p < 0.05$) attaining significantly higher scores. Obese pupils performed significantly worse than normal weight ($p < 0.05$).

Participant evaluations

Pupil evaluation forms found that 84.7% (n = 72) wanted to do another VFT in the future. Significantly more pupils in the active condition (97.4%; n = 38) wanted to do another VFT than the sedentary condition (75.6%; n = 34) ($F(1,83) = 8.83$, $p < 0.005$). Pupils in the active condition also rated the VFT session significantly better (M = 4.5, SD = 0.98) than the sedentary condition (M = 3.86, SD = 1.24) ($F(1,79) = 6.52$, $p < 0.02$). Pupils across both conditions commented that improvements could be made to make future trips more interactive and realistic.

Teacher evaluation forms found that all teachers (n = 4) wished to run another VFT session in the future, with ratings from 3 and over out of 5. Evaluations were highest in an active class where the teacher proactively reorganised the classroom to facilitate activity. Teachers praised the

Table 5 One-way ANOVAs of physical activity during school day including VFT session

Physical activity level	All N = 83	Active VFT N = 38	Sedentary VFT N = 45	p
Sedentary Bouts	2.54 (1.89)	2.26 (1.59)	2.78 (2.10)	0.218
Sedentary Time (mins)	198.44 (34.33)	196.30 (27.69)	200.26 (39.31)	0.604
Light Time (mins)	111.60 (25.33)	113.90 (21.51)	109.65 (28.26)	0.450
Moderate Time (mins)	21.49 (9.56)	21.41 (8.07)	21.56 (10.75)	0.947
Vigorous Time (mins)	14.26 (8.54)	15.11 (9.46)	13.54 (7.73)	0.409

Note: Mean (SD).

Table 6 Backward multiple regression models of post-VFT learning outcome with greatest adjusted R^2

Step/predictor	B	β
Gender	−0.42	−0.11
Asian	−0.55	−0.13
Mixed Ethnicity	−1.06	−0.12
Obese	−1.21	−0.26*
Watched Olympics on TV	−1.46	−0.25*
F	3.20	
Adjusted R^2	0.12	

Note: *$p < 0.05$.

use of Google Earth software as being free, readily available and easy to use.

Discussion

This pilot study assessed the effects of a one-day VFT intervention in primary-school classes. To the authors' knowledge, it is the first study to examine VFTs as physically active classroom sessions. The aims were to assess the impact of this pilot VFT on physical activity and content recall as a learning outcome, as well as assessing pupil and teacher evaluations.

Physical activity during VFT

Accelerometer data found that the active VFT intervention group engaged in significantly less sedentary time and more light, moderate and vigorous activity during the VFT than the sedentary group. Multiple regression analysis also found VFT condition to be a positive significant predictor of all PA intensities during the VFT. However, although pupils in the active intervention group were standing and visibly active throughout the session, 63.9% of the active group's VFT activity was still recorded as sedentary. Such standing, on-the-spot activity clearly does not comply with officially defined sedentary behaviour: energy expenditure ≤ 1.5 metabolic equivalents and a sitting or reclining posture [36]. Although a thorough review of published child cut-points was performed to identify the most suitable available cut-points; accelerometers still detected the majority of active VFT activity as sedentary. This review found no cut-points specifically calibrated for non-locomotor, on-the-spot movements. Consequently, Pulsford cut-points [34] were selected as they feature calibration of sedentary through to VPA intensities and via non-treadmill, self-paced activity. Recording of active VFT time as sedentary is likely a consequence of accelerometers' insensitivity in measuring non-ambulatory movements, such as cycling and on-the-spot movement in comparison to accelerating, travelling movements [37].

Given health and safety considerations in classroom environments, it is difficult to expect high amounts of MVPA during VFT sessions. Although MVPA was low (only 4.2% of the active VFT session), sedentary time was reduced in active VFT participants and largely replaced with objectively recorded light activity. Emerging research is investigating the benefits of converting school sedentary time to light activity time, via examples such as standing desks [38]. Accordingly, future VFT research could instead aim to displace sedentary with light intensity activity as a minimum. Behaviour change techniques such as goal setting and rewards [39] or gamification elements [40] could be applied in future VFT research to potentially add sustained activity improvement.

No significant differences were found between genders and ethnicities. Larger-scale research is needed to see if VFTs are effective at increasing activity in girls and ethnic minorities, who frequently demonstrate lower PA [41,42].

School day physical activity

Whole school day activity did not significantly differ according to VFT condition: suggesting the session did not affect overall day activity levels. This may have been due to the afternoon timing of the session, as pupils' activity was only recorded for around an hour after the VFT. Sample size for assessing activity during a typical school due was reduced as two classes were permitted extended play post-VFT by their teachers due to good weather. No participants with typical post-VFT teaching achieved ≥60 minutes MVPA during the school day, much lower than found in recent research [43]. As activity was only recorded during school time, it is unknown if VFT condition was associated with any differences in after-school leisure activity. As in previous studies [1,43], girls were found to be more sedentary than boys across the school day. Although girls engaged in equal VFT activity to boys, a gender bias is still evident in their lower overall school PA. Further study is needed to assess if VFTs as a novel physically active lesson can improve PA in girls.

Content recall

Post-VFT content recall was assessed as another secondary outcome in this pilot study. There were no significant differences in post-VFT quiz results between intervention groups: suggesting no detrimental effects from the active VFT. This suggests that active VFTs could be integrated into teaching curriculum to improve physical activity and without compromising academic attainment. As there was no non-VFT control group, it is unknown if scores would have been lower or higher in classes without a novel VFT experience. Other studies have similarly found in-class activity sessions to cause neither deficit nor improvement to academic performance [43,44]. However the majority of evidence from reviews indicates positive associations between physically active class sessions and learning [21].

A potential ceiling effect was noted with high scores across participants. Although questions were provided across a range of difficulties, the recent nature of the Olympic subject matter may not have sufficiently challenged students. No pre-VFT questionnaire was provided to assess existing Olympic knowledge, as the primary outcome of this study was on feasibility rather than learning outcomes. However, future iterations should include a pre-assessment to better assess the impact of VFT on the learning outcome.

Participant evaluations

Experiences of the principal researcher and evaluations of teachers and pupils identified active VFTs to be feasible in this study. Pupils in the active VFT condition rated sessions significantly better than those in the sedentary condition. The novelty of the active session as opposed to the more typical, seated class format of the sedentary VFT may have increased pupil enjoyment [43,45]. A range of teacher evaluations were found, with ratings from middling to upmost success. The highest ratings were given by a physically active VFT teacher who rearranged the class layout to allow more movement. Previous physically active classroom sessions have been delivered at-desk [20,24]. However, early evidence found here suggests that this extra effort may provide a more successful active VFT session for both teacher and pupils. Improvements of VFT software and class layout changes will be considered in the development of future sessions.

Strengths and limitations

Accelerometers provided usable data and were acceptable by 97.6% participants in this pilot. However Pulsford et al. [34] cut-points used recorded the majority of active VFT group time as sedentary, despite participants standing and engaging in on-the-spot activity throughout. There is currently an absence of calibrated cut-points for on-the-spot activity. Future VFT research should be aware that accelerometers may record much of standing time as sedentary. Researchers could consider using non-ambulatory movement measurement devices such as inclinometers [46] if budgets allow.

Accelerometry data was only available for one day in this pilot study, meaning a novelty factor may have been present. Activity of reluctant or conversely over-enthusiastic pupils in this single session may have been less accurate results than measurement after multiple sessions [24]. Future, longitudinal study will explore whether the increased activity seen here can be maintained over more regular active VFTs. In this study, sessions were provided immediately after lunch-breaks, providing only around an hour of post-VFT activity assessment. Additionally, two classes were permitted extended post-VFT play by their teachers. This further reduces the ability of this pilot to understand the effects of VFTs on subsequent activity in typical teaching. Further study should provide VFTs earlier in the school day and set clear expectations for typical teaching to be otherwise enforced by teachers. The provision of VFTs longitudinally would also allow clearer assessment of their impact on activity during regular teaching arrangements. To be effective as PA interventions they must reduce sedentary time and sustain activity over repeated sessions without leading to compensation effects in subsequent reduced activity.

Conclusions

This pilot research found active VFTs to be feasible for primary-school classrooms. An Olympic-themed VFT elicited reduced sedentary time and increased light, moderate and vigorous physical activity compared to a sedentary version. However, there was scope for improvement of VFT technology. These findings provide preliminary evidence into the potential of VFTs in primary-school classes. Longitudinal research is needed to assess whether VFTs can reduce sedentary time and improve PA in a larger sample and over a prolonged period of sessions.

Abbreviations

VFT: Virtual field trip; MVPA: Moderate to vigorous activity; PA: Physical activity; CPM: Counts per minute.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

NS, ODW & ES obtained funding for the research. EN led the study's development and fieldwork. All authors were involved in the reviewing, editing and approving the final version of the paper. EN is the guarantor and accepts full responsibility for the conduct of the study. All authors read and approved the final manuscript.

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Author details

[1]Department of Epidemiology & Public Health, University College London, 1-19 Torrington Place, London WC1E 7HB, UK. [2]Department of Clinical, Educational and Health Psychology, University College London, 26 Bedford Way, London WC1H 0AP, UK. [3]Department of Information Studies, University College London, Foster Court, London WC1E 6BT, UK. [4]Charles Perkins Centre, University of Sydney, Sydney, Australia. [5]Exercise and Sport Sciences, Faculty of Health Sciences, University of Sydney, Sydney, Australia.

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Appendix 5B. Logo and contact information attached to each accelerometer

Front

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If found, please contact:
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Appendix 5C. BMC Research Notes paper of Study One

Norris *et al. BMC Res Notes* (2015) 8:719
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BMC Research Notes

RESEARCH ARTICLE Open Access

Teacher and pupil perspectives on the use of Virtual Field Trips as physically active lessons

E. Norris[1*], N. Shelton[1], S. Dunsmuir[2], O. Duke-Williams[3] and E. Stamatakis[1,4,5]

Abstract

Background: Virtual Field Trips (VFTs) are emerging physically active lessons that combine curriculum content with globe-based movement using interactive whiteboards. No research has yet examined the acceptability of these sessions by target users. This study aimed to (1) assess current physically active lesson teaching practices, (2) assess teacher attitudes towards VFTs and (3) investigate pupil perceptions of VFTs.

Methods: Data was collected from teaching staff interviews (n = 12) and three elementary school pupil focus groups (k = 3, n = 18), with all participants provided with a sample VFT session. Thematic analysis was used to analyse data.

Results: Teachers described VFTs as a flexible teaching tool, allowing inclusive learning across abilities and a range of taught subjects. They stressed a packed curriculum may make delivering VFT sessions problematic and warned that some teachers may be resistant to their use of technology. Pupils enjoyed the ability to move in the classroom and the ability to share a new teaching experience with their peers.

Conclusions: This work suggests positive attitudes towards VFTs as novel, physically active lessons and identifies potential teacher concerns for consideration in forthcoming intervention planning. Future experimental work will assess if these attitudes persist during longitudinal exposure to VFTs.

Keywords: Virtual Field Trips, Physically active lessons, Qualitative, Schools, Children

Background

Today's children spend around 7–8 h a day in sitting (sedentary) behaviours [1]. This is despite current guidelines recommending children to minimise their sedentary time and engage in 60 min or more of moderate or vigorous physical activity (MVPA) [2]. A recent English study found only 24 % of children met these MVPA guidelines, including 19 % girls and 29 % boys [3]. Evidence has shown sedentary behaviour in children to have negative effects on cognitive performance [4] and poorer mental health [5]. With physical activity (PA) [6] and sedentary behaviour (SB) found to track from childhood into adulthood [7], it is clear that both good and bad habits developed in childhood are likely to persist into adulthood. Hence, early intervention to reduce SB and increase PA is imperative [8].

Schools provide an ideal environment to improve children's PA, as they allow frequent access to children in an inclusive way and over regular periods of time [9]. A wide range of interventions have improved PA across the school day, including active travel [10], playtime [11, 12] and after-school activity [13]. Research has found that school-based PA can improve [14] or not compromise children's academic performance [15].

Teachers consistently report a lack of time as a barrier for PA interventions [16, 17]. Multiple demands for academic, physical and social outcomes are present in schools [18], often making it challenging for teachers to integrate PA into their busy curriculum [19]. As such, current research is investigating the potential of

*Correspondence: e.norris.11@ucl.ac.uk
[1] Department of Epidemiology and Public Health, University College London, 1-19 Torrington Place, London WC1E 7HB, UK
Full list of author information is available at the end of the article

'physically active lessons': integrating movement within curriculum teaching [20]. Examples of programmes include Physical Activity Across the Curriculum [21] and Take 10! [22]: integrating short-bursts of movement into Maths and English teaching. Increases in PA and educational outcomes have been found with physically active lesson programmes [20, 21]. These findings along with neurological evidence finding positive associations between PA and mental function in children [23], provide strong support for the inclusion of regular, physically active lessons in typical teaching.

Despite evident positive effects of school PA interventions, implementation rates are relatively low [17, 21]. Previous qualitative interviews and process evaluation research has uncovered facilitators and barriers effecting the implementation of school-based PA interventions [17, 24, 25]. The most commonly cited barrier is lack of time: with teachers perceiving PA interventions as difficult to fit in around academic demands [16, 17, 26]. Additional school-level barriers include lack of space for PA, safety concerns, high staff turnover and curriculum clashes with PA interventions [27, 28]. Child and teacher interest towards PA and the intervention itself have also been shown to be important mediators of PA intervention behaviour change [29]: with greater intervention enthusiasm likely in those already active [16, 27, 28, 30]. In order to maximise implementation, it is essential that institutional and individual barriers at all stages of intervention are anticipated and accounted for [31] pilot work and collaborative development between researchers and teachers can help identify potential barriers and minimise attrition for newly developed interventions [32].

Virtual Field Trips (VFTs) may be a viable format of physically active lesson. Originally developed as sedentary, computer-based activities for university teaching [33], VFTs allow individuals or classes to explore virtual maps and landmarks alongside educational content and media [34]. A recent feasibility study tested 10-min VFT sessions in primary schools [35]. These use interactive whiteboards, a pervasive form of classroom technology found in over 70 % of UK classrooms [36]. Via Google Earth-based software, these sessions allow pupils to simulate movements around the world featuring questions and information included according to teaching objectives. Pupils stand throughout these VFT sessions and complete on-the-spot movements simulating actions at or travelling to different locations. This feasibility study showed significantly increased light, moderate and vigorous activity in an active VFT session compared to a sedentary version [35]. Although the study enabled practical VFTs considerations to be identified and addressed in future work, it did not allow documentation of perceived barriers and facilitators to VFT use in teachers and pupils. A qualitative study was hence devised to evaluate the appropriateness, strengths and weaknesses of VFTs in teacher and pupil populations prior to larger-scale intervention work [37, 38].

This study aimed to: (1) assess current physically active lesson teaching practices, (2) assess teacher attitudes towards physically active VFTs after a sample session and (3) investigate pupil attitudes of physically active VFTs after a sample session. The research questions for this study were: (1) To what extent are physically active lessons present in UK teaching practice? (2) What are the perceptions of teachers towards VFTs as physically active lessons? (3) What are the perceptions of pupils towards VFTs as physically active lessons?

Methods

Design

Teacher semi-structured interviews and pupil focus groups were carried out. Children are less familiar with one-to-one discussion with an adult [39], hence focus group methodology was used to obtain the views of multiple children in a more relaxed environment. The interviewer (EN) acted as a 'moderator' to facilitate comfort, ensure a focused discussion contributed to by all and to seek clarification of unclear points [40]. The Consolidated criteria for Reporting Qualitative studies (COREQ) checklist was followed [41].

Participants

Convenience sampling in the London area was used for both teacher interviews and pupil focus groups. Teachers were recruited during the 2013/14 school summer holidays via personal contacts and social media. Pupils were recruited during the Autumn 2014 school term via direct enquiries to schools, with no pupils from the same schools as interviewed teachers. No teachers or pupils had experienced VFTs prior to the interview and pupil focus group sessions. Discussions were organised until saturation of ideas was judged as reached by the researcher (EN) [42].

Instrumentation

An interview script of open-ended questions was developed for teacher interviews and pupil focus groups to ensure standardised enquiry. This featured opening questions exploring perceptions on child school-based physical activity and physically active lessons. A demonstration of a developed Olympic-themed VFT was then provided. Full details on the development of this VFT can be found in the pilot study paper [35]. A 10-min version of the pilot study VFT was used in this session, developed by the lead researcher (EN). Teachers and students visited three locations from the London

2012 Olympics before visiting Rio: the site of the 2016 Olympics. Activities were integrated in travel between locations e.g. simulating swimming across the Atlantic Ocean and in videos at locations e.g. cycling around the London Velodrome. The VFT used in this study was a shortened version of that used in the pilot study [35] and was provided using Google Tour Builder. This is a browser-based modification of Google Earth, which allows users to plot journeys via different locations around the world [43]. Questions then assessed the potential benefits and weaknesses of VFTs as physically active lessons. Interviews were recorded using an Olympus DM-450 Dictaphone.

Procedure

Teacher interviews were held at a time and place convenient to each participant, typically in their home. Pupil focus groups were held at schools in vacant classrooms. Seating was arranged in a circle and children were allowed to choose their own seat [39]. Focus groups were run by the lead researcher (EN), with no teachers present to prompt honest responses [40]. The researcher also acted as a 'moderator' to ensure a focused discussion contributed to by all pupils [40]. To ensure audible recorded comments, an inflatable globe was passed between pupils to denote the person speaking at that time. The researcher made field notes during teacher interviews and pupil focus groups.

Informed consent forms were signed prior to interview, with pupil consent forms signed by parents. Teacher interviews lasted between 20 and 60 min and pupil focus groups lasted between 40 and 60 min. Questions first assessed the interviewee's attitudes towards school-based physical activity. A demonstration of a VFT was then provided by the researcher on a laptop (teacher interviews) or an interactive whiteboard (pupil focus groups). Questions then assessed the potential benefits and weaknesses of VFTs as physically active lessons (Fig. 1). Ethical approval from University College London was granted for both components of this research.

Data analysis

All interviews were audio recorded and transcribed verbatim on the day of the interview using Express Scribe software. Thematic analysis was used to analyse transcripts, with related quotes clustered to provide raw data themes [44]. An inductive approach was used to allow themes to emerge directly from the data [45]. Statements were read and re-read by two research team members, with emerging themes noted before being clustered into

Teacher Interviews

How much exercise do children do during the school day?
Besides PE, are there some lessons where physical activity could be integrated?
What have you heard about Virtual Field Trips?
- VFT Demonstration

What benefits could active Virtual Field Trips bring to your teaching?
What difficulties would you see in using active Virtual Field Trips?
How could you imagine active Virtual Field Trips being used in your classroom?
Is there anything else you would like to say about Virtual Field Trips?

Pupil Focus Groups

What do you like about going to school?
What exercise do you do at school and in the playground?
- VFT Demonstration

What did you like about the Virtual Field Trip?
What bits of the Virtual Field Trip do you think could be made better?
What places would you like to visit if you did another Virtual Field Trip?
Is there anything else you would like to say about Virtual Field Trips?

Note: Questions were repeated twice if necessary before prompts were used

Fig. 1 Teacher interview and pupil focus group questions related concepts [44]. The number of participants reporting each theme was recorded.

Results

Themes are organised according to each research aim and presented in order of diminishing prevalence.

Teacher interviews

Twelve teachers were interviewed, with ten working in primary-schools (ages 4–11) and two working in secondary schools (ages 11–18). Eleven interviewees were female, one interviewee was a primary school head teacher, one was a PE co-ordinator and two worked primarily with Special Educational Needs (SEN) children. Collectively, the participants held 62 years' experience working in schools.

Current physically active lesson teaching practices

Many interviewees (n = 8, 66.7 %) described physical activity in taught lessons as "becoming more the norm" and routinely taught in modern teacher training. Incorporating PA was also described as representative of engaging teaching practice by some participants (n = 4, 33.7 %), "If teachers aren't doing that then they're boring teachers". There was evident variability in use of physically active lessons, with teachers (n = 4, 33.7 %) describing use of PA lessons according to perceived group learning styles. "I think it just depends on the children". PA breaks and lessons were mentioned by interviewees (n = 8, 66.7 %) as a de-stressing and focusing technique for children: "it gives you both a bit of a break as well and it just re-jigs their mind and gets them back on task".

Barriers of physically active Virtual Field Trips

(1) Time

All teachers described children as insufficiently active during school hours due to a "packed curriculum" and academic pressures. Movement was stated as often restricted to break and lunchtimes due to academic pressures. For example, P.E. classes were mentioned by some (n = 4, 33.3 %) as often removed in favour of other academic lessons: "PE as well is one of the lessons where if you've got something else planned that you need to do then PE is the one that goes". One participant summarised this sentiment: "I think how much time do you have? There's so much pressure on what they're learning and the timetable's so rammed so you can't fit any more in." All but one interviewee (n = 11, 91.7 %) stressed that future VFT intervention packages must provide ready-to-use sessions: "anything like this needs to be easy to implement that can be used straight away". Many (n = 8, 66.7 %) also mentioned a need for clear guidance as to how each VFT session fit into curriculum topics, to help teachers envisage their usage more easily.

(2) Resistance to technology

Some interviewees (n = 7, 58.3 %) highlighted that VFTs could receive different reactions from teachers depending on their ICT competencies. They reflected on the attitudes of other colleagues towards interactive whiteboard use: "There's some staff who rely so heavily on technology... but there's teachers who are just very old school who don't even want to use the interactive whiteboards". This was stressed as a vital consideration to keep in mind during school and teacher recruitment. However no interviewed teachers felt that they themselves would have difficulties using the technology.

A minority of teachers (n = 3, 25 %) queried the suitability of VFT technology to reduce sedentary behaviour: "You could use electrical tools like this but you don't have to". They explained how they saw technology itself as a primary cause of child inactivity and that a non-technological alternative may be more appropriate. For example, "we're using technology to solve a problem that technology has caused", suggests perception of a cyclical relationship between technology and activity in these interviewees. Some teachers (n = 2, 16.7 %) described how outside activity is valued over class-based movement in their schools. For example "Schools like mine (would say) 'Take them outside'".

(3) Potential novelty factor

Some interviewees (n = 3, 25 %) identified a potential limited "novelty" factor for the interactive maps and media content in VFTs. Although all teaching staff had not seen the Google Tour Builder used before, some were wary it could become stale after a few lessons. For example: "think the novelty will be there with un-technological children but for those that are used to technology, they'll be like 'OK I get it'" Additionally, two teachers (n = 2, 16.7 %) reflected that schools find it difficult to keep up with frequent evolutions in technology: "with technology, nothing impresses them. If anything we're more impressed because we are behind, children are ahead of us".

Facilitators of physically active Virtual Field Trips

(1) Flexibility of VFTs as teaching tool

All teachers provided a variety of creative ways that VFTs could be used in their teaching. These ranged from "starters or plenaries' and as brain breaks to increase children's attention in the morning or after lunch. Teachers also enthusiastically provided a multitude of topics that VFTs could cover. Common areas included geography and history based themes, such as "With Year 5… the Victorians, Africa, the Aztecs, water, Geography, Earth Sun and Moon in Science, extreme Earth like tsunamis and lightning...". Some teachers (n = 5, 41.7 %) also mentioned the potential for 'Maths' or English-based sessions: "You could also do a story map of a book." One teacher (8.3 %) also emphasised the potential for VFTs as physical education teaching tools: "this lends itself beautifully to PE teaching... give me something on there that shows me the correct technique... we learn together as we practice it in class."

Additionally, some (n = 5, 41.7 %) described physically active VFTs as being "cross-curricular" in nature by linking physical activity to other topics: an important feature in the new English National Curriculum [46]. A minority (n = 3, 25 %) also mentioned the opportunity to add a competitive element to VFTs: encouraging group-based challenges to be more active. For example, "You could have competition and a leader board that was topic-based like with the fire (Great Fire of London): 'who could run away from the fire?' or 'Who can escape the plague quickest today?'

(2) VFTs for inclusive learning

A common theme throughout all teachers was the potential of VFTs as teaching tools to include all pupils in an equal learning environment. The presence of both visual and kinaesthetic elements in active VFTs was appealing to many (n = 6, 50 %) who saw this as "encouraging all types of learning styles to participate in lesson which is really good". Some teachers (n = 5, 41.7 %) also described physically active VFTs as useful to manage behaviour in pupils with attention disorders. Examples of conditions included ADHD, autism, or "those that a general static lesson doesn't necessarily grasp their attention for long enough". Teachers reflected on their use of physical activity in lessons especially to cater for these populations: "We do that all the time if any kid with SEN or ADHD, we always have physical activity involved in their lessons and that's mainly for them!"

Pupil focus groups

Three focus groups were held, two with Year 4 pupils (n = 12; 8–9 years old) and one with Year 5 pupils (n = 6; 9–10 years old). Nine boys and nine girls participated.

Experiences of school-based physical activity

All pupils reflected on their enjoyment of school playtime, swimming and extra-curricular physical activity opportunities. They also provided memorable experiences of lessons combining physical activity: "I enjoy when we have Maths and sometimes we go outside and we do activities... have to do charts of the activities."

Views on physically active Virtual Field Trips

(1) VFTs to share experiences with peers

All students commented on VFTs as an opportunity to have "fun" with their peers. As seen in teacher interview, pupils also suggested the introduction of teams to encourage physical activity competitiveness during the sessions. It was also mentioned that alternation of these teams would allow interaction socialisation with different pupils. For example, "You could have like a weekly group and you could keep changing it round so you get to socialise with other people... and just like try and also get to know them while learning." Three students (16.7 %) mentioned how VFTs could be used to explore and share countries of their heritage, "I would like to go back to my home country... I've heard these really cool stories about this really big volcano there and I would like to see it".

(2) VFT novelty

Pupils indicated familiarity with Google Earth software but described liking the novelty of using their bodies during the lesson and to answer questions. "I liked it... You could move around and use body movements to get picked (to answer a question)." Pupils also discussed how being active made them feel more immersed in the locations of the VFT: "you was like moving your arms, legs and your stomach to actually feel like you're actually going to that country".

(3) Exertion of VFT physical activity

Some children commented on feeling tired after the demonstration VFT: "You really get tired as you start to travel somewhere..." This may be expected given that this teaching style is innately different to the sedentary style they are used to.

Discussion

A range of evidence from qualitative interviews and process evaluation work exists evaluating the efficacy of school-based PA interventions. This study extended previous pilot work which trialled VFT technology and outcome measurements, by assessing teachers and pupils perceptions towards physically active VFTs. Despite there being little empirical evidence in the UK [20], teachers reported common use of physically active lessons in their own practice. A range of factors facilitating VFT use were identified. Teachers praised VFTs as inclusive learning tools due to their innate combination of kinaesthetic, audio and visual elements. They also provided a broad range of suggestions for potential VFT sessions, showing big scope for integration across the curriculum. Both teachers and pupils identified a potential for active VFTs to enable challenges between classmates: encouraging pupils to compete and be more active in sessions. This desire for competitiveness in VFT sessions contradicts previous research, finding increased overall PA enjoyment when rivalry is not involved [47].

Various important barriers were identified. Firstly, as with previous school-based PA intervention research; teachers saw a lack of teaching time as a potential barrier for VFT use [16, 17]. To maximise recruitment and fidelity in future research, teacher training must stress research showing increased PA in schools to not compromise academic achievement [15]. VFT interventions must be presented and acceptable to multiple stakeholders such as the head-teacher, teachers, parents and governors [18] to maximise uptake and minimise disruption.

Secondly, although VFTs were described by the researcher as ready-made sessions, some warned of potential resistance in teachers less confident in using technology. This may produce a biased sample as such teachers may hence be less likely to participate in VFT interventions or less likely to complete them as intended. Full training will be provided in future intervention work but this may still be insufficient to encourage some teachers of the merits of active VFTs. Some teachers also queried the use of technology to improve sedentary behaviour, as they described this as the result of children's increasingly technological lives. It seems a cyclical relationship between technology and activity is observed by these interviewees, which may again prevent VFTs being implemented. These considerations of VFT use replicate the Technology Acceptance Model [48, 49]. Under this model, teachers that perceive VFT technology as useful, easy to use and worthwhile will be more likely to use them. It will hence be necessary in future work to maximise these perceptions in teachers by stressing the practical benefits of VFT technology to teachers, such as its quick set-up time and multi-modal functionality. Finally, teachers predicted a potentially short novelty factor for VFTs. By integrating a variety of media, locations and movements into future VFT programmes, it is hoped that pupil's perceived enjoyment and novelty will persist. Longitudinal VFT study will assess if these perceptions of novelty remain during regular sessions and whether children become more attuned to being active during VFT sessions.

Methodologies used have some limitations. Firstly, there is mixed evidence for holding child focus groups in school settings and using existing class relationships. Pupils may have been positively prompted to answer to the best of their ability as with typical teaching, or may have conversely felt distracted by existing peer relationships or repressed by school expectations of adult-child hierarchies [50]. Secondly, there are specific issues within teacher methodology used. Interviews were held in a variety of locations, as chosen by each participant to maximise recruitment. As these were held during the school holidays, some were held in the interviewee's home. This may have led to differences in perceived trust or comfort in the interviewee, compared to more neutral environments [51]. Also, the use of convenience sampling to gain teacher participants via personal contacts and social media approaches may have biased responses. Two teachers taught secondary school age pupils to provide insight into teaching considerations for this age-group, although no secondary aged pupils were interviewed. Finally, teachers took part in a demonstration VFT session with the interviewer. However, use of a VFT by teachers themselves in an actual lesson may have prompted different responses. Future longitudinal intervention work will include a full process evaluation using teacher and pupil data, to enable deep assessment of VFT facilitators and barriers.

Conclusions

This study provides valuable insight into the perceptions of teachers and pupils of physically active lessons generally, as well as novel Virtual Field Trips as active lessons. Potential VFT barriers identified here will need to be addressed in future longitudinal work during recruitment, training and intervention development. It is clear from this study that although teachers and pupils are receptive to physically activity lessons; the use of classroom technology for interventions must be made transparent and efficacious for maximal uptake.

Abbreviations

VFTs: Virtual Field Trips; PA: physical activity.

Author details

[1] Department of Epidemiology and Public Health, University College London, 1-19 Torrington Place, London WC1E 7HB, UK. [2] Department of Clinical, Educational and Health Psychology, University College London, 26 Bedford Way, London WC1H 0AP, UK. [3] Department of Information Studies, University College London, Foster Court, London WC1E 6BT, UK. [4] Charles Perkins Centre, University of Sydney, Sydney, Australia. [5] Exercise and Sport Sciences, Faculty of Health Sciences, University of Sydney, Sydney, Australia.

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Competing interests

The authors declare that they have no competing interests.

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Appendix 5D. Study One Parent information sheet

DEPARTMENT OF EPIDEMIOLOGY AND PUBLIC HEALTH

UCL

VIRTUAL FIELD TRIP FOCUS GROUP
PARENT INFORMATION SHEET

This study is being carried out by Emma Norris, a PhD student at University College London (UCL), funded by the CRUCIBLE studentship fund. The project is being run in conjunction with the UCL Departments of Epidemiology and Public Health, Information Science and Clinical, Educational and Health Psychology. This sheet tells you more about the research and why it is being carried out.

What is a Virtual Field Trip?

Virtual Field Trips are a new teaching tool led by class teachers on their Interactive Whiteboard. They can allow incorporation on physical activity into teaching time by exploring curriculum-relevant maps and scenery. Virtual Field Trips are not intended to replace existing class trips, but provide an interactive tool to support class learning and activity.

What is this study about?

After a successful pilot in four primary schools, we want to learn more about what pupils would like from an ideal Virtual Field Trip. We are looking for Year 3-5 pupils to form a focus group to help us evaluate our current ideas and suggest new ones. Pupils will test out our existing Virtual Field Trip to help them understand how they work. Focus group discussions will be audio recorded to allow us to record opinions given. Photos may be taken during testing of these sessions to be included in research articles produced by this work. No identifying information will be taken from pupils.
I have undergone an enhanced DBS check. This project has received UCL Ethical Approval under Project ID: 3500/003.

How can my child be involved?

After reading this information:

- Please read and sign the attached parent informed consent sheet.
- Help your child read their own pupil information sheet and sign their attached informed consent sheet.
- **Please return these documents to the class teacher by ………………………………..**

We will be running a Virtual Field Trip Focus Group session with your child's class on ………………… ……………..

- Pupils in this focus group will be anonymous. No personally identifying information will be recorded.
- **Views and opinions expressed will be treated as strictly confidential and handled in accordance with the Data Protection Act 1998.**

Thank you for your co-operation.

For further information, please contact Emma Norris at:
Health & Social Surveys Group, Dept. of Epidemiology & Public Health, University College London, 1-19 Torrington Place, London, WC1E 6BT
e.norris.11@ucl.ac.uk / 07927 781575

Appendix 5E. Study One Parent informed consent sheet

DEPARTMENT OF EPIDEMIOLOGY AND PUBLIC HEALTH

UCL

VIRTUAL FIELD TRIP FOCUS GROUP
PARENT or GUARDIAN INFORMED CONSENT FORM

Please complete this form after you have read the Information Sheet.

Title of Project: Focus groups to inform main Virtual Field Trip study
This study has been approved by the UCL Research Ethics Committee (Project ID Number): 3500/003

Thank you for your interest in this research. Before you agree to take part you must be sure that you fully understand the project. If you have any questions arising from the Information Sheet or explanation given to you, please email e.norris.11@ucl.ac.uk or call 07927 781575.

Parent/ Guardian Statement

As parent/ guardian of a participating student ……..

1. I have read and understand the information sheet titled "Virtual Field Trip Focus Group – Parent Information Sheet" for the above study. I have been given a copy to keep. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I understand that if my child decides at any time that they no longer wish to take part in this project, they can notify the researchers involved and withdraw immediately.
3. I consent to the processing of my child's confidential study information for the purposes of this research.
4. I understand that photos may be taken when pupils are trying our existing Virtual Field Trip. These may be used in future publications of research findings. No identifying information will be taken or presented either in these photos or as part of the study.
5. I understand that information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.
6. I agree that the research project named above has been explained to me to my satisfaction and I agree for my child to take part in the above study.

Signed: …………………………………………………………………………. Date: ……………………………………

Appendix 5F. Study One Pupil information sheet

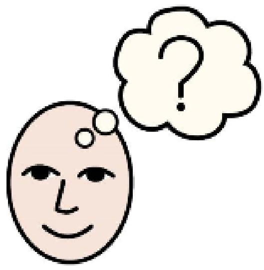
Virtual Field Trips in the Classroom

Pupil Information Sheet

Hello! My name is Emma. Just like you, I go to school every day. I study at a place called University College London. Universities are where people go to learn after they leave school. This is called being a student.

When at school, your teacher might ask you to research things. This is what I do every day at university. My project is to look at how your class interactive whiteboard can help you learn in a new way. In a small group, we will try out a Virtual Field Trip about the London 2012 Olympics.

LONDON 2012



In your small group, I will ask you some questions about what you have seen in the Virtual Trip. This is called evaluating: where you think of strengths and weaknesses about something. I will also ask you what you like about school and learning in general.

We may take pictures during the Virtual Field Trip. This will help us show other people what the lesson involves. I will record our conversation during the Focus Group to allow me to remember what you said.

If you are happy to take part, please sign the attached consent form.

Appendix 5G. Study One Pupil informed consent sheet

Virtual Field Trips in the Classroom

Pupil Informed Consent Form

Thank you for agreeing to take part in this study. Please make sure you have read the Pupil Information Sheet. An adult will also have to read and complete their own Informed Consent Sheet before you can take part in the study.

If you have any questions, please ask your parent or guardian to contact me (Emma) before you decide to take part.

I,

- have read the Pupil Information Sheet and understand what the study is about.
- understand that I can stop taking part at any time by telling my teacher or the researcher (Emma).
- know that the opinions that I give will be looked at in this research.
- understand my opinions will be private.
- Know that all conversations during the group conversation will be recorded.
- know that photos may be taken of the group when we try out a Virtual Field Trip
- agree that the study has been explained to me and I agree to take part.
-

Signed: ……………………………………………………. **Date:** …………………………………

Appendix 5H. Study One Teacher information sheet

DEPARTMENT OF EPIDEMIOLOGY AND PUBLIC HEALTH

UCL

VIRTUAL FIELD TRIP FOCUS GROUP
TEACHER INFORMATION SHEET

This study is being carried out by Emma Norris, a PhD student at University College London (UCL), funded by the CRUCIBLE studentship fund. The project is being run in conjunction with the UCL Departments of Epidemiology and Public Health, Information Science and Clinical, Educational and Health Psychology. This sheet tells you more about the research and why it is being carried out.

What is a Virtual Field Trip?

Virtual Field Trips are a new teaching tool led by class teachers on their Interactive Whiteboard. They can allow incorporation on physical activity into teaching time by exploring curriculum-relevant maps and scenery. Virtual Field Trips are not intended to replace existing class trips, but provide an interactive tool to support class learning and activity.

What is this study about?

After a successful pilot in four primary schools, we want to learn more about what teachers would like from an ideal Virtual Field Trip. We would also appreciate teachers' expert advice on practical considerations for running these sessions. We are looking for teachers of Year 3-5 classes to form a focus group to help us evaluate our current ideas and suggest new ones. Focus group discussions will be audio recorded to allow us to record opinions given.
I have undergone an enhanced DBS check. This project has received UCL Ethical Approval under Project ID: 3500/003.

How will I be involved?

After reading this information:

- Please read and sign the attached teacher informed consent sheet.

We will be running a Teacher Virtual Field Trip Focus Group session at your school at ……………. on ………………

- Participants in this focus group will be anonymous. No personally identifying information will be recorded.
- **Views and opinions expressed will be treated as strictly confidential and handled in accordance with the Data Protection Act 1998.**

Thank you for your co-operation.

For further information, please contact Emma Norris at:
Health & Social Surveys Group, Dept. of Epidemiology & Public Health, University College London, 1-19 Torrington Place, London, WC1E 6BT
e.norris.11@ucl.ac.uk / 07927 781575

Appendix 5I. Study One Teacher informed consent sheet

DEPARTMENT OF EPIDEMIOLOGY AND PUBLIC HEALTH

UCL

VIRTUAL FIELD TRIP FOCUS GROUP
TEACHER INFORMED CONSENT FORM

Please complete this form after you have read the Information Sheet.

Title of Project: Focus groups to inform main Virtual Field Trip study
This study has been approved by the UCL Research Ethics Committee (Project ID Number): 3500/003

Thank you for your interest in this research. Before you agree to take part you must be sure that you fully understand the project. If you have any questions arising from the Information Sheet or explanation given to you, please email e.norris.11@ucl.ac.uk or call 07927 781575.

Participant's Statement

I ………………………………………………………………,

1. I have read and understand the information sheet titled "Virtual Field Trip Focus Group – Teacher Information Sheet" for the above study. I have been given a copy to keep. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I have read the notes writen above and the Information Sheet, and understand what this study involves.
3. I understand that all discussions held during the Focus Group will be recorded for analysis.
3. I understand that information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.
4. I agree that the research project named above has been explained to me to my satisfaction and I agree for my class to take part in the above study.

Signed: …………………………………………………………………………. Date: ………………………………

Appendix 5J. Study One teacher interview script

A. Introduction

- First of all, thanks you for coming along today.
- My name is Emma Norris and I am a PhD student from University College London.
- I am researching new ways to increase exercise in children during school time. I am interested in hearing your views as a teaching expert on this subject and on a related teaching method I am developing. I would like to tape your comments and make notes on some of your ideas, feelings and thoughts as we go along.
- The session should last no longer than 60 minutes.
- Before we begin, I want to assure you that all of todays' discussions will be confidential. I can promise that no-one will be able to identify you or what you said. I hope that this means you will feel able to speak freely and not hold anything back that you think is important.
- Your views are valuable and will help to influence the development of future work I carry out with other schools during my PhD.
- In a minute, we shall begin the session and I shall start recording the discussion. Please talk loudly and clearly so the microphone can pick up what you say and we get a clear tape recording. It would be very helpful if you could say your name and the yeargroup you work with to start off.
- Are you happy to continue?

B. Focus group questions

N.B. Repeat question twice if necessary, before using prompt

1. How much exercise do children do during the school day?

PROMPT – Do you think children get enough exercise during school time? And/or How do children get their exercise during school? and/or Are there any differences in exercise between children?

2. Besides PE, are there some lessons where physical activity could be integrated?

PROMPT – For example, movements in drama lessons or alongside counting in Maths? and/or Have you used lessons that incorporate physical activity before?

3. What have you heard about Virtual Field Trips?

PROMPT – What do you think Virtual Field Trips involve?

VFT Description: Virtual Field Trips can come in many forms. Current examples mostly focus on museum projects such as the Louvre and Google Art Project sites (show pictures). Some are designed to be used individually by pupils and others by the class as a whole via interactive whiteboards. They all allow pupils to explore locations around the world.

My project is exploring if Virtual Field Trips can be used in a new way: to integrate physical activity into the classroom. Specifically, I will be working with Year 5 pupils. In 10-minute sessions, pupils will complete movements to simulate travel between different locations. It is hoped that with use of this new teaching method, pupils will increase their exercise during the day.

VFT Demo

4. What benefits could active Virtual Field Trips bring to your teaching?

PROMPT – How could you see active Virtual Field Trips as beneficial in your teaching?
And/or Are there any groups of children that this could benefit in particular?

5. What difficulties would you see in using active Virtual Field Trips?

PROMPT – What would constrain your use of active Virtual Field Trips?

6. How could you imagine active Virtual Field Trips being used in your classroom?

PROMPT – What curriculum topics could this be useful for?
And/or How long could the sessions be used for?
And/or How often would you use these sessions?
And/or When would you use the sessions?
And/or How often would you use these sessions?
And/or What age-groups could you see these sessions as useful for?

7. Is there anything else you would like to say about Virtual Field Trips?

C. Closing remarks

Once again, thank you for taking part. I hope you have found the discussion interesting. Your comments and ideas will be extremely useful in creating new ideas and addressing practical issues for the remainder of my PhD work.

Appendix 5K. Study One pupil focus group script

A. Introduction

- First of all, thanks to all of you for coming along today.
- My name is Emma Norris and I am researching new ways to help children learn at school. Today I want to hear your opinions on school and on a new way of learning in school. You will be helping me think of new lessons for other children like you.
- We will talk for no longer than an hour.
- This is Dr Nicola Shelton, who will be taking pictures and writing notes to help me remember what you said today.
- I would like to tape your comments and make notes on some of your ideas, feelings and thoughts as we go along. This will help me make improvements to the lesson and think of ideas for other lessons in the future.
- Everything that you say today will be private and between us. I can promise that no teachers or parents will be able to tell who said what. I hope that this means you will feel able to speak freely and tell me your true opinions on school and the lesson you will try out.
- We will use this ball to make sure that only one person speaks at a time. The person holding the ball can say their opinion. It is important to listen to others when they are talking. Once a person has finished speaking and you want to say something, raise your hand for the ball to be passed to you. There are no wrong answers as I want to know what your real thoughts are: good or bad.
- In a minute, we will begin and I shall start recording the discussion. Please talk loudly and clearly so the microphone can pick up what you say. It would be very helpful if you could say your name before you speak.

B. Focus group questions

N.B. Repeat question twice if necessary, before using prompt

1. What do you like about going to school?

PROMPT – What do you look forward to about going to school?

2. What exercise do you do at school and in the playground?

PROMPT – What exercise do you do doing school time?

VFT Introduction:

We will now try a new way of learning in the classroom. This is called a Virtual Field Trip. It allows classes to travel around the world without leaving the classroom. It is also slightly different to normal lessons as you will need to stand up throughout. When you are doing different movements, try to stay on-the-spot and do not bump into other pupils. The trip will last no more than ten minutes.

Demo

3. What did you like about the Virtual Field Trip?

PROMPT – What bits of the Virtual Field Trip did you enjoy?

4. Why did the session make you more active?

PROMPT – What about the Virtual Field Trip made you move more? And/or Was the session too short, just right or too long?

5. What bits of the Virtual Field Trip do you think could be made better?

PROMPT – What would you change about the Virtual Field Trip?

6. You can travel anywhere in the world on a Virtual Field Trip. What places would you like to discover if you did another trip?

PROMPT – Where can you imagine travelling to on a Virtual Field Trip And/or How often would you like to do an active session? Once every two weeks, once a week, twice a week, three times a week, every day?

7. Is there anything else you would like to say about Virtual Field Trips?

C. Closing remarks

Once again, thanks to all of you for taking part. I hope you have found our discussion interesting. Your comments and ideas will be extremely useful in helping to plan Virtual Field Trips for other pupils like you.

Appendix 6A. BMJ Open protocol paper of Study Two's Virtual Traveller intervention

BMJ Open

Protocol for the 'Virtual Traveller' cluster-randomised controlled trial: a behaviour change intervention to increase physical activity in primary-school Maths and English lessons

E Norris,[1] S Dunsmuir,[2] O Duke-Williams,[3] E Stamatakis,[1,4,5] N Shelton[1]

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For numbered affiliations see end of article.

Correspondence to
E Norris;
e.norris.11@ucl.ac.uk

ABSTRACT

Introduction: Physical activity (PA) has been shown to be an important factor for health and educational outcomes in children. However, a large proportion of children's school day is spent in sedentary lesson-time. There is emerging evidence about the effectiveness of physically active lessons: integrating physical movements and educational content in the classroom. 'Virtual Traveller' is a novel 6-week intervention of 10-min sessions performed 3 days per week, using classroom interactive whiteboards to integrate movement into primary-school Maths and English teaching. The primary aim of this project is to evaluate the effect of the Virtual Traveller intervention on children's PA, on-task behaviour and student engagement.

Methods and analysis: This study will be a cluster-randomised controlled trial with a waiting-list control group. Ten year 4 (aged 8–9 years) classes across 10 primary schools will be randomised by class to either the 6-week Virtual Traveller intervention or the waiting-list control group. Data will be collected 5 times: at baseline, at weeks 2 and 4 of the intervention, and 1 week and 3 months postintervention. At baseline, anthropometric measures, 4-day objective PA monitoring (including 2 weekend days; Actigraph accelerometer), PA and on-task behaviour observations and student engagement questionnaires will be performed. All but anthropometric measures will be repeated at all other data collection points. Changes in overall PA levels and levels during different time-periods (eg, lesson-time) will be examined. Changes in on-task behaviour and student engagement between intervention groups will also be examined. Multilevel regression modelling will be used to analyse the data. Process evaluation will be carried out during the intervention period.

Ethics and dissemination: The results of this study will be disseminated through peer-review publications and conference presentations. Ethical approval was obtained through the University College London Research Ethics Committee (reference number:
3500-004).

Strengths and limitations of this study

- Use of objective monitoring to assess physical activity (PA).
- Assessment of PA and educational outcomes.
- Intervention developed with teachers according to National Curriculum teaching objectives.
- Use of self-selected participation from teachers and classes.
- Blinding of participants and experimenter not possible due to novel nature of intervention.

INTRODUCTION

Physical activity (PA) in children has been linked to a range of positive health outcomes, including improved cardiometabolic profiles[1 2] and motor skills.[3] PA has also been shown to improve educational outcomes, such as on-task behaviour,[4] cognitive function[5] and academic achievement.[6] However, despite these wide-ranging benefits, children currently spend around 8.6 hours a day in sedentary activities,[7] found to be negatively associated with health[8] and educational outcomes.[9] Obligatory seated classroom lessons are an important contributor to this typically sedentary lifestyle. As PA[10] and sedentary behaviour levels[11] have been found to track into adulthood, it is vital that active habits are facilitated as much as possible during childhood.

Although schools and teachers are obliged by the National Curriculum[12] and OFSTED assessments[13] to facilitate PA and overall health and well-being, a lack of time is typically cited by teachers as the primary barrier for PA provision.[14] As such, interventions have attempted to make educational time more physically active via physically active lessons.[15] These integrate educational content with physical movements in the classroom environment: allowing curriculum and health objectives to be simultaneously addressed.[16] Physically active lessons are distinct from 'activity-breaks' or 'brain-breaks' which provide bouts of classroom-based PA without educational content.[17] Examples of physically active lesson programmes include Take 10![18] and Physical Activity Across the Curriculum (PAAC):[19] largely limited to American populations.

A recent systematic review of emerging physically active lesson research[15] found increased light and moderate-to-vigorous physical activity (MVPA) levels,[19 20] on-task behaviour[21] and academic achievement.[19] The increasing body of evidence shows the benefits of physically active lessons across PA and educational outcomes, indicating physically active lessons as a promising new teaching method.[22] However, this existing evidence-base has mostly assessed PA during the school day only and featured limited sample sizes.[15] Despite being relatively novel interventions, reporting of intervention details in physically active lesson research is often poor, preventing replication in research and educational contexts.[15] The effects of physically active lessons on student engagement, an essential precursor for learning reflecting an individual's behaviours and cognitions related to learning and the school environment,[23 24] has not yet been assessed. Physically active lesson research has also not used available classroom technology of interactive whiteboards,[25] used to deliver educational content in over 70% of UK classrooms.[26]

The Virtual Traveller intervention was developed to address these identified issues. It provides 10-min sessions of physically active Virtual Field Trips (VFTs) for teachers to deliver via the class interactive whiteboard during Maths and English teaching. VFTs allow classes to explore preselected locations around the world, using their movements to simulate interaction with and travel to destinations.[25] The Virtual Traveller intervention has been developed following mixed-methods feasibility work. A one-off VFT pilot intervention comparing a physically active VFT with a sedentary version found significantly reduced sedentary time and increased light and MVPA time in active VFT students.[25] A qualitative feasibility study of teacher interviews and student focus groups found positive perceptions of active VFTs as a fun, simple and inclusive method of combining movement and teaching.[27]

Hypotheses and aims

Following previous evidence into physically active lessons and a pilot study,[25] we hypothesise that the Virtual Traveller intervention will: (1) increase children's time in light PA and MVPA and reduce sedentary time during the school day, (2) increase children's time in light PA and MVPA and reduce sedentary time during lesson-time and (3) improve on-task behaviour during lesson-times. The primary aim of the study is to evaluate the provision of the Virtual Traveller intervention on children's PA, on-task behaviour and student engagement.

METHODS AND ANALYSIS

Study design

Virtual Traveller is a 6-week classroom-based physically active lesson intervention. It will be evaluated using a cluster-randomised controlled trial with a waiting-list control group. The waiting-list control group will be provided with the full programme of Virtual Traveller sessions after the final data collection period. Data collection will take place on a rolling basis from March 2015 until May 2016. Baseline data collection will take place before classes are randomised by computer programme[27] by the first author to either intervention or waiting-list control groups. Data will be collected twice during the 6-week intervention period at weeks 2 and 4 and twice at 1-week and 3-month follow-up (figure 1).

Recruitment and study participants

Ten state-funded primary schools from in and around Greater London will be recruited by the first author to participate in the Virtual Traveller study. One year 4 (aged 8–9 years) class from each school will participate, with the Virtual Traveller programme content developed around Maths and English National Curriculum for this year-group. Single classes across multiple schools will be recruited, as adding sites (schools in this study) is more consequential for multilevel modelling (MLM) power than adding participants per site.[28] Schools will be recruited via (1) Public Health and School Sports organisations in boroughs across Greater London and (2) via social media participant calls from the study's developed Twitter account. These recruitment approaches will be used as a very low follow-up rate (20%) was experienced by approaching schools on an individual basis via email in the previous pilot study.[25]

Following initial expressed interest, a face-to-face visit will be organised to explain the study details to participating head-teachers and teachers before schools give their final agreement to participate. To recruit children into the study, the lead researcher (EN) will deliver a 10-min presentation to participating classes 2 weeks prior to baseline assessment, introducing the Virtual Traveller project, accelerometer devices and benefits of participating. At the end of presentations, participants will be provided with hard copy parent and student information and informed consent sheets and a parent questionnaire to complete and return. To encourage participant retention and accelerometer wear adherence, an ongoing incentive competition will be run within each class. A certificate will be given to the child in each class with the longest accelerometer wear time at each data collection phase. Also, the child in each class with the longest overall wear time across intervention phases will be given a certificate and £10 activity vouchers for their local leisure centre. To prevent potential

Norris E, *et al. BMJ Open* 2016;6:e011982. doi:10.1136/bmjopen-2016-011982

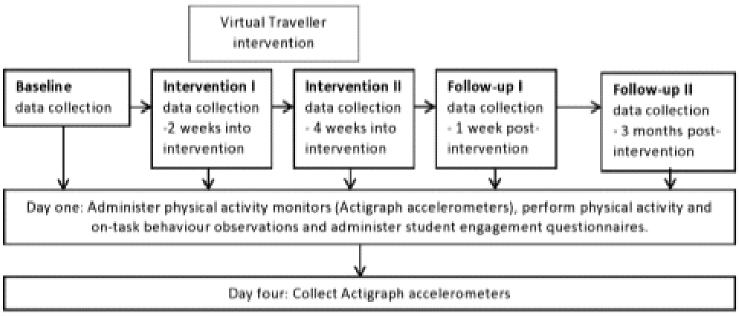

Figure 1 Virtual Traveller intervention study design.

bias from this competition element, the researcher will remind all students at each data collection phase that the prize is based on their wear time alone and not based on how active they are.

Intervention

The Virtual Traveller programme is designed to be integrated into year 4 National Curriculum Maths and English teaching.[12] The programme consists of eighteen, 10-min physically active VFT sessions, to be run three times a week over the 6-week intervention period. Nine sessions are based on English and nine on Maths content. Sessions were developed with consultation from 2-year four teachers identified during qualitative feasibility work.[27] Each session has its own identifying code number, with a summary of all sessions provided in figure 2. Sessions can be run in any order to best suit content being taught by teachers at the time. Sessions can also be run at any point of Maths and English teaching, that is, not restricted to being used as a starter or plenary only. Globe-based movement throughout sessions also makes them highly cross-curricular,[12 27] combining Maths, English and Geographical content. Qualitative feasibility work identified that the sessions should be provided on simple, familiar software to best facilitate teacher-use.[27] Virtual Traveller sessions will hence be provided on ubiquitous Microsoft Powerpoint software with embedded Google Earth videos[29] via USB stick.

Sessions will be delivered using classroom interactive whiteboards. Teachers will stand and lead each session, read included questions and movement prompts, and demonstrate movements. Students will stand behind their desks and complete prompted movements throughout each session. Included Google Earth videos will show transitions between locations on a virtual globe, with accompanying text prompting children to simulate appropriate movements as they 'travel', such as running on-the-spot. Additional images, YouTube videos and sound effects,[30] were also included to add interest. Detailed overviews of example Maths and English Virtual Traveller sessions are provided in online supplementary appendices A and B.

Teacher training

Following baseline measurements and randomisation by class, all intervention classroom teachers will be required to attend a 30-min one-on-one training session with the lead researcher. This will be organised according to the teachers' availability, either before school or after school, or during teachers' preparation, planning and assessment time. Training will briefly outline research showing the benefits of child PA on health, education and well-being (~5 min). Teachers will then be asked to reflect on the extent they integrate PA into their own teaching and discuss their experiences of this (~5 min). An outline of Virtual Traveller will then be given, detailing the length, intensity and features of the intervention. A sample Virtual Traveller session will be demonstrated by the researcher on their laptop (~5 min). The process evaluation log sheet will then be introduced: requiring teachers to record which Virtual Traveller sessions they run, when and their perceived success out of 5. Teachers will be requested to complete the log immediately after each session to minimise forgetting. Finally, a Virtual Traveller Guide will be introduced and provided for teachers to use as a reference document during the intervention (~5 min). This includes brief information on how to access the Virtual Traveller sessions, a brief summary of all sessions and description of physical activities included and an answer key for questions included within sessions. The researcher will also discuss the teacher's upcoming short-term and medium-term planning to see how the Virtual Traveller programme could best be imbedded into their Maths and English teaching (~10 min). Email and telephone contact details for the researcher will be given to support all teachers with intervention or measurement procedure queries during the study. Face-to-face support for teachers will also be provided during data collection visits.

Procedures

Data collection procedures will take place over 3 months in each participating class. The lead researcher will collect data on a date convenient to each class teacher. Data collection sessions will last ~20 minutes.

Maths	English
M1: Tens and Hundreds Challenge Pupils use their movements to show multiplications and divisions by tens and hundreds.	**E1: Kung Fu Punctuation 1 (White Belt)** Visit China for your Kung Fu Punctuation training. Use Kung Fu moves to represent appropriate punctuation in example sentences.
M2: Maths Marching Practice times tables and angles whilst marching for the Queen's Trooping the Colour. Choose the times table appropriate for your class.	**E2: Kung Fu Punctuation 2 (Black Belt)** Add some more complex punctuation to your Kung-Fu Punctuation repertoire, before a freestyle session.
M3: Maths: True or False? Use movements to show if you think statements related to Maths are true or false.	**E3: English: True or False?** Pupils use movements to show if you think statements related to English are true or false.
M4: London 2012 Olympics and beyond Explore the London Olympic park and the future of the Olympics. Count and time the actions of famous Olympians whilst simulating their actions.	**E4: Explanation Texts** Pupils show their understanding of explanation text features using movements.
M5: Metric Movements Practice metric measurements using movements to answer length, weight and capacity questions.	**E5: Mystery Monsters** You are given adjectives to an imaginary monster. Pupils use movements to show how they think the monster would move and act.
M6: Sports Galore Practice addition, multiplication and subtraction using sports movements.	**E6: Noun Reverse Charades** The class use movements to act out a mystery word for one pupil to guess.
M7: Rock around the Clock Learn how to use different periods of time from seconds to millennia using movements.	**E7: Persuasive Writing** The class use movements to show their understanding on the features of persuasive writing.
M8: Money, Money, Money! Practice calculations with money using movements to show the answers.	**E8: Frozen Vocabulary** Practice your class' own target spellings to practice definitions and spelling to movement. 'Frozen' as in freezing your movements-not the movie! *requires spellings to have been set*
M9: Global Dance Count Count how many target moves you do to dance crazes.	**E9: Apostrophes & Plurals** Pupils use movements to indicate where apostrophes should go in possessive and plural sentences.

Figure 2 Summary of Virtual sessions.

Anthropometric assessments will be taken at baseline only, taking an additional 10 min. Objective devices (accelerometers) will be given to children to monitor their PA behaviour as soon as they arrive at school on the first day of each data collection phase. It is recommended that accelerometers are worn for at least 4 days to provide a reliable estimate of children's habitual PA.[31] Devices will hence be provided to participating children for four full days (2 weekdays and 2 weekend days) at each data collection phase and to capture school-time and leisure-time activity. Trained researchers will observe children's PA and on-task behaviour during Virtual Traveller sessions (in intervention students only) or typical teaching (control students and intervention students during baseline and follow-up assessments). A student engagement questionnaire will be provided to students. On day 4, participants will return the device to the lead researcher at school. This process will be repeated at all data collection points.

After baseline assessments, cluster randomisation of classes to intervention or waiting-list control groups will be done via computer programme.[32] Randomisation will continue until five intervention classes and five control classes are allocated. Waiting-list control classes will continue to receive their normal teaching during the study: receiving teacher training and the full intervention on USB stick after the final data collection point.

Use of behaviour change theory and techniques

As identified in the aforementioned systematic review,[15] physically active lesson research has been largely atheoretical to date. This study embeds the COM-B model[33] (figure 3) to increase children's PA during lesson-time and beyond. The key COM-B model cognitions of Capability, Opportunity and Motivation are applied within the Virtual Traveller intervention context to maximise PA behaviour change. As the provision of physically active lessons is ultimately the decision of the teacher, it is important that such interventions address teacher cognitions specifically. First, teachers' capability to integrate activity into teaching will be addressed in this study via teacher training: planning how and when Virtual Traveller sessions will be integrated into Maths and English teaching. Head-teacher support will also be secured via a face-to-face meeting with the researcher to ensure teachers' capability is supported at an institutional level. Second, teachers' opportunity to teach physically active lessons must be increased. Virtual Traveller will provide this by physically supplying relevant, ready-made teaching resources and ensuring activities are suitable given class space restrictions. Teacher's motivation to teach physically active lessons will be addressed by

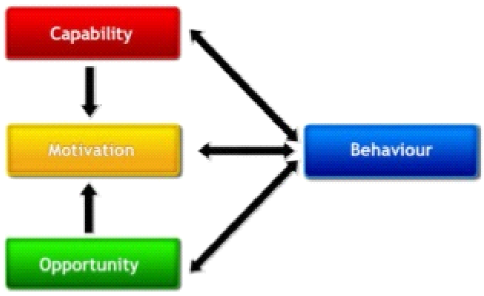

Figure 3 COM-B model.

Norris E, et al. BMJ Open 2016;6:e011982. doi:10.1136/bmjopen-2016-011982

providing Virtual Traveller sessions that are quick to run,[14] provided on familiar Powerpoint software[27] and produce visible activity and educational benefits to students.

As identified in the aforementioned systematic review,[15] specific reporting of physically active lesson intervention details to date has been mostly weak. By reporting the exact nature and content of these novel interventions in a standardised way, studies can be more accurately compared and replicated.[34] To aid replication of the Virtual Traveller intervention, the Behaviour Change Techniques (BCTs) embedded into the intervention and its procedures are reported according to the Behaviour Change Technique Taxonomy V.1 (BCTTv1).[35] BCTs represent the 'active ingredients' of interventions influencing behaviour change in participants.[36] The BCTs embedded during teacher training and the intervention itself are listed in figure 4. For example, during teacher training, the researcher will work with participating teachers to formulate action plans (BCT 1.4) on how they would integrate the three Virtual Traveller sessions each week into their Maths and English teaching. During the intervention, a Virtual Traveller-branded teacher log will be placed on the wall by the teacher's computer as a prompt (BCT 7.1) to remind them to run the Virtual Traveller sessions.

Measurement and instruments

Anthropometric

At baseline, weight will be assessed by the researcher to the nearest 0.1 kg (Weight Watchers 8961U electronic scales, Milton Keynes, UK) and height to the nearest mm (2 m tape measure). Body mass index (BMI; kg/m^2) will be produced from these measurements, to allow assessments of potential differential effects of the Virtual Traveller intervention between BMI categories. Underweight, overweight and obesity prevalence will be estimated using the 2nd, 85th and 95th centiles of the 1990 UK reference curves.[37]

Accelerometer

Accelerometers are recognised to provide the most valid and reliable measurement of children's PA.[31] This study will use Actigraph GT1M accelerometers: wearable motion sensors that measure movement across X- and Y-axes and provide date and time-stamped data on activity duration and intensity throughout the day. These devices have been identified as having acceptable validity and reliability in children.[38] Objective PA monitoring has been successfully used in other physically active lesson interventions.[19 39] The Actigraph will be attached to an adjustable elastic belt and worn on the child's right hip. Accelerometers will be activated at 09:00 on day 1 when accelerometers are distributed at the start of school and deactivated at 23:59 on day 4. This will provide a total of 86 hours maximum wear time for each data collection phase. Children will be asked to wear the device during waking hours every day for four consecutive days, but not during water-based activities or sleep to limit device damage and participant discomfort.

Observations

Pilot work identified a need for additional PA measurements in active VFT sessions. Although children were physically observed by teachers and researchers to be highly active during a one-off active VFT session, Actigraph GT1M accelerometer output recorded the majority of session time as sedentary.[25] Accelerometers

Taxonomy Category	Behaviour Change Techniques (BCTs)	Definition	Example in Virtual Traveller intervention
During teacher training			
1. Shaping knowledge	4.1 Instruction on how to perform the behaviour	Advise or agree on how to perform the behaviour (includes skills training)	Provided an individual training session to each intervention teacher: instructing how to run Virtual Traveller sessions and how they address the English and Maths National Curriculum
2. Natural consequences	5.1 Information about health consequences	Provide information about health consequences of performing the unwanted behaviour	Training presented findings from previous research showing negative effects of extended sitting and benefits of physical activity on pupil's health, wellbeing and educational outcomes
3. Comparison of outcomes	9.1 Credible source	Present verbal or visual information from a credible source in favour of the behaviour	The scientific validity behind studies discussed in teacher training was shown at a basic level
4. Comparison of behaviour	6.3 Information about others' approval	Provide information about what other people think of the behaviour	Share anonymous pupil and teacher feedback from VFT feasibility work[25,27]
5. Goals & planning	1.4 Action planning	Prompt detailed planning of performance of the behaviour	During training teachers planned when to teach three Virtual Traveller sessions a week within Maths and English lessons
During intervention			
6. Associations	7.1 Prompts/Cues	Introduce environmental or social stimuli designed to prompt behaviour	A teacher log was placed by the teacher's computer to remind them to do Virtual Traveller sessions
7. Feedback & Monitoring	2.3 Self-monitoring of behaviour	Establish a method for the person to monitor and record their behaviour	Teachers were prompted at all contact points to complete the teacher log after each Virtual Traveller session
8. Repetition & substitution	8.2 Behaviour substitution	Prompt substitution of unwanted behaviour with a wanted behaviour	The intervention replaces inactive teaching practices with physically active Virtual Traveller sessions in Maths and English
9. Goals & planning	1.1 Goal setting (behaviour)	Set or agree a goal defined in terms of the behaviour to be achieved	Teachers agreed with researcher to teach three Virtual Traveller sessions a week within Maths and English lessons during the intervention

Figure 4 Behaviour Change Techniques embedded into Virtual Traveller intervention and teacher training.

have weaker sensitivity to non-ambulatory, on-the-spot movements such as those elicited by VFT sessions, compared to accelerating, travelling movements such as running.[40] Triangulation of accelerometers with other PA measurement methods seems appropriate. Physical activity observations are recognised as a useful validation technique for controlled activity situations.[41] The Children's Activity Rating Scale (CARS)[42] will be used to code observed PA behaviour during Virtual Traveller and control sessions. This defines observed activities into five intensity categories: stationary, stationary with limb or trunk movements, slow movement, moderate movement and fast movement. CARS has previously been triangulated with objective data in other child-based studies.[43 44]

On-task behaviour during Virtual Traveller and control sessions will be assessed using the Observing Teacher and Pupils in Classrooms (OPTIC) tool.[45] This rates behaviour as on-task (making eye contact with teacher or task, following teacher's instructions) or off-task. Observations similar to OPTIC have been previously used to assess on-task behaviour in physically active lesson interventions.[21 46]

Both tools will be applied in the same observations to reduce researcher and class burden. Two VFT (intervention group) or two typically taught Maths or English lessons (control group) will be observed for each class. Teachers will provide researchers with a class seating plan featuring participant numbers to enable identification during each observation. Sessions will be observed for 20-min periods using a monetary time sampling technique. Participating students will be observed in turn for 4 s before the next child is observed, with data recorded on a standardised score sheet. To allow inter-rater reliability of both measures, one session in each class (N=10; 20% of all observations) will be observed by two researchers. An observer training session will be run in a baseline session to assess absolute agreement in inter-rater reliability of both measures.

Questionnaires

Parents will be provided with a hard copy demographic questionnaire along with their informed consent documents. This will take ~ 5 min to complete and contains questions on the child's sex, ethnicity, English language status, disability status and free school meal status and family income.

Student engagement will be assessed in children at each data collection point using the Student Engagement Instrument—Elementary Version (SEI-E),[47] a primary-school version of the well-validated School Engagement Instrument (SEI).[48 49] The SEI-E features 24 items assessed on 4-point Likert scales, ranging from strongly disagree to strongly agree. It takes 15–20 min to administer and assesses four constructs of student engagement: Teacher–Student Relationships, Peer Support for Learning, Family Support for Learning and Future Goals and Aspirations.[47] The SEI-E is a relatively new instrument, to date only validated in its original sample (n=1943);[47] however, few other tools are available to assess student engagement in primary-school ages.[24 48] As previous research has shown student engagement to be more accurately reported by students themselves rather than teacher proxy reports,[50] it seemed appropriate to use a direct student questionnaire measure. Teachers, teaching assistants and research staff will assist students in completing the questionnaire.

Process evaluation

The overall feasibility of the Virtual Traveller intervention and its implementation will be assessed via a process evaluation within all intervention classes.[51] This will be based around the RE-AIM framework to assess: Reach, Effectiveness, Adoption, Implementation and Maintenance.[52 53] First, teachers will be provided with a Virtual Traveller log sheet to record which sessions they run, when and the perceived success of the session out of 5. Teachers will be requested to complete the log immediately after each session to minimise forgetting. Second, a process evaluation questionnaire will be provided to students and teachers at weeks 2 and 4 of the 6-week intervention. Providing these questionnaires on two occasions will allow any potential change in satisfaction during the intervention to be recorded. Six questions of 5-point Likert scales will be used in each questionnaire. Example items include 'I liked being physically active during the Virtual Traveller programme' for students and 'Virtual Traveller sessions that I have run have met appropriate learning outcomes' for teachers. The student questionnaire will also feature the one-item pictorial Children's OMNI scale of perceived exertion[54] to assess perceived physical effort during Virtual Traveller sessions. Student and teacher questionnaires also contained two questions for free-text responses: 'What do you like about Virtual Traveller?' and 'What do you not like about Virtual Traveller?' Finally, teacher interviews and student focus groups will be run after the intervention period. Student focus groups and teacher interviews will last around 15-min, use semistructured questions and be audio-recorded and transcribed by the lead researcher. For student focus groups, one mixed sex group of six students per class will take part. Each teacher will be asked to select two children of lower, middle and higher overall academic ability, as done in previous physically active lesson evaluation.[55] Questions will explore students' perceptions and enjoyment of Virtual Traveller sessions, examples of memorable sessions and potential improvements. Teacher interviews will be arranged according to teacher availability. Questions will investigate teacher perceptions of Virtual Traveller sessions compared to typical Maths and English teaching. Perceived effects of Virtual Traveller on children's PA and educational outcomes will be explored, as well as challenges to implementing the programme.

Norris E, *et al. BMJ Open* 2016;6:e011982. doi:10.1136/bmjopen-2016-011982

ANALYSIS

Outcomes

The primary outcome for this study will be the change in average daily time spent in MVPA as recorded by the Actigraph accelerometer. Secondary outcomes assessed via accelerometers, observations and student questionnaires will include (1) changes in daily time spent in light, moderate and vigorous lesson-time PA, (2) changes in lesson-time spent in light, moderate and vigorous lesson-time PA, (3) changes in on-task behaviour during lesson-time and (4) change in student engagement.

Quantitative analysis

Raw data will be extracted from each Actigraph accelerometer and analysed using ActiLife software. To maximise the study sample, participants will be included in analysis if they provide at least 1 day of valid accelerometer wear time, including one Virtual Traveller day in intervention students. Sensitivity analysis will be carried out to compare results if a minimum of 3-day valid accelerometry data are included. Valid accelerometer wear time will be defined as at least 500 min wear time between 07:00 and 00:00. This replicates criteria previously used in research utilising The International Children's Accelerometry Database (ICAD),[2] the world's largest resource of pooled child accelerometer data. Data will be collected in 5 s epochs[31] and analysed using Pulsford cut-points[56] to classify activity as sedentary: (<100 counts per minute, CPM), light (100–2240 CPM), moderate (2241–3840 CPM) or vigorous (≥3841 CPM). As per methods followed in the International Children's Accelerometry Database, non-wear will be defined as 60 min of consecutive zeros, allowing for 2 min of non-zero interruptions.[57] MLM will be used to reflect the hierarchical relationships between students and schools (one class tested in each school).[58] Three-level multilevel models will be developed to assess the differences in outcomes between time-point (Level 1), pupils (Level 2) and classes (Level 3). All authors will have access to the final trial data set.

Sample size calculations

Sample size calculations were run to assess the number of students and classes needed to detect changes in the primary outcome of accelerometer-assessed PA in CPM. The Optimal Design MLM sample size calculation programme was used (Raudenbush SW. Optimal Design Software for Multi-level and Longitudinal Research. Version 3.01, 2011). Considering available resources, it was initially decided that a maximum of 10 classes could be recruited. Settings for the power calculations reflected those used in other physically active lesson research.[39] Calculations were based on baseline post-test correlation scores of r=0.30,[39] 80% power, α levels set at p<0.05, a conservative intraclass correlation coefficient (ICC=0.15) and a maximum class cluster of J=10. It was calculated that a study sample of n=140 with 10 clusters (ie, classes) of 14 students providing valid accelerometry data will be needed to provide sufficient power to detect a between-intervention group difference.

DISCUSSION

Strengths and limitations

Strengths of this study include its use of objective monitoring to assess PA, its assessment of PA and educational outcomes and its teacher-supported programme development. A limitation of this study is its reliance on self-selected participation from teachers and classes. This may limit the applicability of findings to wider teaching environments.

Ethical consideration and dissemination

Teachers of each participating class will be asked to provide written consent for their schoolchildren to participate in the study. The researcher will then deliver a 10-min session to classes 2 weeks prior to baseline assessment, introducing the Virtual Traveller project and accelerometer devices. All parents of children in participating classes will then be asked to provide written consent for their child to participate. Children will also be provided with age-appropriate consent information. Participants will be identified by participant number only and can withdraw from the study at any time. Data will be only collected in students with completed consent forms; however, all students in each intervention classroom will take part in Virtual Traveller sessions. A 10-min debriefing session will be provided by the researcher in each class after the final data collection phase. Unintended and adverse effects will be assessed within process evaluation assessment. Permission for any important protocol modifications will be sought by the ethics committee and reported to trial participants and in subsequent publications.

The findings from this study will first be disseminated to Public Health and School Sports organisations contacted during recruitment. Second, we will also disseminate to social media channels via the developed Virtual Traveller Twitter account. Finally, we will disseminate to academic researchers and policymakers via academic conference presentations and journal articles.

Author affiliations
[1]Department of Epidemiology & Public Health, University College London, London, UK
[2]Department of Clinical, Educational and Health Psychology, University College London, London, UK
[3]Department of Information Studies, University College London, London, UK
[4]Charles Perkins Centre, Prevention Research Collaboration, School of Public Health, Sydney Medical School, University of Sydney, Sydney, New South Wales, Australia
[5]Faculty of Health Sciences, University of Sydney, Sydney, New South Wales, Australia

Twitter Follow Emma Norris at @EJ_Norris

Contributors EN, SD, OD-W, ES and NS made substantial contributions to the concept and design of the study. EN drafted the manuscript and SD, OD-W, ES and NS critically revised it.

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Competing interests None declared.

Patient consent Obtained.

Ethics approval Ethical approval was obtained through the University College London Research Ethics Committee (reference number 3500-004).

Provenance and peer review Not commissioned; externally peer reviewed.

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Appendix 6B. Virtual Traveller study flyer for Study Two

DEPARTMENT OF EPIDEMIOLOGY AND PUBLIC HEALTH

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Inviting Year 4 classes to try a new form of lesson:

VIRTUAL TRAVELLER STUDY

- 10-minute ready-made, physically active Maths & English sessions
- Travel around the world, without leaving the classroom
- Highly cross-curricular
- Have fun and learn at the same time!

If you'd like to know more, please contact me (Emma Norris)
https://virtualtravellerstudy.wordpress.com/
Email: e.norris.11@ucl.ac.uk / Phone: 07927 781575

Information will be treated as strictly confidential and handled in accordance with the Data Protection Act 1998.

Appendix 6C. Example of Virtual Traveller accelerometer wear-time competition certificate for Study Two

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Well Done

DIAMOND AWARD

Well Done

For wearing the red box for the longest time during the whole Virtual Traveller study in Class 4D

VIRTUAL TRAVELLER

Presented to

………………………………………………………………

Signed by Lead Researcher, Emma Norris

Appendix 6D. Teacher information sheet for Study Two

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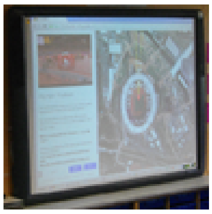
VIRTUAL TRAVELLER

Teacher Information

This study is being carried out by Emma Norris, a PhD student at University College London (UCL), funded by the CRUCIBLE studentship fund. This sheet tells you more about the research and why it is being carried out.

What is the Virtual Traveller programme?



The Virtual Traveller programme uses Virtual Field Trips to **add movement into teaching**. These **10-minute sessions** use interactive whiteboards to teach core **Key Stage 2** competencies in **Maths and English** using physical actions. Virtual Traveller is also highly **cross-curricular**, integrating geography in its use of map-based orientation and P.E. with its range of movement. It is also quick and easy to use. There is no need to re-organise furniture as pupils stand behind their chairs to complete actions and only a free Google Earth browser plug-in is required.

What is this study about?

We have already piloted Virtual Field Trips as one-off sessions in primary school classes. We have also interviewed teachers to gauge what curriculum topics could be integrated into such sessions. We are now looking for **Year 4** classes to help us test our **6-week programme**.
Your Headteacher has kindly agreed for us to work with your school and we would be very happy to work with you and your class.

We want to answer two key questions:

1) Can Virtual Field Trips improve physical activity in and outside the classroom?
2) Can Virtual Field Trips provide improve student engagement?

I have undergone an enhanced CRB/DBS check. This project has received UCL Ethical Approval under Project ID: 3500/004.

How will you be involved?

Following your informed consent (please see attached form), you will be involved in three ways:

1) **Distributing and collecting information packs**
These will be provided for home-school bags 2 weeks before the allotted study date. They provide information sheets and informed consent sheets for both parents and pupils and a brief parent questionnaire. No identifying data will be collected in this questionnaire, with all participants identified by a number only. **Pupils cannot participate without both a parent and pupil informed consent form.**
- I will (with your permission) speak to pupils on this distribution day to introduce myself, the project and assist with the information pack distribution. Information packs will be resent 1 week before the study date to non-responders.

2) Teaching Virtual Traveller programme or typical teaching

We will first take a baseline assessment of measurements in typical teaching. You will then be randomly allocated to teach either:

1) teach the 'Virtual Traveller' programme of 10-minute Virtual Field Trips 3x a week during Maths and English lessons **OR**

2) typical teaching over a 6-week period.

If you are selected to use Virtual Traveller, I will meet with you at a time and date convenient to you for a brief training session and provide you with a guidebook. These trips will be readily available via our website (http://virtualtravellerstudy.wordpress.com/) and simply require a Google Earth browser plug-in. Even if you are not allocated to the Virtual Traveller programme, you will be provided with the lessons, guidebook and training at the end of the study.

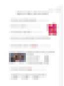
3) Allowing me into your classroom to:

- Weigh and measure participating children and provide Actigraphs (taking 2 mins. per child)
- Distribute questionnaires (taking 30 minutes)
- Observe pupil on-task behaviour and movement (for one lesson). These sessions will be video-recorded to allow the research team to check coding. They will not be used to assess teaching and will be destroyed after analysis.

4) Provide feedback of Virtual Traveller (if randomised to receive it) in an interview at the end of the 6-week programme. This will last up to 30 minutes and will be audio recorded for analysis.

Study Timeline

Measurements

	 Height & weight	 Exercise (Box 1)	 Questionnaires (Box 2)	 Observe Class behaviour (Box 3)
Week 1– Typical teaching	✓	✓	✓	✓

Week 2-7– 6 weeks of either: 10-minute **Virtual Field Trips** 3x a week in Maths and English lessons

OR Typical **teaching**

Week 2				
Week 3		✓		✓
Week 4				
Week 5		✓	✓	✓
Week 6				
Week 7				

Week 8– Typical teaching	✓	✓	✓	✓
3 months later	✓	✓	✓	✓

Is this survey confidential?

Yes. We take great care to protect the confidentiality of the information we are given. **Information will be treated as strictly confidential and handled in accordance with the Data Protection Act 1998.** These results will not be presented in a form which can reveal you or your pupil's identity. Pupils will only be identified by the number given on their informed consent sheet.

Box 1: Information on Actigraphs

What is an 'Actigraph' monitor?

The Actigraph is a small machine that records information about physical activity patterns. The monitor records body movements during normal daily activities such as walking and jogging. Unlike pedometers, they do not give feedback on activity via a screen. They only give feedback via specific software.

How will my pupils wear the monitor?

The monitor is worn on the waist using the elastic belt provided. It will sit above the right side of their body, above their right hip. Ideally the monitor should be worn under their clothes and kept fastened to the belt to prevent it getting lost.

How long will my pupils wear the monitor?

Pupils will wear the Actigraph 5 times in total: once before the intervention period, twice during, one week afterwards and 3 months afterwards. This allows us to track changes in activity over time. Pupils will wear the Actigraph for 4 consecutive days: 2 weekdays and 2 weekend days e.g distributed on Thursday morning and collectec Monday afternoon. I will be in school to distribute and collect devices. These device will be re-used for other studies so it is very important that children look after ther Pupils will be given a diary to help them record their wear-time.

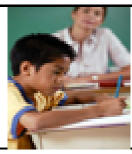
Box 2: Questionnaires used

Children will complete questionnaires taking no longer than 30 minutes during school time on:

- Their enjoyment of exercise and school
- Evaluation of Virtual Field Trip sessions (if receiving these)

Box 3: Class behaviour

I will observe the on-task behaviour of all participating children during classroom time. I will not interfere or participate in teaching time. As with all elements of this study, results will remain anonymous.



What are the benefits of this study?

- Allows pupils to be involved in scientific research and record their own physical activity
- Receive a ready-made range of 10-minute active Maths and English sessions.
- Result reports provided to you and your school
- Participating classes will be provided with a 'Thank You' certificate! Also, **the pupil in each class with the most wear-time will receive swimming vouchers**

Thank you for your co-operation.

For further information, please contact Emma Norris at:

Health & Social Surveys Group, Dept. of Epidemiology & Public Health, University College London, 1-19 Torrington Place, London, WC1E 6BT

e.norris.11@ucl.ac.uk / 07927 781575 / http://virtualtravellerstudy.wordpress.com/

Appendix 6E. Teacher informed consent form for Study Two

DEPARTMENT OF EPIDEMIOLOGY AND PUBLIC HEALTH

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VIRTUAL TRAVELLER

Teacher Informed Consent

Please complete this form after you have read the Information Sheet.

Title of Project: Virtual Field Trips to reduce children's sedentary time and improve wellbeing in Primary School Children

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 3500/004

Thank you for your interest in this research. Before you agree to take part you must be sure that you fully understand the project. If you have any questions arising from the Information Sheet or explanation given to you, please email e.norris.11@ucl.ac.uk or call 07927 781575.

Participant's Statement

As teacher of class...............

1. I have read and understand the information sheet titled "Virtual Field Trip Study – Teacher Information Sheet" for the above study. I have been given a copy to keep. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I confirm that depending on the random allocation of my class, I will be providing either the 'Virtual Traveller' programme or typical teaching.
3. I understand that my class' participation is voluntary and that we are free to withdraw at any time without penalty.
4. I understand that some lessons during this study will be video recorded regardless of the intervention group we are allocated to. This is to assess the pupils' behaviour and not the quality of teaching. I understand that these recordings will be destroyed after the researchers' analysis.
5. If receiving Virtual Traveller, I understand that I will be interviewed for up to 30 minutes to evaluate the programme at the end of the 6-week programme.
6. I have read the notes written above and the Information Sheet, and understand what the study involves.
7. I understand that information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.
8. I agree that the research project named above has been explained to me to my satisfaction and I agree for my class to take part in the above study.

Signed: .... **Date:** ....

Appendix 6F. Parent information sheet for Study Two

DEPARTMENT OF EPIDEMIOLOGY AND PUBLIC HEALTH

UCL

Parent Information

This study is being carried out by Emma Norris, a PhD student at University College London (UCL), funded by the CRUCIBLE studentship fund. This sheet tells you more about the research and why it is being carried out.

What is a Virtual Field Trip?

Virtual Field Trips are a new teaching tool we have developed to introduce exercise into taught lessons. They are led by class teachers on their Interactive Whiteboard. Classes explore different maps whilst completing movements related to the scenery. Virtual Field Trips are not intended to replace existing class trips, but provide an interactive tool to support learning.

What is this study about?

We are testing the effects of using Virtual Field Trips into class teaching time. We are looking for Year 4 classes to help us in our pilot research. Your teacher has kindly agreed for us to work with your school.

We want to answer three key questions:

1) Can Virtual Field Trips improve movement in the classroom?
2) Can Virtual Field Trips provide movement without reducing learning?
3) Can Virtual Field Trips improve attention in the classroom?

I have undergone an enhanced CRB/DBS check (Jan. 2013). This project has received UCL Ethical Approval under Project ID: 3500/004.

How can my child and I be involved?

1) After reading this information:

- Please read and sign the attached parent informed consent sheet and complete the short parent questionnaire.
- Help your child read their pupil information sheet and sign their informed consent sheet.
- **Please return these documents to the class teacher by ………………..**

2) Your child's class will randomly take part in one of two study arms, with their teacher either:

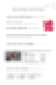
- teaching **10-minute Virtual Field Trips 3 x a week in Maths and English lessons over 6 weeks with your child's class** (intervention group)

OR - providing **typical teaching** (comparison group; will receive full range of materials at the end of the study)

Please note; both groups are as important as each other. We cannot assess how effective Virtual Field Trip sessions are without a typical teaching comparison group.

Study Timeline

Measurements

	Height & weight	Exercise (Box 1)	Questionnaires (Box 2)	Observe Class behaviour (Box 3)
Week 1– Typical teaching	✓	✓	✓	✓

Week 2-7– 6 weeks of either: 10-minute **Virtual Field Trips** 3x a week in Maths and English lessons
OR Typical teaching

	Height & weight	Exercise (Box 1)	Questionnaires (Box 2)	Observe Class behaviour (Box 3)
Week 2				
Week 3		✓		✓
Week 4				
Week 5		✓	✓	✓
Week 6				
Week 7				
Week 8– Typical teaching	✓	✓	✓	✓
3 months later	✓	✓	✓	✓

Box 1: Exercise measurements - Actigraphs

What is an 'Actigraph' monitor?

The Actigraph is a small machine that records information about physical activity patterns. The monitor records body movements during normal daily activities such as walking and jogging. The monitor records no other information and is not harmful.

How will my child wear the monitor?

The monitor is worn on the waist using the elastic belt provided. It will sit above the right side of their body, above their right hip. Ideally the monitor should be worn under their clothes and kept fastened to the belt to prevent it getting lost.

How long will my child wear the monitor?

On the weeks indicated on the Study Timeline; children will wear Actigraphs for four consecutive days: 2 weekdays and 2 weekend days. Depending on class schedules, the Actigraph will be given to pupils on either a Thursday or Friday morning and collected on either Monday or Tuesday afternoon.
Your child will be given an Actigraph diary to help them remember to wear it.

Actigraphs only provide activity information when connected to special software.
Please ensure the Actigraph is returned as they will be used with other participants and in other research.

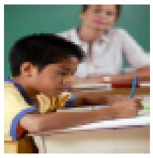
Box 2: Questionnaires used

Children will complete questionnaires taking no longer than 30 minutes during school time on:

- Their enjoyment of exercise and school
- Evaluation of Virtual Field Trip sessions (if receiving these)

Box 3: Class behaviour

I will observe the on-task behaviour and physical activity of all participating children during classroom time. I will not interfere or participate in teaching. To enable researchers in the team to check my findings, observed lessons will be video-recorded. These will be destroyed after these checks. As with all elements of this study, results will remain anonymous.



What will my child gain from this study?

- **Certificates will be given to the child in each class who wears Actigraph for the longest during each phase**
- **Activity prize given to the child in each class who wears Actigraph for longest overall**
- Take part in cutting-edge research from one of the UK's top universities
- Providing information for results that will be distributed to participating schools
- Be the first to help test a new teaching tool that could be used by many in the future

Is this survey confidential?

Yes. We take great care to protect the confidentiality of the information we are given. **Information will be treated as strictly confidential and handled in accordance with the Data Protection Act 1998.** These results will not be presented in any way which can reveal you or your child's identity. Pupils will only be identified by the number given on their and your informed consent sheet.

Thank you for your co-operation.

For further information, please contact Emma Norris at:

Health & Social Surveys Group, Dept. of Epidemiology & Public Health, University College London, 1-19 Torrington Place, London, WC1E 6BT

e.norris.11@ucl.ac.uk / 07927 781575

Please find more information at: http://virtualtravellerstudy.wordpress.com/

Appendix 6G. Parent informed consent form for Study Two

DEPARTMENT OF EPIDEMIOLOGY AND PUBLIC HEALTH

UCL

VIRTUAL TRAVELLER

Parent Informed Consent

Please complete this form after you have read the Information Sheet.

Title of Project: Virtual Field Trips to improve health and learning outcomes in Primary School Children
This study has been approved by the UCL Research Ethics Committee (Project ID Number): 3500/004

Thank you for your interest in this research. Before you agree to take part you must be sure that you fully understand the project. If you have any questions arising from the Information Sheet or explanation given to you, please email e.norris.11@ucl.ac.uk, call 07927 781575 or visit http://virtualtravellerstudy.wordpress.com/

Parent/ Guardian Statement

As parent/ guardian of participant no. ……..
Child's name (for identification in-school only)……………………………………………………………

1. I have read and understand the information sheet titled "Virtual Traveller Study – Parent Information Sheet" for the above study. I have been given a copy to keep. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I understand that if my child decides at any time that they no longer wish to take part in this project, they can notify the researchers involved and withdraw immediately.
3. I understand that my child will only be identified by their participant number.
4. I agree to complete the Parent Questionnaire provided in the information pack.
5. I understand that my child's biometric details (height and weight) will be taken. This will only be used to assess the effectiveness of the Virtual Field Trip. This information will be confidential.
6. I agree for 3 teaching sessions in my child's class to be video-recorded to assess on-task behaviour and physical activity in the classroom. No identifying information will be captured. This is only to allow checking of results by the research team. Videos will be destroyed after this analysis.
7. I understand that information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.
8. I agree that the research project named above has been explained to me to my satisfaction and I agree for my child to take part in the above study.

Signed: ………………………………………………………………………… **Date:** ………………………………

Appendix 6H. Pupil information sheet for Study Two

Pupil Information

Hello! My name is Emma Norris and I am a PhD student researcher. I will be working with your class at school to carry out a research project called 'Virtual Traveller'.

You should only take part if you want to – choosing not to take part will be ok too. If you would like to take part, I will be asking you and your parent/carer to complete the consent form and a questionnaire before the programme.

What is the study about?

The Virtual Traveller project is looking at how your class interactive whiteboard can help you learn and be more active during class time.

What will I be doing?

If you take part in this study, I will:

- give you some questionnaires to complete
- weigh and measure you
- watch and record some of your lessons. This is for me to remember what your lessons were like.
- give you a red box to wear around your waist that measures how much you move. It does not tell me where you are or what you are doing; only how much movement your body is doing. You will wear this red box for four days in a row, including two weekdays and two weekend days. I will then collect it from you at school.

P.T.O

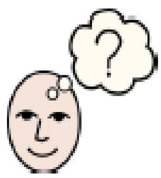
Over the next 6 weeks, your teacher will then either continue to teach you as normal **or** run some 10-minute sessions in your Maths and English classes on your interactive whiteboard. We will decide which class has which type of lesson at random.

If you take part in this study, I will give you the red box again during this time. After the 6 weeks, I will give you the red box again, as well as give you some questionnaires and weigh and measure you during school time. I will then come in 3 months later and give you a red box, measure you and give you questionnaires again during school time.

What do I get from taking part?

- **The person who wears the red box for the longest time during each phase will win a certificate. The person who wears it for the longest overall during the study will win an activity prize!**
- You will be the first in the world to try and test this new type of lesson. If you enjoy it, other teachers and children may go on to use these lessons
- You will be using the red box to measure how active you are in a scientific way.
- I will give ALL teachers the Virtual Traveller lessons to use once the study is over. That means that you all will still be one of the first to use these new lessons!

I will not record your name so any measurements or anything you say or do will be private. **If you are happy to take part, please sign the consent form.**



Appendix 6I. Pupil informed consent form for Study Two

Participant Number ☐

VIRTUAL TRAVELLER

Pupil Informed Consent

Thank you for agreeing to take part in this study. Please make sure you have read the Pupil Information Sheet. An adult will also have to read and complete their own Informed Consent Sheet before you can take part in the study.

If you have any questions, please ask your parent or guardian to contact me (Emma) before you decide to take part.

Name ……………………………………………………………………….

I,

- have read the Pupil Information Sheet and understand what the study is about.
- understand that I can stop taking part at any time by telling my teacher or the researcher (Emma).
- know that I will be wearing a red box activity monitor for four days in a row at five times during this study. I will be given a diary to help me remember to wear the red box.
- know that some of my lessons will be video recorded during this time for Emma to remember them. The videos will be destroyed at the end of the study
- understand that I will only be identified by my participant number and my study results will be private.
- agree that the study has been explained to me and I agree to take part.

Signed: ……………………………………………………. **Date:** ….……………………………

Appendix 6J: Teacher record sheet for returned consent documents in Study Two

Virtual Traveller: Returned consent sheet

Participant No	Pupil Name	Parent Informed Consent Received	Parent Questionnaire Received	Pupil Informed Consent Received
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
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24				
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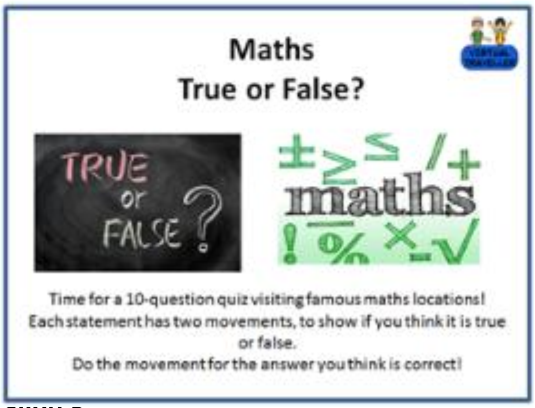
28				
29				
30				
31				

Appendix 6K: Sample Maths Virtual Traveller session – M3: Maths True or False

Slide 1

Welcome & provides summary of session



Slide 2

Video: Pupils jump along from space to first location

Slide 3

Questions: True response = jump rope on spot/ False response = simulated ball kicks

Slide 4

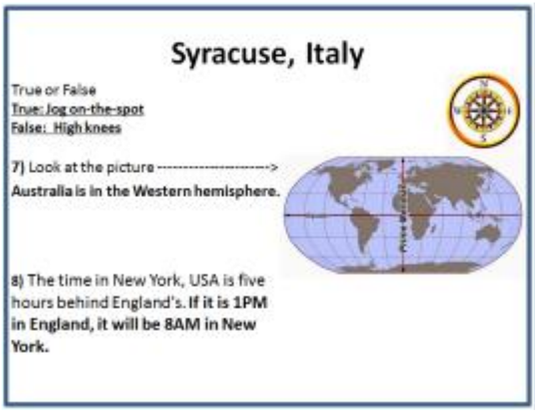
Video: Pupils hop, skip and jump to the next location

Slide 5

Questions: True response = star jumps False response = hip circles

Slide 6

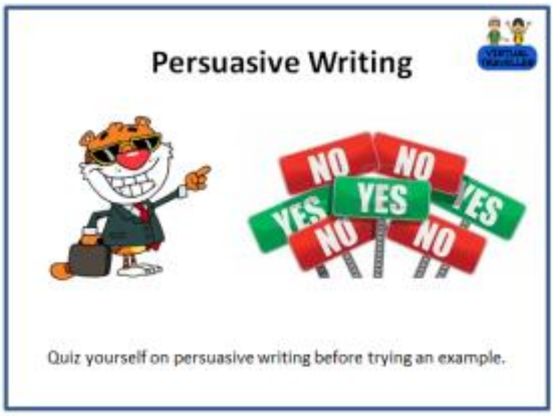
Questions: True response = jog on-the-spot / False response = high knees

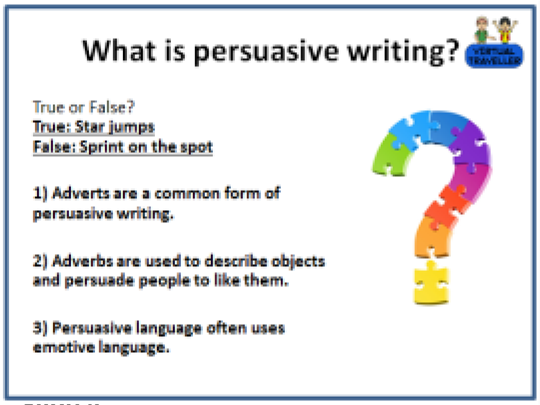


Appendix 6L: Sample English Virtual Traveller session – E7: Persuasive writing

Slide 1
Welcome & provides summary of session

Slide 2
Questions: True response = star jumps
False response = sprint on-the-spot



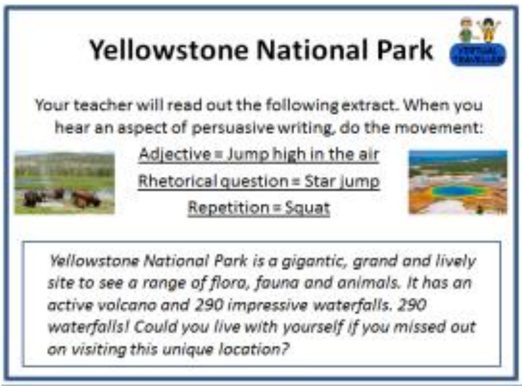


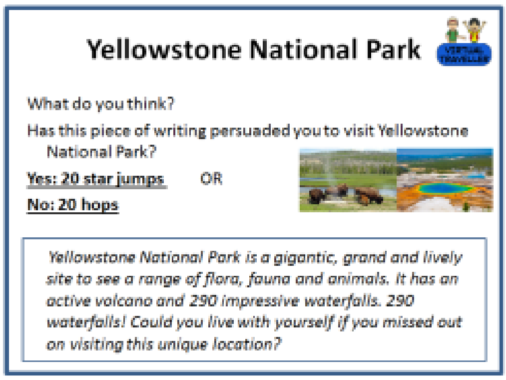
Slide 3
Video: Pupils run on-the-spot to the next location

Slide 4
Introduction to final activity

Slide 5
Activity: Adjective = jump / Rhetorical question = star jump / Repetition= squat

Slide 6
Question: Agree = 20 jumps
Disagree=20 hops

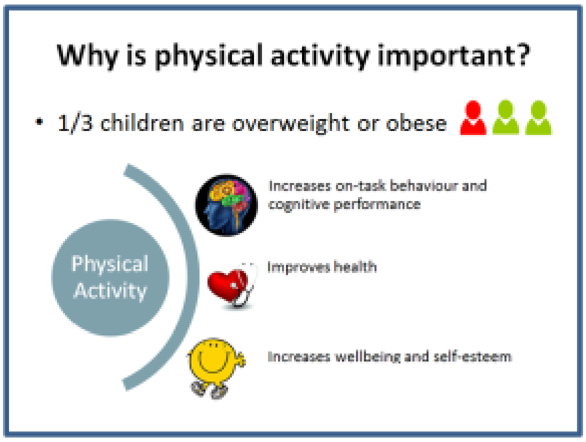


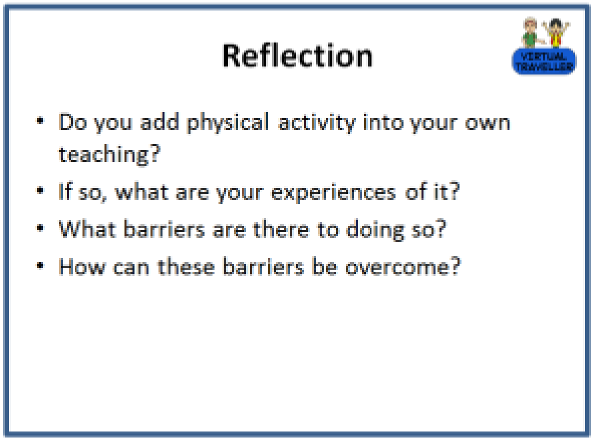


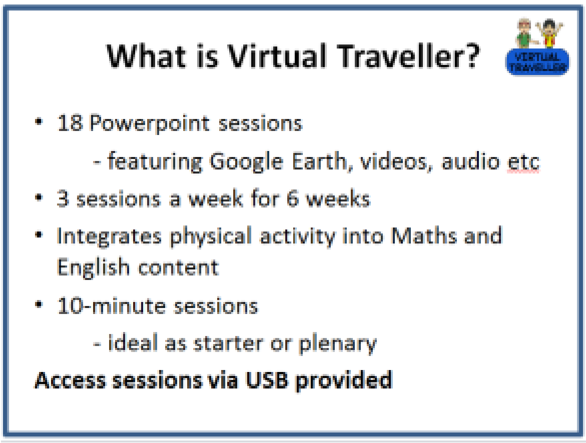
Appendix 6M: Virtual Traveller intervention sessions in Study Two

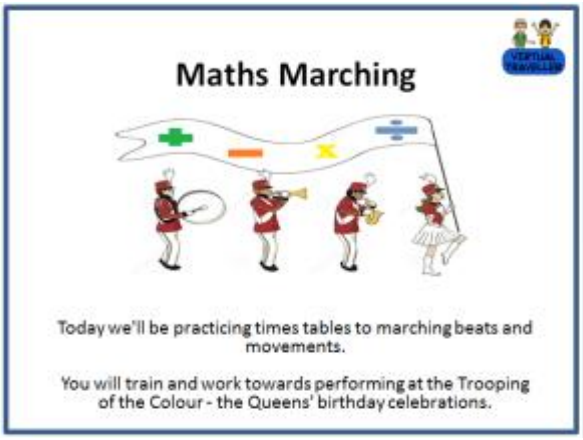
Maths	**English**
M1: Tens and Hundreds Challenge Pupils use their movements to show multiplications and divisions by tens and hundreds.	E1: Kung Fu Punctuation 1 (White Belt) Visit China for your Kung Fu Punctuation training. Use Kung Fu moves to represent appropriate punctuation in example sentences.
M2: Maths Marching Practice times tables and angles whilst marching for the Queen's Trooping the Colour. Choose the times table appropriate for your class.	E2: Kung Fu Punctuation 2 (Black Belt) Add some more complex punctuation to your Kung-Fu Punctuation repertoire, before a freestyle session.
M3: Maths: True or False? Use movements to show if you think statements related to Maths are true or false.	E3: English: True or False? Pupils use movements to show if you think statements related to English are true or false.
M4: London 2012 Olympics and beyond Explore the London Olympic park and the future of the Olympics. Count and time the actions of famous Olympians whilst simulating their actions.	E4: Explanation Texts Pupils show their understanding of explanation text features using movements.
M5: Metric Movements Practice metric measurements using movements to answer length, weight and capacity questions.	E5: Mystery Monsters You are given adjectives to an imaginary monster. Pupils use movements to show how they think the monster would move and act.
M6: Sports Galore Practice addition, multiplication and subtraction using sports movements.	E6: Noun Reverse Charades The class use movements to act out a mystery word for a pupil to guess.
M7: Rock around the Clock Learn how to use different periods of time from seconds to millennia using movements.	E7: Persuasive Writing The class use movements to show their understanding on the features of persuasive writing.
M8: Money, Money, Money! Practice calculations with money using movements to show the answers.	E8: Frozen Vocabulary Practice your class' own target spellings to practice definitions and spelling to movement. *requires spellings to have been set*
M9: Global Dance Count Count how many target moves you do to dance crazes.	E9: Apostrophes & Plurals Pupils use movements to indicate where apostrophes should go in possessive and plural sentences.

Appendix 6N. Teacher training Powerpoint presentation for Study Two









Training

Let's start our training by practicing a times table of your teachers' choice.

March and practice saying the times table out loud to the beat! e.g 1 x 3 is 3, 2 x 3 is 6.
Don't forget to start with a salute!

International Training

The next stage of your training has taken you to the Indian jungle.

March big, heavy steps along with the elephants.
Can you count how many steps the elephants take during this clip?

From India to.....

Jump on a pogo stick to our next location...

The Big Show! Trooping the colour

Keep time as you march with the Queen's Guards in the Trooping the Colour ceremony.

Keep marching and follow your teachers' commands e.g 'Turn 90 degrees to the left/180 degrees to the right'

Teacher log

Teaching Guide

Support available

If you have any questions or issues, during the study, please contact me at:

- E.norris.11@ucl.ac.uk
- 07927 781575
- @VirtFieldTrip

Appendix 6O. Teacher intervention log for Study Two

VIRTUAL TRAVELLER

Teacher VFT Record Sheet

Please tick the days you deliver Virtual Field Trip sessions.
Please also write the VFT topic and rank how successful the session was out of 5.

Week 1 Date:	Week 2 Date:	Week 3 Date:	Week 4 Date:	Week 5 Date:	Week 6 Date:
Monday Topic: Rating out of 5:	Monday Topic: Rating out of 5:	Monday Topic: Rating out of 5:	Monday Topic: Rating out of 5:	Monday Topic: Rating out of 5:	Monday Topic: Rating out of 5:
Tuesday Topic: Rating out of 5:	Tuesday Topic: Rating out of 5:	Tuesday Topic: Rating out of 5:	Tuesday Topic: Rating out of 5:	Tuesday Topic: Rating out of 5:	Tuesday Topic: Rating out of 5:
Wednesday Topic: Rating out of 5:	Wednesday Topic: Rating out of 5:	Wednesday Topic: Rating out of 5:	Wednesday Topic: Rating out of 5:	Wednesday Topic: Rating out of 5:	Wednesday Topic: Rating out of 5:
Thursday Topic: Rating out of 5:	Thursday Topic: Rating out of 5:	Thursday Topic: Rating out of 5:	Thursday Topic: Rating out of 5:	Thursday Topic: Rating out of 5:	Thursday Topic: Rating out of 5:
Friday Topic: Rating out of 5:	Friday Topic: Rating out of 5:	Friday Topic: Rating out of 5:	Friday Topic: Rating out of 5:	Friday Topic: Rating out of 5:	Friday Topic: Rating out of 5:

Appendix 6P. Virtual Traveller Teaching Guide for Study Two

Virtual Traveller

Teaching Guide

Thank you for taking part in this project.

This guide will give you all the information you need to know to run Virtual Traveller sessions.

What is Virtual Traveller?

- Uses PowerPoint-based 'Virtual Field Trips' to add movement into teaching
- 10-minute sessions ideal as session starters
- Cover core Year 4 competencies in Maths and English using physical actions.
- Highly cross-curricular: integrates geography and P.E. into Maths and English

You should teach all of the sessions across the Maths and English sections. However it is up to you which order you teach them to best fit your timetable.

More information on the measurements we are taking before, during and after the programme can be found on your School Information Sheet.

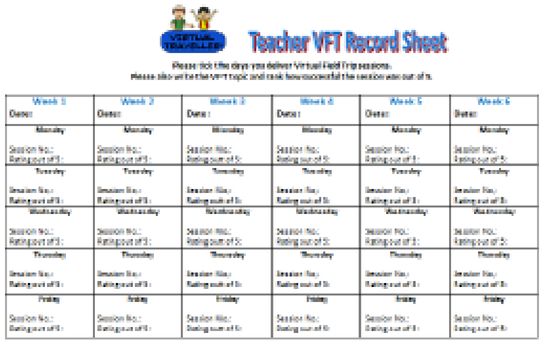
How to run a Virtual Traveller session

During the 6-week programme, we ask you to teach **3 Virtual Traveller** sessions a week. You should teach all of the sessions provided. However it is up to you which order you teach them to best fit your timetable.
The sessions last 10 minutes and so are ideal as a starter or plenary.
We recommend that you browse the sessions before you begin teaching them.

- You can access all Virtual Traveller Powerpoint sessions using the USB stick provided.

- Answers for questions within sessions can be found on the Teacher Answer Key (pg 5)

DON'T FORGET: Mark each session you do off on your Teacher Log. You can do the sessions in any order: just make sure you note the session number (e.g M1) and give it a rating out of 5.


Teacher VFT Record Sheet

Please tick the days you deliver Virtual Field Trip sessions.
Please also write the VFT topic and rank how successful the session was out of 5.

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Date:	Date:	Date:	Date:	Date:	Date:
Monday Session No.: Rating out of 5:	Monday Session No.: Rating out of 5:	Monday Session No.: Rating out of 5:	Monday Session No.: Rating out of 5:	Monday Session No.: Rating out of 5:	Monday Session No.: Rating out of 5:
Tuesday Session No.: Rating out of 5:	Tuesday Session No.: Rating out of 5:	Tuesday Session No.: Rating out of 5:	Tuesday Session No.: Rating out of 5:	Tuesday Session No.: Rating out of 5:	Tuesday Session No.: Rating out of 5:
Wednesday Session No.: Rating out of 5:	Wednesday Session No.: Rating out of 5:	Wednesday Session No.: Rating out of 5:	Wednesday Session No.: Rating out of 5:	Wednesday Session No.: Rating out of 5:	Wednesday Session No.: Rating out of 5:
Thursday Session No.: Rating out of 5:	Thursday Session No.: Rating out of 5:	Thursday Session No.: Rating out of 5:	Thursday Session No.: Rating out of 5:	Thursday Session No.: Rating out of 5:	Thursday Session No.: Rating out of 5:
Friday Session No.: Rating out of 5:	Friday Session No.: Rating out of 5:	Friday Session No.: Rating out of 5:	Friday Session No.: Rating out of 5:	Friday Session No.: Rating out of 5:	Friday Session No.: Rating out of 5:

Top Tips

- Pupils should tuck chairs in and stand at their desks. There is no need to move furniture.

- Please have a look through the Powerpoint before you wish to run it.

- Try to initiate movement wherever possible e.g when travelling between different locations in the session. Get your pupils to run, fly, hop, swim or even create new actions!

- Use our 'Teacher Answer Key' for all the answers to session questions.

- Make sure you have volume on – there will be music & videos!

If you have any questions or comments during the study, please contact Lead Researcher, Emma Norris at: e.norris.11@ucl.ac.uk / 07927 781575

Session Guide

Sessions can be run in any order.

Maths

M1: Tens and Hundreds Challenge

The class is split into 2 teams to answer questions multiplying and dividing by tens and hundreds. Pupils have 15 seconds to calculate and do movements to show when they have worked it out the answer.

M2: Maths Marching

Practice times tables and angles whilst marching for the Queen's Trooping the Colour. The level of challenge for your pupils is up to you e.g choose times table difficulty.

M3: Maths: True or False?

Use movements to show if you think statements related to Maths are true or false.

M4: London 2012 Olympics and beyond

Explore the London Olympic park and the future of the Olympics. Count and time the actions of famous Olympians whilst simulating their actions.

M5: Metric Movements

Use movements to answer questions of length, weight and capacity.

M6: Sports Galore

Practice addition, multiplication and subtraction using sports movements.

M7: Rock Around the Clock

Practice longer, medium and short term time-period calculations using movements.

M8: Money, Money, Money

Convert pennies into pounds and vice versa.

M9: Global Dance Count

Counting how many target moves you do to dance crazes.

English

E1: Kung Fu Punctuation 1 (White Belt)
Visit China for your Kung Fu Punctuation training. Use Kung Fu moves to represent appropriate punctuation in example sentences.

E2: Kung Fu Punctuation 2 (Black Belt)
Add some more complex punctuation to your Kung-Fu Punctuation repertoire.

E3: English: True or False?
Use movements to show if you think statements related to English are true or false.

E4: Explanation Texts
Pupils show their understanding of explanation text features using movements.

E5: Mystery Monsters
You are given adjectives to an imaginary monster. Pupils use movements to show how they think the monster would move and act.

E6: Noun Reverse Charades
Pick students one at a time to guess noun-based Charades performed by the rest of the class.

E7: Persuasive writing
Understand elements of persuasive writing to movements.

E8: Frozen Vocabulary
Practice your class' own target spellings to practice definitions and spelling to movement. 'Frozen' as in freezing your movements-not the movie! *requires spellings to have been set*

E9: Apostrophes and Plurals
Understand the correct use of apostrophes for plurals and possession.

Teacher Answer Key

Many sessions have questions with specific, correct answers.

Maths

M1 – Tens and Hundreds Challenge **1)** 1500 **2)** £8.20 **3)** 37 miles each **4)** 1600 **5)** £230 **6)** 120	**M2 - Maths Marching** Jungle Book – 60 elephant steps
M3 - Maths: True or False? **1)** True **2)** False, £98 **3)** False, 200 **4)** True **5)** True **6)** False, £5 **7)** False, Eastern hemisphere **8)** True **9)** True **10)** False	**M4 – London 2012 Olympics & beyond** **1)** USA **2)** 17 **3)** No **4)** 10 **5)** 5 **6)** 1000
M5 – Metric Movements **1)** 4m **2)** 6km **3)** 5m **4)** 9kg **5)** 7g **6)** 12t **7)** 10cl **8)** 5l **9)** 4	**M6 - Sports Galore** **1)** 8 **2)** 16 **3)** 18 **4)** 8 **5)** 4 **6)** 26
M7 – Rock around the Clock **1)** 10 **2)** 15 **3)** 3 **4)** 5 **5)** 20 **6)** 10 **7)** 12 **8)** 4	**M8 – Money, money, money** **1)** £3.50 **2)** £7.40 **3)** £2.60 **4)** £15.21 **5)** £4.79 **6)** £62 **7)** £38
M9 – Global Dance-Count **Gangnam Style** - 24 **Walk Like an Egyptian** - 8 **Cha-Cha Slide** - 6 **How many altogether?** 38	

English

E3 - English True or False? **1)** False **2)** False **3)** True **4)** True **5)** False - He also wrote short stories for adults. **6)** False (must have) **7)** False **8)** True **9)** False **10)** False	**E4 – Explanation Texts** **1)** False **2)** True **3)** False **4)** True **5)** False **6)** False **7)** True **8)** True
E9 – Apostrophes and Plurals **1)** The bag is Emma's. **2)** The handsome princess' sword was sharp. **3)** You're very funny. **4)** The teachers' class jumped very high. **5)** Plural **6)** Possession **7)** Plural **8)** Correct **9)** Correct **10)** Incorrect	

Appendix 6Q. Lesson observation sheet for Study Two

Time: Class:

Observation schedule

- 4s observations for 20 minutes

Children's Activity Rating Scale (CARS)

Observed activity code	Operational definition	Representative activity
1	Stationary/ motionless	Sitting and talking
2	Stationary with limb/trunk movements	Sitting and playing
3	Slow/easy movement	Slow walking
4	Moderate movement	Fast walking
5	Fast movement	Jogging

Observing pupils and teachers in classrooms (OPTIC)

Observed code	Operational definition
1	On-task (making eye contact with teacher or task, following teacher's instructions)
2	Off-task

Part.	CARS Rating	On task?	Part.	CARS Rating	On task?	Part.	CARS Rating	On task?

Appendix 6R. Parent demographic questionnaire for Study Two

DEPARTMENT OF EPIDEMIOLOGY AND PUBLIC HEALTH

UCL

Participant No. ☐

VIRTUAL TRAVELLER

Parent / Guardian Questionnaire

Thank you for agreeing for your child to take part in this study.
As well as signing the attached Parent Consent Form, we would be grateful if you would complete this short questionnaire. Please tick accordingly:

1) My child is: Male ☐ Female ☐

2) How old is your child? 8 years ☐ 9 years ☐ 10 years ☐

3) Was your child born in the United Kingdom? Yes ☐ No ☐

If not, when did they most recently arrive to live here? Month ☐ Year ☐

4) Is English your child's first language? Yes ☐ No ☐

If no, what is your child's first language? ....

5). To which of the groups listed do you consider your child to belong?

White: White British, White Irish, White, Any other White background; ☐

Mixed: Mixed White and Black Caribbean, Mixed White and Black African, Mixed White and Asian, Mixed, Any other mixed background; ☐

Asian or Asian British: Asian and Asian British Indian, Asian and Asian British Pakistani, Asian and Asian British Bangladeshi, Asian and Asian British, Any other Asian background; ☐

Black or Black British: Black or Black British Caribbean, Black or Black British African, Black or Black British, Any other Black background; ☐

Chinese: Chinese; ☐

Any other ethnic group: Any other ethnic group ☐

6) Does your child have Special Educational Needs? Yes ☐ No ☐

If yes, please provide additional details: ....

7) Does your child have any physical difficulties that make exercise challenging?

Yes ☐ No ☐

If yes, please provide additional details: ....

8) Does your child receive free school meals? Yes ☐ No ☐

9) What is your total household net income? Under £15,000 ☐ £15,000-£19,999 ☐
£20,000-£29,999 ☐ £30,000-£39,999 ☐ £40,000-£50,000 ☐ Over £50,000 ☐

Appendix 6S. Teacher demographic questionnaire for Study Two

Class No. ☐

VIRTUAL TRAVELLER

Teacher Questionnaire 1

Thank you again for taking part in the Virtual Traveller Study. We would like to ask you a few questions about you, your teaching experience and physical activity to help us evaluate the programme. We will not request any personally identifiable information. Your responses will remain confidential, anonymous and only identifiable by your class participation number.

1) Are you: Male ☐ Female ☐

2) How is your health in general?
Very good ☐ Good ☐ Fair ☐ Bad ☐ Very bad ☐

3) What is your ethnic group?
White: White British, White Irish, White, Any other White background; ☐
Mixed: Mixed White and Black Caribbean, Mixed White and Black African, Mixed White and Asian, Mixed, Any other mixed background; ☐
Asian or Asian British: Asian and Asian British Indian, Asian and Asian British Pakistani, Asian and Asian British Bangladeshi, Asian and Asian British, Any other Asian background; ☐
Black or Black British: Black or Black British Caribbean, Black or Black British African, Black or Black British, Any other Black background; ☐
Chinese: Chinese; ☐
Any other ethnic group: Any other ethnic group ☐

4) How many years' experience do you have as a class teacher? ……………………………………………………

5) How much do you agree with this statement?
I think children get enough physical activity during school time.
Not at all ☐1 ☐2 ☐3 ☐4 ☐5 Very much

6) How often do you integrate physical activity into your non-PE teaching time?
Example: jumping whilst reciting times tables
Every day ☐ Most days ☐ Sometimes ☐ Not often ☐ Never ☐

7) How often do you use Brain Breaks? e.g relaxation/ other non-curriculum physical activity
Every day ☐ Most days ☐ Sometimes ☐ Not often ☐ Never ☐

8) Is your school part of the 'Healthy Schools' initiative?
Yes ☐ No ☐

9) How often does your class have P.E a week?
Once a week ☐ Twice a week ☐ Three times a week ☐ More ☐

10) How often do you lead the teaching of PE?
Never ☐ Once in a while ☐ Most sessions ☐ Every session ☐

Appendix 6T: Student Engagement Instrument-Elementary version (SEI-E) for Study Two

Participant No. [ ]

School Questionnaire

VIRTUAL TRAVELLER

We want to know what you think about the learning you do at school.
Tick the box you most agree with.
There is no right or wrong answer. Try to answer as truthfully as possible.
Your answers are private and your teacher will not be shown what you tick.

	1 Strongly Disagree	2 Disagree	3 Agree	4 Strongly Agree
1. My family/guardian(s) are there for me when I need them.				
2. My teachers are there for me when I need them				
3. Other students here like me the way I am.				
4. Adults at my school listen to the students.				
5. Other students care about me.				
6. Students at my school are there for me when I need them.				
7. My education will create many chances for me to reach my future goals				
8. The rules at my school are fair.				
9. Continuing to learn after secondary school is important.				
10. My family/guardian(s) want to know when something good happens at school				
11. Most teachers care about me as a person, not just a student				
12. Students here respect what I have to say				
13. My teachers are honest with me				
14. I plan to go to university after I finish secondary school.				

Appendix 6U. Pupil Virtual Traveller evaluation questionnaire for Study Two

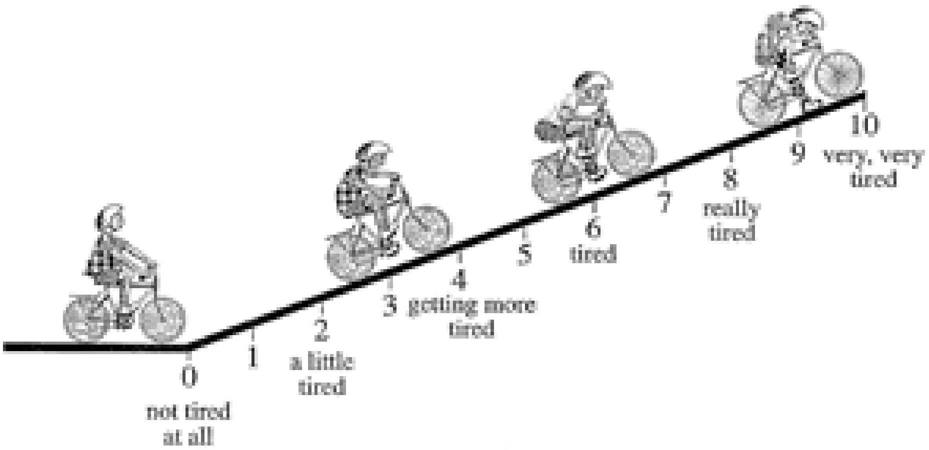
Participant Number

Pupil Virtual Traveller Evaluation

Thank you for taking part in the Virtual Traveller study!

Please answer the questions below to tell us what you think about Virtual Traveller sessions.

1. On a scale of 0 to 10, how tired did Virtual Traveller sessions make you? Circle the number you agree with.



2. On a scale of 1 to 5, how much do you like Virtual Traveller sessions?

Not very much [1] [2] [3] [4] [5] Very much

3. I think Virtual Traveller sessions are fun.

Don't agree at all [1] [2] [3] [4] [5] Agree very much

4. Virtual Traveller sessions help me learn.

Don't agree at all [1] [2] [3] [4] [5] Agree very much

Participant Number

5. What do you like about Virtual Traveller sessions?

Try to think of as many reasons as you can.

6. What do you not like about Virtual Traveller sessions?

Try to think of as many reasons as you can.

Appendix 6V. Teacher Virtual Traveller evaluation questionnaire for Study Two

Class No. ☐

Teacher Questionnaire 2

Thank you again for taking part in the Virtual Traveller Study. We hope you have enjoyed it!

We would like to ask you a few questions about how you have found the Virtual Traveller programme and on your physical activity. Please be as honest as possible. Your comments will help us understand the benefits and challenges of Virtual Field Trips as physically active lessons. Your responses will remain confidential, anonymous and only identifiable by class participation number.

1) Virtual Traveller sessions were easy to use.

Strongly Disagree [1] [2] [3] [4] [5] Strongly Agree

2) Virtual Traveller sessions were enjoyable to use.

Strongly Disagree [1] [2] [3] [4] [5] Strongly Agree

3) Since teaching Virtual Traveller, I feel more confident in incorporating physical activity into lessons.

Strongly Disagree [1] [2] [3] [4] [5] Strongly Agree

4) I will continue to add physical activity into my teaching.

Strongly Disagree [1] [2] [3] [4] [5] Strongly Agree

5) I will recommend the Virtual Traveller programme to other teachers

Strongly Disagree [1] [2] [3] [4] [5] Strongly Agree

6) My pupils have enjoyed Virtual Traveller.

Strongly Disagree [1] [2] [3] [4] [5] Strongly Agree

7) What did you like about Virtual Traveller?

8) What do you not like about Virtual Traveller?

Appendix 6W. Process evaluation pupil focus group script for Study Two

A. Introduction

- First of all, thanks to all of you for coming along today and for taking part in the Virtual Traveller study.
- I am researching new ways to increase exercise in children during school time. I am interested in hearing your views as teaching experts on this subject and on a related teaching method I am developing. I would like to tape the comments of group members and make notes on some of your ideas, feelings and thoughts as we go along.
- The session should last between 15 and 30 minutes.
- Before we begin, I want to assure you that all of todays' discussions will be confidential. I can promise that no-one will be able to tell who said what. I hope that this means you will feel able to speak freely and not hold anything back that you think is important.
- Your views are valuable and will help to influence the development of future work I carry out with other schools during my PhD.
- In a minute, we shall begin the session and I shall start recording the discussion. Please talk loudly and clearly so the microphone can pick up what you say and we get a clear tape recording. It would be very helpful if you could say your name and the yeargroup you work with to start off.
- Is everybody happy to continue?

B. Focus group questions

N.B. Repeat question twice if necessary, before using prompt

1. How would you describe your Maths and English lessons before Virtual Traveller lessons?

PROMPT – What do you think of your normal Maths and English lessons at school?

2. How did you find the Maths Virtual Traveller sessions?

PROMPT – Can you give an example of a Maths Virtual Traveller session that you enjoyed? Can you give an example of a Maths Virtual Traveller session that you didn't enjoy?

3. How did you find the English Virtual Traveller sessions?

PROMPT – Can you give an example of a English Virtual Traveller session that you enjoyed?
Can you give an example of a Maths Virtual Traveller session that you didn't enjoy?

4. Did the added movements make Maths and English more interesting?

PROMPT – How interesting were the Virtual Traveller sessions?
How active did you find the Virtual Traveller sessions?

5. Did the Virtual Traveller sessions affect your behaviour in lesson-time?

PROMPT – What would constrain your use of active Virtual Field Trips?
Can you give me an example?

6. Did the Virtual Traveller programme help you learn?

PROMPT – If yes: Why do you think Virtual Traveller helped you learn?
If no: Why do you think they didn't help you learn?
Can you give me an example?

7. What did you like about the Virtual Traveller programme?

PROMPT – What good bits were there about the Virtual Traveller sessions?

8. What did you not like about the Virtual Traveller programme?

PROMPT – What could we improve in the Virtual Traveller sessions?

9. Is there anything else you would like to say about Virtual Traveller?

<u>C. Closing remarks</u>

Once again, thanks to all of you for taking part. I hope you have found Virtual Traveller fun and this discussion today interesting. Your comments and ideas will help us evaluate Virtual Traveller and make it better for children in the future.

Appendix 6X. Process evaluation teacher interview schedule for Study Two

A. Introduction

- First of all, thank you very much to you and your class for participating in the Virtual Traveller study.
- As you know, the Virtual Traveller programme was developed to add physical activity into lesson time. The purpose of today's discussion is for me to hear your experiences of using the programme with your class. I would like to tape your comments and make notes on some of your ideas, feelings and thoughts as we go along.
- The session should last no longer than 15 minutes.
- Before we begin, I want to assure you that all of todays' discussions will be confidential. I can promise that no-one will be able to identify you or what you said. I hope that this means you will feel able to speak freely and not hold anything back that you think is important.
- Your views are valuable and will help to influence the development of future work I carry out with other schools during my PhD.
- In a minute, we shall begin the session and I shall start recording the discussion. Please talk loudly and clearly so the microphone can pick up what you say and we get a clear tape recording.
- Are you happy to continue?

B. Interview questions

N.B. Repeat question twice if necessary, before using prompt

1. Did you enjoy teaching active Maths and English sessions as opposed to typical teaching?

PROMPT – How did teaching Virtual Traveller sessions compare to typical teaching? How did you find teaching active Maths content? How did you find teaching active English content?

2. What did you think of the length of the Virtual Traveller sessions?

PROMPT – Could the Virtual Traveller sessions be longer?

3. How well do you think pupils understood content delivered in Virtual Traveller sessions?

PROMPT – Can you give an example of students showing understanding of the content? Can you give an example of students not understanding the content?

4. What challenges did you experience when running Virtual Traveller sessions?

PROMPT – How did you find recording and rating the sessions on the Virtual Traveller log sheet?
Did you have any problems with the USB stick, Powerpoint or interactive whiteboard?
Were there any sessions in particular that could be improved?

5. What benefits did you experience when running Virtual Traveller sessions?

PROMPT –Were there any sessions in particular that worked well?
Did you notice any change to pupil's behaviour following Virtual Traveller?
Are there any groups of children that this benefited in particular?

6. Do you think your students enjoyed Virtual Traveller sessions?

PROMPT – Did some students enjoy Virtual Traveller sessions more than others?
Do you think student's enjoyment changed during the programme?

7. Do you think Virtual Traveller sessions could be integrated into other curriculum topics?

PROMPT – What curriculum topics could Virtual Traveller be useful for?

8. Have you used Virtual Traveller sessions with your class since the intervention?

PROMPT – Can you think of any occasions you have used the sessions since?

9. Is there anything else you would like to say about Virtual Traveller?

C. Closing remarks

Once again, thank you for taking part in this interview and the whole Virtual Traveller study. I hope you have found the discussion interesting. Your comments and ideas will be extremely useful in evaluating the Virtual Traveller programme and making suggestions for future physically active lesson research.

Appendix 7A: Sensitivity analysis comparing one and three valid day accelerometer data participant inclusion criteria

	1 day valid accelerometer data n= 227	**3 days valid accelerometer data n= 219**	**p**
Intervention group	n=115 (50.7%)	n=113 (51.6%)	0.14
Demographics			
Sex			
Male	n=113 (49.8%)	n=111 (50.7%)	0.15
Female	n=114 (50.2%)	n=108 (49.3%)	
Age Mean (SD)	8.56 (0.70)	8.59 (0.49)	0.36
Ethnicity			0.73
White	n=110 (48.5%)	n=105 (47.9%)	
Mixed	n=15 (6.6%)	n=15 (6.8%)	
Asian or Asian British	n=90 (39.6%)	n=88 (40.2%)	
Black or Black British	n=11 (4.8%)	n=11 (5.0%)	
Chinese	n=1 (0.4%)	n=0 (0%)	
Born in UK	n=174 (76.7%)	n=167 (76.3%)	0.46
English as first language	n=178 (78.4%)	n=170 (77.6%)	0.13
BMI Category			
Underweight	n=3 (1.3%)	n=3 (1.4%)	0.55
Normal	n=137 (60.4%)	n=134 (61.2%)	
Overweight	n=70 (30.8%)	n=66 (30.1%)	
Obese	n=17 (7.5%)	n=16 (7.3%)	
Special Educational Needs	n=4 (1.8%)	n=3 (1.4%)	0.10
Physical difficulties	n=3 (1.3%)	n=3 (1.4%)	0.74
Free School Meals	n=51 (22.5%)	n=50 (22.8%)	0.49
Total household income			
Under £15,000	n=68 (30.0%)	n=67 (30.6%)	0.65
£15,000-£19,999	n=87 (38.3%)	n=82 (37.4%)	
£20,000-£29,999	n=63 (27.8%)	n=61 (27.9%)	
£30,000-£39,999	n=8 (3.5%)	n=8 (3.7%)	
£40,000-£49,999	n=1 (0.4%)	n=1 (0.5%)	
Primary outcome			
Overall MVPA at T4	n=198	n=193	0.22
Mean (SD)	180.31 mins (55.22)	181.74 mins (54.57)	
Secondary outcomes			
Overall SB at T4	n=198	n=193	0.08
Mean (SD)	2161.22 mins (607.26)	2175.86 mins (597.92)	
Overall LPA at T4	n=198	n=193	0.10
Mean (SD)	446.66 mins (142.43)	450.14 (140.98)	
Overall MVPA at T4	n=198	n=193	0.22
Mean (SD)	180.31 mins (55.22)	181.74 mins (54.57)	
Average School day SB at T4	n=198	n=193	0.35
Mean (SD)	650.91 mins (29.59)	650.59 mins (29.76)	
	n=198	n=193	0.18

Average School day LPA at T4 Mean (SD)	140.92 mins (18.88)	141.09 mins (19.06)	
Average School day MVPA at T4 Mean (SD)	n=198 58.59 mins (6.77)	n=193 58.72 mins (6.78)	0.78
Lesson-time accelerometer-assessed MVPA at T1 Mean (SD)	n=211 1.09 mins (1.20)	n=206 1.11 mins (1.20)	0.94
Lesson-time accelerometer-assessed MVPA at T2 Mean (SD)	n=202 1.31 mins (1.24)	n=202 1.31 mins (1.24)	1.00
Lesson-time physical activity observation ratings at T1* Mean (SD)	n=211 2.56/5 (1.12)	n=206 2.57/5 (1.12)	0.91
Lesson-time physical activity observation ratings at T2* Mean (SD)	n=202 2.54/5 (1.10)	n=202 2.54/5 (1.10)	1.00
On-task behaviour observation ratings at T1^{+} Mean (SD)	n=211 1.19/2 (0.07)	n=206 1.19/2 (0.08)	0.87
On-task behaviour observation ratings at T2^{+} Mean (SD)	n=202 1.20/2 (0.08)	n=202 1.20/2 (0.08)	1.00
Overall student engagement scores at T4^{0} Mean (SD)	n=198 73.45/96 (5.83)	n=192 73.50/96 (5.90)	0.99

Notes. * indicates outcomes assessed using the Children's Activity Rating Scale (CARS), with a maximum score of 5 indicating fast movement ; $^{+}$ indicates outcomes assessed using the Observing Pupils and Teachers in Classrooms (OPTIC) scale, with a maximum score of 1 indicating on-task behaviour at all observation points; ^{0} indicates outcomes assessed using the Student Engagement Instrument Elementary Version (SEI-E), with a maximum scores of 96 across all sub-scales indicating maximum student engagement.

Appendix 7B: Sensitivity analysis comparing three valid days and three valid days including one weekend day accelerometer data participant inclusion criteria

	3 days valid accelerometer data n= 219	3 days valid accelerometer data with 1 weekend day n= 208	p
Intervention group	n=113 (51.6%)	n=107 (51.4%)	0.84
Sex			
Male	n=111 (50.7%)	n=104 (50.0%)	0.38
Female	n=108 (49.3%)	n=140 (50.0%)	
Age Mean (SD)	8.59 (0.49)	8.60 (0.49)	0.12
Ethnicity			
White	n=105 (47.9%)	n=98 (47.1%)	0.34
Mixed	n=15 (6.8%)	n=15 (7.2%)	
Asian or Asian British	n=88 (40.2%)	n=84 (40.4%)	
Black or Black British	n=11 (5.0%)	n=11 (5.3%)	
Chinese	n=0 (0%)	n=0 (0%)	
Born in UK	n=167 (76.3%)	n=161 (77.4%)	0.08
English as first language	n=170 (77.6%)	n=163 (78.4%)	0.27
BMI Category			
Underweight	n=3 (1.4%)	n=3 (1.4%)	0.12
Normal	n=134 (61.2%)	n=129 (62.0%	
Overweight	n=66 (30.1%)	n=62 (29.8%)	
Obese	n=16 (7.3%)	n=14 (6.7%)	
Special Educational Needs	n=3 (1.4%)	n=3 (1.4%)	0.69
Physical difficulties	n=3 (1.4%)	n=3 (1.4%)	0.69
Free School Meals	n=50 (22.8%)	n=46 (22.1%)	0.28
Total household income			
Under £15,000	n=67 (30.6%)	n=63 (30.3)	0.82
£15,000-£19,999	n=82 (37.4%)	n=79 (38.0%)	
£20,000-£29,999	n=61 (27.9%)	n=57 (27.4%)	
£30,000-£39,999	n=8 (3.7%)	n=8 (3.8%)	
£40,000-£49,999	n=1 (0.5%)	n=1 (0.5%)	
Primary outcome			
Overall MVPA at T4	n=193	n=186	0.62
Mean (SD)	181.74 mins (54.57)	181.65 mins (54.67)	
Secondary outcomes			
Overall SB at T4			
Mean (SD)	n=193 2175.86 mins (597.92)	n=186 2175.50 mins (594.53)	0.54
Overall LPA at T4			
Mean (SD)	n=193 450.14 mins (140.98)	n=186 450.03 mins (138.50)	0.71

Average School day SB at T4 Mean (SD)	n=193 650.59 mins (29.76)	n=184 650.58 mins (29.30)	0.62
Average School day LPA at T4 Mean (SD)	n=193 141.09 mins (19.06)	n=184 141.12 mins (19.11)	0.99
Average School day MVPA at T4 Mean (SD)	n=193 58.72 mins (6.78)	n=184 58.95 (6.76)	0.43
Lesson-time accelerometer-assessed MVPA at T1 Mean (SD)	n=206 1.11 mins (1.20)	n=199 1.12 mins (1.22)	0.74
Lesson-time accelerometer-assessed MVPA at T2 Mean (SD)	n=202 1.31 mins (1.24)	n=195 1.32 mins (1.24)	0.61
Lesson-time physical activity observation ratings at T1* Mean (SD)	n=206 2.57/5 (1.12)	n=199 2.57/5 (1.13)	0.94
Lesson-time physical activity observation ratings at T2* Mean (SD)	n=202 2.54/5 (1.10)	n=195 2.55/5 (1.10)	0.53
On-task behaviour observation ratings at T1⁺ Mean (SD)	n=206 1.19/2 (0.08)	n=199 1.19/2 (0.08)	0.47
On-task behaviour observation ratings at T2⁺ Mean (SD)	n=202 1.20/2 (0.08)	n=195 1.19/2 (0.08)	0.55
Overall student engagement scores at T4⁰ Mean (SD)	n=192 73.50/96 (5.90)	n=183 72.78/96 (5.86)	0.52

Notes. * indicates outcomes assessed using the Children's Activity Rating Scale (CARS), with a maximum score of 5 indicating fast movement ; ⁺ indicates outcomes assessed using the Observing Pupils and Teachers in Classrooms (OPTIC) scale, with a maximum score of 1 indicating on-task behaviour at all observation points; ⁰ indicates outcomes assessed using the Student Engagement Instrument Elementary Version (SEI-E), with a maximum scores of 96 across all sub-scales indicating maximum student engagement

Appendix 7C: Pupil demographics of full and analytic sample

Demographics	All n= 264	Intervention Group n= 133	Control Group n=131	p	Analytic Sample n= 219	Intervention Group n=113	Control Group n=106	p
Sex Male	n=137 (51.9%)	n=66 (49.6%)	n=71 (54.2%)	0.46	n=111 (50.7%)	n=52 (46.10)	n=59 (55.7%)	0.16
Female	n=127 (48.1%)	n=67 (50.4%)	n=60 (45.8%)		n=108 (49.3%)	n=61 (54.0%)	n=47 (44.3%)	
Age Mean (SD)	8.56 (0.68)	8.50 (0.82)	8.61 (0.49)	0.20	8.59 (0.49)	8.59 (0.49)	8.59 (0.49)	0.88
Ethnicity White	n=125 (47.3%)	n=71 (53.4%)	n=54 (41.2%)	0.24	n=105 (47.9%)	n=60 (53.1%)	n=45 (42.5%)	0.27
Mixed	n=20 (7.6%)	n=5 (3.8%)	n=15 (11.5%)		n=15 (6.8%)	n=5 (4.4%)	n=10 (9.4%)	
Asian or Asian British	n=104 (39.4%)	n=49 (36.8%)	n=55 (42.0%)		n=88 (40.2%)	n=42 (37.2%)	n=46 (43.4%)	
Black or Black British	n=14 (5.3%)	n=7 (5.3%)	n=7 (5.3%)		n=11 (5.0%)	n=6 (5.3%)	n=5 (4.7%)	
Chinese	n=1 (0.4%)	n=1 (0.8%)	n=0 (0%)		n=0 (0%)	n=0 (0%)	n=0 (0%)	
Born in UK	n=204 (77.3%)	n=104 (78.2%)	n=100 (76.3%)	0.72	n=167 (76.3%)	n=89 (78.8%)	n=78 (73.6%)	0.37
English as first language	n=205 (77.7%)	n=103 (77.4%)	n=102 (77.9%)	0.94	n=170 (77.6%)	n=88 (77.9%)	n=82 (77.4%)	0.93
BMI Category Underweight	n=3 (1.1%)	n=2 (1.5%)	n=1 (0.8%)	0.85	n=3 (1.4%)	n=2 (1.8%)	n=1 (0.9%)	0.99
Normal	n=156 (59.1%)	n=78 (58.6%)	n=78 (59.5%)		n=134 (61.2%)	n=68 (60.2%)	n=66 (62.3%)	
Overweight	n=88 (33.3%)	n=45 (33.8%)	n=43 (32.8%)		n=66 (30.1%)	n=35 (31.0%)	n=31 (29.2%)	

Obese	n=17 (6.4%)	n=8 (6.0%)	n=9 (6.9%)		n=16 (7.3%)	n=8 (7.1%)	n=8 (7.5%)	
Special Educational Needs	n=6 (2.3%)	n=2 (1.5%)	n=4 (3.1%)	0.99	n=3 (1.4%)	n=2 (1.8%)	n=1 (0.9%)	0.60
Physical difficulties	n=6 (1.1%)	n=1 (0.8%)	n=2 (1.5%)	0.55	n=3 (1.4%)	n=1 (0.9%)	n=2 (1.9%)	0.53
Free School Meals	n=59 (22.3%)	n=33 (24.8%)	n=26 (19.8%)	0.33	n=50 (22.8%)	n=28 (24.8%)	n=22 (20.8%)	0.48
Total household income				0.29				0.47
Under £15,000	n=80 (30.3%)	n=40 (30.1%)	n=40 (30.5%)		n=67 (30.6%)	n=33 (29.2%)	n=34 (32.1%)	
£15,000-£19,999	n=100 (37.9%)	n=55 (41.4%)	n=45 (34.4%)		n=82 (37.4%)	n=47 (41.6%)	n=35 (33.0%)	
£20,000-£29,999	n=74 (28.0%)	n=36 (27.1%)	n=38 (29.0%)		n=61 (27.9%)	n=31 (27.4%)	n=30 (28.3%)	
£30,000-£39,999	n=9 (3.4%)	n=2 (1.5%)	n=7 (5.3%)		n=8 (3.7%)	n=2 (1.8%)	n=6 (5.7%)	
£40,000-£49,999	n=1 (0.4%)	n=0 (0%)	n=1 (0.8%)		n=1 (0.5%)	n=0 (0%)	n=1 (0.9%)	

Notes: Participants were included in the analytic sample if they provided at least three days of valid accelerometer wear time (≥500 minutes wear time between 07:00 and 00:00) during the study, including one VFT day in intervention pupils. Independent *t*-tests found no significant differences of any demographic variables between intervention groups in both the full and analytical sample.

Appendix 7D. Pupil demographics by class

Demographics	Analytic Sample n= 219	Class 1 (control) n=19	Class 2 (interv) n=23	Class 3 (control) n=21	Class 4 (control) n=22	Class 5 (interv) n=24	Class 6 (interv) n=24	Class 7 (interv) n=17	Class 8 (control) n=24	Class 9 (control) n=20	Class 10 (interv) n=25
Sex Male	n=111 (50.7%)	n=9 (47.4%)	n=10 (43.5%)	n=11 (52.4%)	n=13 (59.1%)	n=14 (58.3%)	n=11 (45.8%)	n=6 (35.3%)	n=13 (54.2%)	n=13 (65.0%)	n=11 (44.0%)
Female	n=108 (49.3%)	n=10 (52.6%)	n=13 (56.5%)	n=10 (47.6%)	n=9 (40.9%)	n=10 (41.7%)	n=13 (54.2%)	n=11 (64.7%)	n=11 (45.8%)	n=7 (35.0%)	n=14 (56.0%)
Age Mean (SD)	8.56 (0.70)	8.68 (0.48)	8.43 (0.51)	8.33 (0.48)	8.55 (0.51)	8.46 (0.51)	8.50 (0.51)	8.71 (0.47)	8.58 (0.50)	8.85 (0.37)	8.84 (0.37)
Ethnicity White	n=105 (47.9%)	n=2 (10.5%)	n=12 (52.2%)	n=11 (52.4%)	n=10 (45.5%)	n=14 (79.2%)	n=12 (50.0%)	n=2 (11.8%)	n=11 (45.8%)	n=11 (55.0%)	n=20 (80.0%)
Mixed	n=15 (6.8%)	n=2 (10.5%)	n=0 (0%)	n=2 (9.5%)	n=2 (9.1%)	n=1 (4.2%)	n=3 (12.5%)	n=1 (5.9%)	n=2 (8.3%)	n=2 (10.0%)	n=0 (0%)
Asian or Asian British	n=88 (40.2%)	n=14 (73.7%)	n=9 (39.1%)	n=6 (28.6%)	n=10 (45.5%)	n=8 (33.3%)	n=8 (33.3%)	n=13 (76.5%)	n=10 (41.7%)	n=6 (30.0%)	n=4 (16.0%)
Black or Black British	n=11 (5.0%)	n=1 (5.3%)	n=2 (8.7%)	n=2 (9.5%)	n=0 (0%)	n=1 (4.2%)	n=1 (4.2%)	n=1 (5.9%)	n=1 (4.2%)	n=1 (5.0%)	n=1 (4.0%)
Chinese	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)
Born in UK	n=167 (76.3%)	n=13 (68.4%)	n=17 (73.9%)	n=15 (71.4%)	n=14 (63.6%)	n=21 (87.5%)	n=19 (79.2%)	n=9 (52.9%)	n=20 (83.3%)	n=16 (80.0%)	n=23 (92.0%)
English as first language	n=170 (77.6%)	n=12 (63.2%)	n=18 (78.3%)	n=17 (81.0%)	n=17 (77.3%)	n=20 (83.3%)	n=19 (79.2%)	n=8 (47.1%)	n=20 (83.3%)	n=16 (80.0%)	n=23 (92.0%)
BMI Category Underweight	n=3 (1.4%)	n=0 (0%)	n=1 (4.3%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=1 (4.2%)	n=0 (0%)	n=1 (4.2%)	n=0 (0%)	n=0 (0%)
Normal	n=134 (61.2%)	n=12 (63.2%)	n=11 (47.8%)	n=12 (57.1%)	n=12 (54.5%)	n=13 (54.2%)	n=16 (66.7%)	n=10 (58.8%)	n=15 (62.5%)	n=15 (75.0%)	n=19 (76.0%)

Overweight	n=66 (30.1%)	n=6 (31.6%)	n=9 (39.1%)	n=7 (33.3%)	n=8 (36.4%)	n=9 (37.5%)	n=6 (25.0%)	n=6 (35.3%)	n=6 (25.0%)	n=4 (20.0%)	n=5 (20.0%)
Obese	n=16 (7.3%)	n=1 (5.3%)	n=2 (8.7%)	n=2 (9.5%)	n=2 (9.1%)	n=2 (8.3%)	n=1 (4.2%)	n=1 (5.9%)	n=2 (8.3%)	n=1 (5.0%)	n=2 (8.0%)
Special Educational Needs	n=3 (1.4%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=1 (4.2%)	n=0 (0%)	n=1 (4.2%)	n=0 (0%)	n=1 (4.0%)
Physical difficulties	n=3 (1.4%)	n=2 (10.5%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=1 (4.2%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)
Free School Meals	n=50 (22.8%)	n=2 (10.5%)	n=8 (34.8%)	n=5 (23.8%)	n=6 (27.3%)	n=5 (20.8%)	n=6 (25.0%)	n=4 (23.5%)	n=4 (16.7%)	n=5 (25.0%)	n=5 (20.0%)
Total household income											
Under £15,000	n=67 (30.6%)	n=6 (31.6%)	n=10 (43.5%)	n=6 (28.6%)	n=7 (31.8%)	n=4 (16.7%)	n=4 (16.7%)	n=11 (64.7%)	n=6 (25.0%)	n=9 (45.0%)	n=4 (16.0%)
£15,000-£19,999	n=82 (37.4%)	n=5 (26.3%)	n=9 (39.1%)	n=7 (33.3%)	n=8 (36.4%)	n=11 (45.8%)	n=10 (41.7%)	n=4 (23.5%)	n=10 (41.7%)	n=5 (25.0%)	n=13 (52.0%)
£20,000-£29,999	n=61 (27.9%)	n=6 (31.6%)	n=4 (17.4%)	n=7 (33.3%)	n=5 (22.7%)	n=8 (33.3%)	n=10 (41.7%)	n=1 (5.9%)	n=6 (25.0%)	n=6 (30.0%)	n=8 (32.0%)
£30,000-£39,999	n=8 (3.7%)	n=1 (5.3%)	n=0 (0%)	n=1 (4.8%)	n=2 (9.1%)	n=1 (4.2%)	n=0 (0%)	n=1 (5.9%)	n=2 (8.3%)	n=0 (0%)	n=0 (0%)
£40,000-£49,999	n=1 (0.5%)	n=1 (5.3%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)	n=0 (0%)

Appendix 7E. Mean accelerometer minutes for all data measurement points by intervention group

		Intervention (n=113)						Control (n=106)					
Time	**Day**	**n**	**SB**	**LPA**	**MPA**	**VPA**	**MVPA**	**n**	**SB**	**LPA**	**MPA**	**VPA**	**MVPA**
T0	**School day 1 (n=202)**	106	654.54 (48.44)	146.05 (25.74)	37.91 (8.34)	24.85 (6.84)	62.76 (11.76)	96	648.39 (46.18)	151.73 (30.06)	37.40 (8.36)	24.56 (7.71)	61.96 (13.89)
	School day 2 (n=196)	103	658.58 (54.39)	145.91 (28.51)	37.22 (8.30)	22.18 (5.83)	59.41 (11.23)	93	648.14 (61.59)	147.38 (32.90)	38.53 (8.92)	24.33 (7.93)	62.86 (13.84)
	Weekend day 1 (n=165)	87	641.71 (81.50)	131.43 (35.18)	31.96 (10.15)	21.15 (13.24)	53.13 (21.09)	78	654.32 (63.95)	139.50 (34.42)	33.58 (9.19)	20.56 (8.37)	54.13 (14.35)
	Weekend day 2 (n=139)	72	626.08 (56.77)	127.20 (31.33)	29.45 (7.61)	17.94 (5.61)	47.39 (10.95)	67	636.95 (55.62)	128.39 (32.81)	29.07 (8.81)	16.55 (5.82)	45.62 (11.36)
	Total (n=204)	108	2216.18 (593.31)	474.48 (152.67)	118.77 (37.19)	75.14 (25.77)	193.91 (60.17)	96	2267.27 (548.68)	499.92 (152.21)	123.18 (37.84)	77.17 (27.59)	200.35 (62.03)
T1	**School day 1 (n=204)**	105	654.85 (43.94)	138.02 (23.84)	36.62 (6.43)	24.28 (5.93)	60.90 (9.68)	99	654.16 (42.90)	139.91 (25.63)	33.07 (7.61)	20.55 (6.49)	53.62 (12.30)
	School day 2 (n=188)	94	655.30 (43.06)	137.89 (25.36)	36.73 (5.92)	23.56 (4.65)	60.29 (8.23)	94	655.19 (66.88)	142.35 (33.11)	36.50 (8.64)	21.97 (8.34)	58.48 (14.43)
	Weekend day 1 (n=152)	72	643.71 (33.09)	126.52 (33.00)	31.73 (6.17)	19.53 (4.65)	51.25 (9.28)	80	645.37 (50.26)	125.99 (33.54)	30.01 (7.36)	19.16 (6.18)	49.30 (11.72)
	Weekend day 2 (n=126)	62	636.69 (59.60)	117.99 (34.35)	29.71 (7.81)	17.47 (6.12)	47.18 (12.49)	64	632.11 (51.88)	121.25 (32.77)	28.63 (7.63)	17.92 (8.30)	46.55 (13.85)
	Total (n=205)	106	2058.92 (647.13)	416.60 (142.95)	109.42 (38.57)	69.02 (22.75)	178.45 (59.73)	99	2228.73 (569.23)	458.27 (142.91)	111.80 (33.19)	69.81 (26.39)	181.61 (55.23)
T2	**School day 1 (n=200)**	102	648.20 (40.01)	144.91 (25.15)	36.39 (6.86)	23.85 (6.50)	60.23 (10.47)	98	648.16 (48.08)	143.84 (23.87)	35.49 (7.17)	22.13 (7.72)	57.62 (11.75)
	School day 2 (n=190)	98	649.22 (64.64)	140.87 (22.21)	36.06 (6.94)	22.62 (6.67)	58.68 (11.65)	92	648.13 (49.43)	145.56 (28.69)	36.85 (7.24)	22.25 (6.01)	59.10 (11.48)
	Weekend day 1 (n=152)	80	636.62 (56.07)	125.51 (23.62)	30.52 (7.62)	18.84 (5.56)	49.36 (11.16)	72	647.44 (44.70)	134.09 (42.88)	31.78 (9.80)	20.39 (8.24)	52.17 (16.39)

	Weekend day 2 (n=116)	64	627.22 (62.52)	115.99 (22.20)	29.66 (9.25)	16.17 (7.07)	45.83 (14.72)	52	632.15 (43.89)	124.02 (29.93)	29.59 (7.98)	17.53 (7.10)	47.28 (13.91)
	Total (n=202)	104	2147.10 (591.28)	448.03 (136.31)	113.44 (35.58)	71.36 (27.17)	184.80 (60.19)	98	2098.22 (590.88)	449.97 (164.88)	109.85 (37.68)	67.57 (26.94)	177.42 (62.59)
T3	**School day 1 (n=193)**	99	650.73 (42.39)	142.21 (16.11)	36.53 (6.60)	22.59 (5.64)	58.92 (9.71)	94	641.44 (60.11)	141.99 (17.85)	36.90 (7.79)	23.20 (6.08)	60.10 (11.32)
	School day 2 (n=182)	93	657.85 (35.62)	146.08 (25.50)	37.24 (6.21)	22.35 (6.02)	59.62 (9.99)	89	656.41 (42.90)	152.77 (43.46)	38.02 (6.52)	21.95 (5.55)	59.96 (9.65)
	Weekend day 1 (n=146)	74	636.55 (57.37)	124.62 (21.23)	31.65 (7.81)	19.68 (5.08)	51.33 (10.37)	72	626.58 (81.93)	119.51 (21.00)	32.15 (8.65)	18.14 (5.24)	50.28 (12.15)
	Weekend day 2 (n=115)	57	631.03 (57.38)	109.97 (17.90)	29.99 (6.92)	17.76 (6.07)	47.75 (10.51)	58	616.79 (84.70)	109.55 (17.24)	31.05 (5.97)	16.26 (5.60)	47.41 (9.84)
	Total (n=193)	99	2104.83 (624.65)	445.36 (148.73)	108.29 (35.75)	67.86 (25.57)	176.15 (58.66)	94	2135.77 (627.19)	475.32 (188.86)	112.13 (35.52)	66.28 (23.28)	179.12 (55.71)
T4	**School day 1 (n=193)**	101	650.18 (37.98)	140.57 (16.40)	36.72 (5.98)	21.88 (4.87)	58.61 (8.16)	92	651.26 (37.81)	146.137 (27.29)	37.75 (6.86)	21.89 (4.34)	59.64 (7.90)
	School day 2 (n=183)	95	651.15 (35.47)	135.59 (12.53)	37.11 (5.28)	22.21 (4.64)	59.32 (7.45)	88	647.13 (32.93)	143.32 (23.20)	36.84 (5.40)	20.91 (4.10)	57.76 (6.80)
	Weekend day 1 (n=154)	83	643.01 (51.16)	118.40 (14.69)	32.23 (6.80)	18.22 (4.37)	50.46 (9.14)	71	637.99 (58.32)	120.46 (18.41)	33.18 (8.83)	18.59 (4.86)	51.77 (11.05)
	Weekend day 2 (n=110)	59	625.15 (64.19)	112.29 (18.23)	30.29 (7.67)	17.45 (6.20)	47.74 (11.55)	51	630.72 (55.11)	110.44 (18.85)	31.33 (6.44)	15.81 (5.22)	47.13 (9.14)
	Total (n=193)	101	2207.64 (586.59)	450.18 (136.02)	113.20 (33.07)	68.87 (22.73)	182.06 (53.24)	92	2140.97 (611.42)	450.10 (146.99	112.99 (34.06)	68.39 (25.19)	181.386 (56.29)
Total (n=219)		113	9842.85 (3049.29)	2049.18(686.17)	516.62 (173.70)	323.24 (114.19)	839.86 (283.16)	106	9826.98 (2968.31)	2108.92 (709.48)	515.05 (170.04)	316.32 (113.73)	831.37 (277.91)

Appendix 7F. Overall physical activity intensity per day in minutes according to rain status

Time	Day	Intervention (n=113) Wet days	n	SB	LPA	MPA	VPA	MVPA	Control (n=106) Wet days	n	SB	LPA	MPA	VPA	MVPA
T0	Weekend day 1 (n=165)	1/5	68	642.47 (90.53)	134.00 * (39.03)	31.65 (11.05)	19.67 (8.39)	51.35 (17.47)	1/5	61	654.54 (70.61)	144.07 (36.67)	33.62 (9.75)	20.63 (8.80)	54.25 (15.30)
			19	638.97 (34.86)	122.21 (11.29)	33.07 (6.00)	21.20 (5.90)	54.27 (10.05)		17	653.53 (31.43)	123.09 (17.19)	33.41 (7.10)	20.31 (6.84)	53.71 (10.63)
	Weekend day 2 (n=139)	2/5	40	621.92 (67.38)	141.10 *** (35.65)	31.11* (7.48)	17.75 (5.93)	48.86 (11.28)	2/5	40	634.57 (63.41)	132.60 (35.23)	29.57 (9.16)	17.03 (6.63)	46.60 (12.26)
			32	631.28 (40.23)	109.82 (9.41)	27.39 (7.38)	18.17 (5.26)	45.56 (10.42)		27	640.48 (42.42)	122.16 (28.34)	28.33 (8.39)	15.83 (4.39)	44.16 (9.93)
T1	School day 1 (n=204)	1/5	91	656.84 (39.45)	132.97 *** (10.45)	37.21 * (6.01)	23.88 (4.60)	61.09 (7.98)	1/5	83	651.33 (40.85)	133.81 *** (11.56)	34.73 *** (6.32)	21.65 *** (5.58)	56.38 *** (9.82)
			14	641.96 (66.82)	170.89 (49.45)	32.77 (7.92)	26.87 (11.27)	59.64 (17.51)		16	668.86 951.23)	171.54 (47.83)	24.47 (8.14)	14.83 (7.94)	39.31 (14.18)
	School day 2 (n=188)	1/5	73	654.36 (46.73)	139.39 (28.09)	36.44 (6.27)	23.61 (4.91)	60.04 (8.78)	0/5						
			21	658.58 (27.33)	132.67 (10.67)	37.72 (4.44)	23.42 (3.73)	61.14 (6.06)							
	Weekend day 1 (n=152)	1/5	56	644.04 (32.92)	128.02 (36.62)	31.37 (6.33)	19.41 (4.68)	50.78 (9.66)	2/5	46	650.93 (62.13)	135.31** (41.27)	30.40 (7.26)	19.41 (6.83)	50.02 (12.33)
			16	642.54 (34.75)	121.26 (14.08)	32.99 (5.58)	19.93 (4.67)	52.91 (7.84)		34	637.84 (26.13)	113.37 (9.25)	29.50 (7.58)	18.82 (5.30)	48.32 (10.94)

	Weekend day 2 (n=126)	0/5							2/5	37	635.18 (64.75)	131.35 ** (39.66)	28.30 (8.56)	19.83* (9.29)	48.13 (16.25)
										27	627.90 (26.19)	107.41 (8.92)	29.08 (6.29)	15.31 (5.93)	44.39 (9.53)
T2	**Weekend day 1 (n=152)**	2/5	45	645.91 (68.09)	130.97* (29.33)	30.01 (9.01)	18.21 (6.37)	48.23 (13.12)	0/5						
			35	624.68 (32.30)	118.48 (9.63)	31.18 (5.41)	19.65 (4.25)	50.83 (7.90)							
	Weekend day 2 (n=116)	1/5	48	625.76 (68.93)	116.95 (21.64)	28.50 ** (7.89)	15.95 (6.34)	44.45* (13.07)	2/5	31	633.49 (51.70)	132.80 ** (35.61)	30.46 (9.19)	17.46 (8.23)	47.92 (16.30)
			15	637.50 (31.83)	118.08 (14.36)	35.33 (8.70)	17.94 (8.29)	53.26 (13.79)		21	630.17 (29.94)	111.06 (9.26)	28.29 (5.73)	17.62 (5.20)	46.34 (9.62)
T3	**School day 2 (n=182)**	0/5							1/5	72	654.62 (45.35)	155.74 (47.73)	38.24 (6.89)	22.34 (5.86)	60.58 (10.34)
										17	663.97 (30.34)	140.21 (8.57)	37.07 (4.63)	20.30 (3.67)	57.36 (5.38)
	Weekend day 1 (n=146)	1/5	60	634.74 (61.50)	124.88 (23.26)	31.26 (7.69)	19.62 (5.47)	50.88 (10.74)	0/5						
			14	644.31 (35.21)	123.53 (8.59)	33.35 (8.41)	19.91 (3.02)	53.26 (6.69)							
	Weekend day 2 (n=115)	1/5	45	623.05* (60.91)	109.29 (17.50)	30.36 (6.95)	18.10 (6.40)	48.46 (10.60)	1/5	49	605.76* (86.99)	109.02 (18.49)	31.64 (5.95)	16.45 (5.81)	48.09 (10.10)
			12	663.55 (25.77)	117.58 (9.96)	29.62 (6.27)	17.12 (4.28)	46.74 (8.78)		9	676.87 (29.94)	112.42 (7.48)	27.86 (5.28)	15.86 (4.49)	43.72 (7.75)

T4	**Weekend day 1 (n=154)**	0/5							2/5	40	617.29 *** (66.32)	117.04 (22.82)	33.27 (10.74)	17.81 (5.21)	51.08 (13.03)
										30	666.28 (26.62)	125.13 (7.79)	33.07 (5.40)	19.65 (4.19)	52.72 (7.67)
	Weekend day 2 (n=110)	2/5	34	608.81* (77.42)	112.94 (22.27)	30.64 (7.88)	18.36 (6.37)	49.00 (11.77)	0/5						
			25	647.38 (28.66)	111.41 (10.92)	29.81 (7.52)	16.20 (5.87)	46.01 (11.25)							

Notes. Only study days where the postcode of at least one participating school provided a weather forecast featuring rain are presented; Figures in bold indicate wet days. Significance indicates difference between wet and dry activity within the given intervention group; * *p*<0.05; ** *p*<0.01; *** *p*<0.001

Appendix 7G. Average overall physical activity multilevel modelling for the intervention period

Multilevel modelling for average overall accelerometer-assessed sedentary behaviour (SB) during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	2234.86 (53.01)***	2272.00 (61.14)***	2268.55 (70.99)***
Sex	36.01 (48.09)	30.80 (48.22)	30.14 (48.10)
Ethnicity	-26.17 (48.11)	-32.74 (48.36)	-33.47 (48.22)
T1[0]	-98.57 (58.44)	-99.42 (58.38)	-36.99 (84.33)
T2[0]	-114.94 (58.69)	-115.81 (58.62)*	-166.21 (84.59)*
Intervention		-58.73 (48.34)	-50.86 (82.98)
T1*Intervention			-120.59 (116.55)
T2*Intervention			98.09 (117.00)
Random effects (SE)			
Variance between classes	0.01 (0.01)	0.01 (0.01)	1.81 (1.35)
Variance within classes	590.88 (16.90)	590.17 (16.88)	588.47 (16.38)
Model deviance	-4766.14	-4765.40	-4763.64

Notes: [0] indicates comparison of scores between given time-point and TI (first intervention period); * *p*≤0.05; *** *p*≤0.001.

Multilevel modelling for average overall accelerometer-assessed light physical activity (LPA) during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	492.48 (22.69)***	505.49 (29.72)***	508.15 (30.97)***
Sex	4.27 (11.51)	4.00 (11.51)	3.77 (11.49)
Ethnicity	0.08 (12.19)	0.02 (12.19)	-0.15 (12.17)
T1[0]	-51.89 (13.72)***	-51.92 (13.72)***	-44.92 (19.83)*
T2[0]	-40.95 (13.78)**	-40.97 (13.78)**	-55.25 (19.91)**
Intervention		-25.64 (38.37)	-30.24 (41.60)
T1*Intervention			-13.68 (27.42)
T2*Intervention			27.56 (27.53)
Random effects (SE)			
Variance between classes	59.32 (14.90)	57.91 (14.61)	58.03 (14.63)
Variance within classes	138.65 (4.00)	138.65 (4.00)	138.38 (3.99)
Model deviance	-3892.87	-3892.65	-3891.48

Notes: [0] indicates comparison of scores between given time-point and TI (first intervention period); **p*<0.05; ** *p*<0.01; *** *p*≤0.001.

Multilevel modelling for average overall accelerometer-assessed moderate-and-vigorous physical activity (MVPA) during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	188.72 (5.31)***	188.20 (6.13)***	190.95 (7.14)***
Sex	16.74 (4.82)***	16.82 (4.84)***	16.68 (4.84)***
Ethnicity	-0.94 (4.82)	-0.85 (4.85)	-0.87 (4.85)
$T1^0$	-16.60 (5.86)**	-16.59 (5.86)**	-17.93 (8.48)*
$T2^0$	-15.13 (5.88)*	-15.11 (5.88)**	-21.69 (8.50)*
Intervention		0.82 (4.85)	-4.21 (8.34)
T1*Intervention			2.47 (11.72)
T2*Intervention			12.63 (11.76)
Random effects (SE)			
Variance between classes	6.70 (4.40)	8.18 (0.01)	1.10 (7.77)
Variance within classes	59.22 (1.69)	59.21 (1.69)	59.15 (1.69)
Model deviance	-3360.57	-3360.56	-3359.91

Notes: ^{0} indicates comparison of scores between given time-point and TI (first intervention period); * $p<0.05$; ** $p<0.01$; *** $p\leq0.001$.

Appendix 7H. Average school day physical activity multilevel modelling for the intervention period

Multilevel modelling for average school day accelerometer-assessed sedentary behaviour (SB) during intervention period (T2 as outcome)

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	656.19 (3.88)***	655.59 (4.48)***	652.73 (5.22)***
Sex	-2.74 (3.52)	-2.65 (3.54)	-2.54 (3.53)
Ethnicity	-6.74 (3.52)	-6.64 (3.54)	-6.67 (3.54)
$T1^0$	1.93 (4.28)	1.95 (4.28)	6.69 (6.19)
$T2^0$	-3.59 (4.30)	-3.57 (4.30)	0.04 (6.22)
Intervention			6.25 (6.09)
T1*Intervention			-9.03 (8.55)
T2*Intervention			-6.82 (8.60)
Random effects (SE)			
Variance between classes	8.07 (5.21)	8.31 (5.91)	6.77 (4.45)
Variance within classes	43.12 (1.24)	43.12 (1.24)	42.07 (1.24)
Model deviance	-3146.03	-3146.00	-3145.39

Notes: ^{0} indicates comparison of scores between given time-point and TI (first intervention period); *** $p \leq 0.001$.

Multilevel modelling for average school day accelerometer-assessed light physical activity (LPA) during intervention period (T2 as outcome)

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	149.85 (5.53)***	151.21 (7.64)***	152.46 (7.75)***
Sex	-1.90 (1.68)	-1.90 (1.68)	-1.95 (1.67)
Ethnicity	1.32 (1.79)	1.31 (1.79)	1.32 (1.79)
$T1^0$	-7.44 (2.00)***	-7.44 (2.00)***	-9.31 (2.88)***
$T2^0$	-3.81 (2.00)	-3.81 (2.00)	-5.58 (2.90)
Intervention		-2.70 (10.51)	-5.02 (10.77)
T1*Intervention			3.56 (3.99)
T2*Intervention			3.38 (4.00)
Random effects (SE)			
Variance between classes	16.47 (3.81)	16.41 (3.80)	16.43 (3.80)
Variance within classes	20.14 (0.58)	20.14 (0.58)	20.13 (0.58)
Model deviance	-2711.42	-2711.38	-2710.88

Notes: ^{0} indicates comparison of scores between given time-point and TI (first intervention period); *** $p \leq 0.001$.

Multilevel modelling for average school day accelerometer-assessed moderate-to-vigorous physical activity (MVPA) during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	59.61 (1.01)***	58.50 (1.13)***	59.88 (1.29)***
Sex	3.47 (0.86)***	3.48 (0.86)***	3.44 (0.85)***
Ethnicity	-0.24 (0.88)	0.07 (0.87)	0.10 (0.86)
$T1^0$	-2.69 (1.04)**	-2.66 (1.04)**	-5.74 (1.49)***
$T2^0$	-2.47 (1.04)*	-2.44 (1.04)*	-3.42 (1.49)*
Intervention		1.75 (0.96)	-0.83 (1.53)
T1*Intervention			5.91 (2.06)**
T2*Intervention			1.92 (2.07)
Random effects (SE)			
Variance between classes	1.12 (0.64)	0.66 (0.81)	0.67 (0.79)
Variance within classes	10.47 (0.30)	10.47 (0.30)	10.39 (0.30)
Model deviance	-2296.81	-2295.38	-2291.09

Notes: ^{0} indicates comparison of scores between given time-point and TI (first intervention period); * p<0.05; ** p≤0.01; *** p≤0.001.

Appendix 7I. Average weekend day physical activity multilevel modelling for non-significant T4 outcomes and all intervention period outcomes

Sedentary Behaviour (SB)

1) Multilevel modelling for average weekend day accelerometer-assessed SB at T4 (3-month follow-up)

The VPC of Model 2 was 0.2274, indicating that 22.74% of variance in average weekend day SB at T4 was due to variation between classes and 77.26% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. There were no significant differences in model fit between the co-variates model, Model 1 or Model 2. There was a significant difference between average weekend day SB at T3 compared to T0 (*B*= -15.90 (7.96); 95% CI, -31.51, -0.29; *p*<0.05), whereby there was less SB in the overall sample at T3. These findings suggest there was no effect of the Virtual Traveller intervention on weekend day SB at T4.

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	635.92 (6.54)***	638.21 (8.29)***	642.43 (9.03)***
Sex	2.95 (3.68)	2.92 (3.69)	2.56 (3.68)
Ethnicity	0.33 (3.91)	0.21 (3.91)	0.19 (3.90)
$T1^0$	-0.18 (5.48)	-0.20 (5.48)	-4.12 (7.73)
$T2^0$	-3.75 (5.52)	-3.74 (5.52)	-4.08 (8.02)
$T3^0$	-5.83 (5.58)	-5.85 (5.58)	-15.90 (7.96)*
$T4^0$	0.92 (5.52)	0.93 (5.52)	-5.13 (8.05)
Intervention		-4.39 (9.93)	-12.12 (11.99)
T1*Intervention			7.49 (10.94)
T2*Intervention			0.85 (11.03)
T3*Intervention			19.70 (11.14)
T4*Intervention			11.48 (11.04)
Random effects (SE)			
Variance between classes	14.78 (3.98)	14.61 (3.95)	14.60 (3.95)
Variance within classes	49.73 (1.26)	49.73 (1.26)	49.60 (1.26)
Model deviance	-4217.48	-4217.39	-4215.32

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * *p*<0.05; *** *p*≤0.001.

2) Multilevel modelling for average weekend day accelerometer-assessed sedentary behaviour (SB) during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	639.03 (5.54)***	644.27 (6.59)***	646.13 (7.24)***
Sex	0.92 (4.24)	0.44 (4.24)	0.22 (4.25)
Ethnicity	0.28 (4.42)	0.32 (4.42)	0.13 (4.41)
$T1^0$	1.15 (5.01)	1.00 (5.01)	-3.72 (7.08)
$T2^0$	-2.85 (5.05)	-2.82 (5.05)	-3.30 (7.34)
Intervention		-9.75 (6.97)	-13.20 (8.93)
T1*Intervention			03.72 (7.08)
T2*Intervention			-3.30 (7.34)
Random effects (SE)			
Variance between classes	9.96 (3.55)	8.72 (3.38)	8.69 (3.38)
Variance within classes	45.48 (1.48)	45.48 (1.48)	45.43 (1.48)
Model deviance	-2550.80	-2549.89	-2549.35

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** $p \leq 0.001$.

Light Physical Activity (LPA)

2) Multilevel modelling for average weekend day accelerometer-assessed LPA during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	132.55 (7.73)***	135.38 (10.73)***	135.58 (10.83)***
Sex	3.62 (1.94)	3.61 (1.94)	3.52 (1.94)
Ethnicity	-0.82 (2.07)	-0.83 (2.07)	-0.76 (2.06)
$T1^0$	-7.20 (2.27)**	-7.20 (2.27)**	-9.58 (3.20)**
$T2^0$	-5.35 (2.29)*	-5.35 (2.29)*	-3.24 (3.32)
Intervention		-5.65 (14.91)	-6.00 (15.14)
T1*Intervention			4.90 (4.53)
T2*Intervention			-3.93 (4.57)
Random effects (SE)			
Variance between classes	23.54 (5.39)	23.37 (5.35)	23.40 (5.36)
Variance within classes	20.63 (0.67)	20.63 (0.67)	20.55 (0.67)
Model deviance	-2185.84	-2185.77	-2183.95

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * $p < 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

Moderate-to-Vigorous Physical Activity (MVPA)

1) Multilevel modelling for average weekend day accelerometer-assessed MVPA at T4 (3-month follow-up)

The VPC of Model 2 was 0.0911, indicating that 9.11% of variance in average school day MVPA at T4 was due to variation between classes and 90.89% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. There were no significant differences in model fit between the co-variates model, Model 1 or Model 2. In Model 2 there was a significant effect of sex (*B*=3.16 (0.84); 95% CI, 1.53, 4.80; *p*<0.001), indicating that boys performed greater average weekend day MVPA at T4. There was no significant effect of intervention on average weekend day MVPA at T4. There were also no significant interactions between time-points and intervention group status. These findings suggest that there was no effect of the Virtual Traveller intervention on weekend day MVPA at T4.

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	48.75 (1.05)***	48.33 (1.18)***	47.66 (1.44)***
Sex	3.13 (0.83)***	3.18 (0.84)***	3.16 (0.84)***
Ethnicity	0.29 (0.84)	0.39 (0.84)	0.43 (0.84)
$T1^0$	-2.20 (1.28)	-2.17 (1.28)	-2.45 (1.80)
$T2^0$	-1.54 (1.29)	-1.55 (1.29)	0.61 (1.87)
$T3^0$	-0.99 (1.30)	-0.98 (1.30)	-0.57 (1.86)
$T4^0$	-0.69 (1.29)	-0.71 (1.29)	0.52 (1.88)
Intervention		0.67 (0.84)	1.92 (1.78)
T1*Intervention			0.70 (2.55)
T2*Intervention			-4.07 (2.57)
T3*Intervention			-0.76 (2.60)
T4*Intervention			-2.31 (2.58)
Random effects (SE)			
Variance between classes	1.61 (1.01)	1.15 (8.15)	1.16 (8.07)
Variance within classes	11.61 (0.29)	11.61 (0.29)	11.58 (0.29)
Deviance co-variates model	-3058.23	-3057.91	-3055.77

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** *p*≤0.001.

2) Multilevel modelling for average weekend day accelerometer-assessed MVPA during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	47.73 (1.26)***	47.01 (1.48)***	46.36 (1.70)***
Sex	5.13 (1.17)***	5.23 (1.17)***	5.23 (1.17)***
Ethnicity	0.28 (1.26)	0.46 (1.18)	0.50 (1.18)
$T1^0$	-2.20 (1.41)	-2.16 (1.40)	-2.31 (1.98)
$T2^0$	-1.50 (1.42)	-1.52 (1.42)	0.72 (2.06)
Intervention		1.10 (1.18)	2.31 (1.97)
T1*Intervention			-2.31 (1.98)
T2*Intervention			0.72 (2.06)
Random effects (SE)			
Variance between classes	6.22 (4.04)	2.25 (1.87)	2.33 (1.45)
Variance within classes	12.77 (0.41)	12.76 (0.41)	12.72 (0.41)
Model deviance	-1927.63	-1927.20	-1925.60

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** $p \leq 0.001$.

Appendix 7J: Mean accelerometer minutes and CARS observation ratings during 20-minute lesson periods by class

Group	Class	Time	n	SB	LPA	MPA	VPA	MVPA	CARS
Intervention	2	T0	22	15.9 (1.51)	3.8 (1.40)	0.2 (0.26)	0.1 (0.11)	0.3 (0.36)	1.4 (0.10)
		T1	24	11.0 (2.40)	7.6 (2.40)	0.9 (0.70)	0.6 (0.53)	1.3 (1.10)	3.6 (0.25)
		T2	21	9.8 (2.03)	7.6 (1.54)	1.7 (0.89)	1.1 (0.68)	2.5 (1.01)	3.7 (0.21)
		T3	22	13.1 (3.30)	4.8 (2.26)	1.2 (1.03)	0.7 (0.63)	1.8 (1.39)	1.6 (0.16)
		T4	20	16.1 (1.17)	3.6 (1.16)	0.3 (0.27)	0.1 (0.09)	0.3 (0.35)	1.4 (0.05)
Intervention	5	T0	23	16.5 (1.19)	3.2 (1.08)	0.2 (0.25)	0.1 (0.12)	0.3 (0.36)	1.0 (0.12)
		T1	23	10.1 (2.06)	7.8 (1.67)	1.8 (1.27)	0.9 (0.71)	2.2 (1.04)	3.7 (0.22)
		T2	22	9.9 (1.69)	7.7 (1.40)	1.4 (0.88)	1.0 (0.79)	2.3 (1.10)	3. (0.20)
		T3	22	16.7 (1.24)	2.3 (1.24)	0.2 (0.22)	0.1 (0.11)	0.3 (0.27)	1.4 (0.07)
		T4	22	16.3 (1.59)	3.5 (1.39)	0.3 (0.26)	0.1 (0.12)	0.3 (0.37)	1.4 (0.08)
Intervention	6	T0	23	16.5 (1.10)	3.4 (1.00)	0.1 (0.20)	0.0 (0.06)	0.2 (0.22)	1.4 (0.07)
		T1	23	9.9 (1.43)	7.7 (1.44)	1.5 (0.60)	1.1 (0.80)	2.3 (1.09)	3.6 (0.20)
		T2	22	10.5 (1.60)	7.7 (1.30)	1.2 (0.77)	0.8 (0.68)	1.7 (0.83)	3.5 (0.14)
		T3	21	16.8 (1.22)	3.0 (1.12)	0.2 (0.20)	0.1 (0.10)	0.2 (0.30)	1.4 (0.07)
		T4	23	16.8 (1.19)	3.0 (1.11)	0.2 (0.21)	0.0 (0.06)	0.2 (0.24)	1.4 (0.07)
Intervention	7	T0	15	16.7 (1.26)	3.0 (1.21)	0.3 (0.23)	0.1 (0.09)	0.3 (0.31)	1.5 (0.12)
		T1	16	11.2 (1.46)	7.7 (1.22)	0.6 (0.31)	0.5 (0.41)	0.8 (0.48)	3.7 (0.20)
		T2	16	9.9 (2.13)	7.6 (1.63)	1.6 (1.01)	1.2 (0.72)	2.5 (0.96)	3.6 (0.21)
		T3	13	15.7 (1.96)	3.6 (1.67)	0.3 (0.37)	0.2 (0.38)	0.5 (0.69)	1.5 (0.16)
		T4	14	16.9 (1.30)	3.8 (1.40)	0.3 (0.30)	0.1 (0.09)	0.3 (0.36)	1.5 (0.17)
Intervention	10	T0	25	16.4 (1.27)	3.3 (1.13)	0.2 (0.26)	0.0 (0.07)	0.3 (0.31)	1.4 (0.08)
		T1	23	9.5 (1.23)	7.9 (1.26)	1.7 (0.96)	1.2 (0.76)	2.6 (0.83)	3.7 (0.19)
		T2	23	9.9 (1.39)	7.6 (1.25)	1.7 (0.89)	1.0 (0.60)	2.4 (0.85)	3.5 (0.19)
		T3	23	16.1 (1.96)	3.6 (1.87)	0.3 (0.28)	0.2 (0.28)	0.5 (0.47)	1.5 (0.17)

		T4	24	16.5 (1.48)	3.1 (1.50)	0.2 (0.18)	0.1 (0.10)	0.3 (0.23)	1.4 (0.12)
Control	1	T0	14	16.3 (2.06)	3.3 (1.89)	0.3 (0.29)	0.1 (0.13)	0.4 (0.39)	1.6 (0.14)
		T1	16	15.3 (1.79)	4.4 (1.61)	0.1 (0.20)	0.1 (0.13)	0.2 (0.30)	1.5 (0.13)
		T2	17	16.4 (1.92)	3.3 (1.61)	0.3 (0.27)	0.1 (0.15)	0.4 (0.40)	1.5 (0.15)
		T3	14	16.6 (1.05)	3.1 (1.02)	0.3 (0.21)	0.1 (0.09)	0.3 (0.28)	1.5 (0.09)
		T4	15	16.4 (1.18)	3.4 (1.21)	0.2 (0.15)	0.0 (0.04)	0.2 (0.18)	1.5 (0.08)
Control	3	T0	20	16.8 (1.05)	2.9 (0.99)	0.3 (0.24)	0.1 (0.06)	0.3 (0.27)	1.5 (0.08)
		T1	21	16.4 (1.59)	3.4 (1.38)	0.2 (0.24)	0.0 (0.08)	0.2 (0.31)	1.4 (0.09)
		T2	20	16.7 (1.32)	3.0 (1.23)	0.2 (0.21)	0.1 (0.08)	0.2 (0.28)	1.4 (0.10)
		T3	21	16.3 (1.60)	3.4 (1.46)	0.2 (0.21)	0.0 (0.10)	0.2 (0.29)	1.4 (0.09)
		T4	20	16.8 (1.37)	3.1 (1.76)	0.2 (0.21)	0.1 (0.09)	0.3 (0.30)	1.4 (0.07)
Control	4	T0	20	16.8 (1.28)	3.0 (1.22)	0.2 (0.22)	0.1 (0.12)	0.2 (0.31)	1.4 (0.11)
		T1	22	16.2 (1.53)	3.5 (1.37)	0.2 (0.24)	0.1 (0.12)	0.3 (0.33)	1.4 (0.12)
		T2	22	16.6 (1.24)	3.2 (1.24)	0.3 (0.22)	0.1 (0.09)	0.3 (0.30)	1.5 (0.13)
		T3	20	16.0 (1.70)	3.8 (1.70)	0.3 (0.25)	0.0 (0.11)	0.3 (0.32)	1.4 (0.11)
		T4	21	16.5 (1.28)	3.2 (1.25)	0.2 (0.23)	0.1 (0.10)	0.3 (0.32)	1.4 (0.10)
Control	8	T0	23	16.5 (1.17)	3.3 (1.02)	0.2 (0.25)	0.0 (0.09)	0.2 (0.31)	1.4 (0.09)
		T1	22	17.3 (0.84)	2.6 (0.89)	0.2 (0.19)	0.0 (0.04)	0.2 (0.21)	1.4 (0.07)
		T2	21	16.9 (1.17)	2.9 (1.13)	0.1 (0.17)	0.0 (0.07)	0.2 (0.22)	1.3 (0.07)
		T3	21	16.7 (1.15)	3.1 (0.92)	0.2 (0.20)	0.1 (0.10)	0.3 (0.29)	1.4 (0.11)
		T4	21	16.7 (1.08)	3.2 (1.07)	0.2 (0.19)	0.0 (0.06)	0.2 (0.24)	1.4 (0.10)
Control	9	T0	23	16.5 (1.27)	3.3 (1.28)	0.2 (0.20)	0.1 (0.11)	0.2 (0.27)	1.3 (0.08)
		T1	21	16.0 (1.45)	3. (1.31)	0.2 (0.19)	0.1 (0.10)	0.2 (0.29)	1.4 (0.08)
		T2	18	16.7 (1.54)	2.9 (1.31)	0.3 (0.27)	0.1 (0.13)	0.3 (0.37)	1.3 (0.22)
		T3	20	16.2 (1.10)	3.6 (1.04)	0.2 (0.17)	0.0 (0.08)	0.2 (0.23)	1.4 (0.08)
		T4	19	16.6 (1.20)	3.2 (1.16)	0.2 (0.22)	0.1 (0.08)	0.3 (0.28)	1.4 (0.12)

Note: CARS stands for Children's Activity Rating Scale.

Appendix 7K. Lesson-time physical activity intensity per day in minutes according to rain status

		Intervention (n=113)							Control (n=106)						
Time	**Day**	**Wet days**	**n**	**SB**	**LPA**	**MPA**	**VPA**	**MVPA**	**Wet days**	**n**	**SB**	**LPA**	**MPA**	**VPA**	**MVPA**
T1	School day 1	1/5	91	10.07*	7.74	1.47**	0.97 *	2.14***	1/5	83	16.46**	3.31**	0.18	0.05	0.23
	(n=204)			(1.89)	(1.55)	(0.98)	(0.73)	(1.11)			(1.46)	(1.33)	(0.21)	(0.09)	(0.29)
			14	11.23	7.67	0.61	0.48	0.82		16	15.31	4.44	0.13	0.07	0.20
				(1.46)	(1.22)	(0.31)	(0.41)	(0.48)			(1.79)	(1.61)	(0.20)	(0.13)	(0.30)

Notes. Only study days where the postcode of at least one participating school provided a weather forecast featuring rain are presented; Figures in bold indicate wet days. Significance indicates difference between wet and dry activity within the given intervention group; * p<0.05; ** p<0.01; *** p<0.00

Appendix 7L. Average lesson time physical activity multilevel modelling for the intervention period

Multilevel modelling for lesson time accelerometer-assessed sedentary behaviour (SB) during intervention period (T2 as outcome)

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	16.55 (0.69)***	18.68 (0.22)***	16.46 (0.20)***
Sex	0.00 (0.18)	-0.02 (0.17)	0.07 (0.13)
Ethnicity	0.04 (0.19)	0.07 (0.17)	0.05 (0.13)
$T1^0$	-3.34 (0.21)***	-3.34 (0.21)***	-0.25 (0.22)
$T2^0$	-3.27 (0.21)***	-3.28 (0.21)***	0.10 (0.22)
Intervention		-4.27 (0.17)***	-0.14 (0.23)
T1*Intervention			-5.86 (0.30)***
T2*Intervention			-6.45 (0.31)***
Random effects (SE)			
Variance between classes	2.10 (0.48)	6.72 (5.41)	0.14 (0.10)
Variance within classes	2.13 (0.06)	2.12 (0.06)	1.54 (0.04)
Model deviance	-1350.50	-1328.02	-1133.97

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * p<0.05; ** p≤0.01; *** p≤0.001.

Multilevel modelling for average lesson time accelerometer-assessed light physical activity (LPA) during intervention period (T2 as outcome)

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	3.17 (0.49)***	1.64 (0.17)***	3.17 (0.16)***
Sex	0.00 (0.14)	0.01 (0.14)	-0.05 (0.11)
Ethnicity	0.09 (0.15)	0.10 (0.14)	0.11 (0.11)
$T1^0$	2.43 (0.17)***	2.43 (0.16)***	0.29 (0.19)
$T2^0$	2.18 (0.17)***	2.18 (0.17)***	-0.14 (0.19)
Intervention		3.02 (0.14)***	0.18 (0.19)
T1*Intervention			4.06 (0.26)***
T2*Intervention			4.42 (0.26)***
Random effects (SE)			
Variance between classes	1.49 (0.34)	5.15 (3.78)	0.03 (0.23)
Variance within classes	1.67 (0.05)	1.67 (0.05)	1.33 (0.04)
Model deviance	-1201.97	-1180.46	-1043.59

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** p≤0.001.

Multilevel modelling for lesson time accelerometer-assessed moderate-to-vigorous physical activity (MVPA) during intervention period (T2 as outcome) – presented in Section 7.6

Multilevel modelling for lesson time physical activity observed with the Children's Activity Rating Scale (CARS) during intervention period (T2 as outcome)

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	1.38 (0.24)***	0.63 (0.06)***	1.44 (0.03)***
Sex	0.02 (0.05)	0.01 (0.04)	-0.01 (0.01)
Ethnicity	-0.03 (0.05)	0.00 (0.05)	-0.02 (0.01)
$T1^0$	1.17 (0.05)***	1.17 (0.05)***	-0.01 (0.02)
$T2^0$	1.15 (0.05)***	1.15 (0.05)***	0.00 (0.02)
Intervention		1.46 (0.04)***	-0.03 (0.04)
T1*Intervention			2.24 (0.03)***
T2*Intervention			2.20 (0.03)***
Random effects (SE)			
Variance between classes	0.73 (0.16)	1.78 (1.18)	0.06 (0.01)
Variance within classes	0.55 (0.02)	0.54 (0.02)	0.15 (0.01)
Model deviance	-522.45	-496.06	289.48

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** $p \leq 0.001$.

Appendix 8A: Mean student engagement scores during 20-minute lesson periods by class

Group	Class	Time	n	TSR	PSL	FGA	FSL	n	OPTIC†
Intervention	2	T0	20	23.7	20.9	17.0	13.4	22	1.8
				(2.52)	(3.23)	(3.04)	(2.01)		(0.07)
		T1	21	24.2	20.9	17.0	13.3	23	1.8
				(1.95)	(3.11)	(2.97)	(1.98)		(0.07)
		T2	21	23.2	21.0	17.0	13.5	21	1.8
				(2.66)	(3.05)	(2.94)	(1.97)		(0.07)
		T3	21	22.3	20.6	17.0	13.3	21	1.8
				(3.14)	(3.14)	(3.01)	(1.98)		(0.05)
		T4	19	22.6	20.5	17.2	13.2	19	1.8
				(2.41)	(2.72)	(3.01)	(1.96)		(0.06)
Intervention	5	T0	22	23.2	20.8	16.6	13.3	23	1.8
				(2.63)	(3.16)	(3.50)	(1.76)		(0.05)
		T1	22	24.1	21.0	16.5	13.5	23	1.8
				(2.32)	(3.02)	(3.42)	(1.77)		(0.05)
		T2	21	23.1	21.1	16.6	13.7	22	1.9
				(2.87)	(2.99)	(3.46)	(1.49)		(0.05)
		T3	22	23.0	20.6	16.7	13.4	22	1.8
				(3.40)	(3.14)	(3.47)	(1.76)		(0.06)
		T4	21	22.2	20.7	16.7	13.4	22	1.8
				(3.40)	(2.95)	(3.51)	(1.80)		(0.06
Intervention	6	T0	23	23.4	20.0	16.7	13.7	23	1.8
				(2.78)	(3.75)	(2.48)	(2.14)		(0.08)
		T1	21	24.0	19.8	16.4	14.1	22	1.9
				(2.50)	(3.23)	(2.46)	(1.56)		(0.06)
		T2	22	23.9	19.9	16.4	13.9	22	1.8
				(2.51)	(3.06)	(2.28)	(1.60)		(0.11)
		T3	19	22.3	19.9	16.3	13.8	20	1.7
				(3.66)	(3.62)	(2.34)	(2.22)		(0.06)
		T4	22	23.1	20.0	16.7	13.8	22	1.8
				(2.97)	(3.21)	(2.03)	(2.02)		(0.07)
Intervention	7	T0	15	22.5	20.2	17.3	13.1	15	1.8
				(3.98)	(3.21)	(2.82)	(1.71)		(0.09)
		T1	15	24.3	20.7	17.7	13.3	16	1.9
				(3.10)	(3.04)	(2.22)	(1.71)		(0.06)
		T2	15	24.6	20.8	17.7	13.3	16	1.9
				(3.44)	(3.00)	(2.16)	(1.76)		(0.07)
		T3	13	23.8	20.9	17.7	13.4	13	1.8
				(2.05)	(2.27)	(1.89)	(1.56)		(0.10)
		T4	14	23.0	21.0	17.3	13.0	14	1.8
				(3.33)	(2.35)	(2.33)	(1.57)		(0.08)
Intervention	10	T0	23	23.5	20.4	16.9	13.7	25	1.8
				(2.56)	(2.92)	(2.72)	(2.02)		(0.06)
		T1	23	24.9	20.6	16.4	13.5	23	1.9
				(2.29)	(2.81)	(2.05)	(2.19)		(0.05)

		T2	22	24.4 (2.75)	20.6 (2.87)	16.8 (2.77)	13.5 (2.00)	23	1.9 (0.07)
		T3	22	23.1 (3.44)	20.0 (2.75)	16.0 (2.45)	13.6 (1.97)	23	1.9 (0.07)
		T4	24	23.5 (2.41)	16.9 (2.71)	16.7 (2.68)	13.5 (1.91)	24	1.8 (0.07)
Control	1	T0	13	23.1 (2.81)	20.7 (2.90)	17.0 (2.89)	12.8 (2.05)	14	1.8 (0.07)
		T1	14	23.3 (2.58)	20.7 (2.49)	16.8 (2.64)	12.9 (1.99)	16	1.8 (0.05)
		T2	17	22.7 (2.96)	20.3 (2.49)	16.5 (2.48)	12.8 (1.86)	17	1.8 (0.06)
		T3	14	23.2 (1.76)	20.6 (2.53)	16.6 (2.53)	12.6 (1.65)	14	1.8 (0.05)
		T4	15	22.6 (2.41)	20.7 (2.28)	16.9 (2.42)	12.9 (1.41)	15	1.8 (0.07)
Control	3	T0	19	22.5 (3.31)	20.2 (3.63)	16.4 (3.06)	13.7 (1.73)	19	1.8 (0.06)
		T1	21	22.7 (3.05)	20.2 (3.46)	16.4 (2.91)	13.9 (1.68)	21	1.8 (0.05)
		T2	20	22.8 (3.33)	20.5 (3.24)	16.7 (2.58)	14.0 (1.59)	20	1.8 (0.05)
		T3	20	22.4 (3.28)	20.0 (3.46)	16.2 (2.86)	13.7 (1.74)	20	1.8 (0.05)
		T4	19	22.3 (2.75)	20.2 (2.59)	16.6 (2.52)	13.8 (1.68)	19	1.8 (0.05)
Control	4	T0	20	23.7 (2.79)	20.6 (2.89)	16.8 (2.65)	13.7 (1.66)	20	1.8 (0.06)
		T1	21	24.2 (3.05)	20.6 (2.77)	16.7 (2.53)	13.7 (1.59)	21	1.7 (0.09)
		T2	21	23.1 (3.20)	20.5 (2.89)	16.7 (2.59)	13.7 (1.62)	22	1.8 (0.07)
		T3	20	23.1 (3.04)	20.4 (2.78)	16.8 (2.65)	13.6 (1.57)	20	1.8 (0.06)
		T4	20	23.2 (2.75)	20.2 (2.59)	16.6 (2.48)	13.8 (1.41)	20	1.8 (0.07)
Control	8	T0	22	23.7 (3.03)	20.4 (3.06)	16.9 (2.99)	13.5 (2.32)	23	1.8 (0.07)
		T1	21	23.3 (3.35)	20.4 (3.09)	16.6 (3.04)	13.2 (2.32)	22	1.8 (0.07)
		T2	21	23.0 (3.30)	20.1 (3.06)	16.7 (2.97)	13.1 (2.25)	21	1.8 (0.07)
		T3	21	22.6 (3.02)	20.7 (2.83)	17.0 (2.69)	13.1 (2.33)	21	1.8 (0.07)
		T4	21	22.6 (3.49)	20.6 (2.78)	17.1 (2.69)	13.1 (2.33)	21	1.8 (0.08)

Control	9	T0	18	23.9 (2.40)	19.9 (2.94)	16.7 (2.37)	14.1 (1.61)	20	1.8 (0.06)
		T1	19	24.0 (2.43)	19.9 (2.94)	16.8 (2.21)	13.9 (1.55)	19	1.8 (0.05)
		T2	18	22.9 (2.78)	19.9 (3.10)	16.7 (2.16)	13.8 (1.56)	18	1.8 (0.06)
		T3	18	23.1 (3.44)	20.1 (2.95)	16.7 (2.08)	13.8 (1.47)	18	1.8 (0.08)
		T4	17	23.5 (2.41)	19.8 (2.87)	16.5 (2.06)	13.8 (1.50)	17	1.8 (0.08)

Notes: † denotes where a lower score indicates a better performance; TSR, PSL, FSL & FGA are all constructs from the Student Engagement Instrument-Elementary Version (SEI-E); TSR stands for Teacher-Student Relationship (maximum score of 28); PSL stands for Peer Support for Learning (maximum score of 24); FGA stands for Future Goals and Aspirations (maximum score of 20); FSL stands for Family Support for Learning (maximum score of 16); OPTIC stands for the Observing Pupils and Teachers in the Classroom tool assessing on-task behaviour, with behaviour rated as off-task (1) or on-task (2).

Appendix 8B. OPTIC multilevel modelling for the intervention period

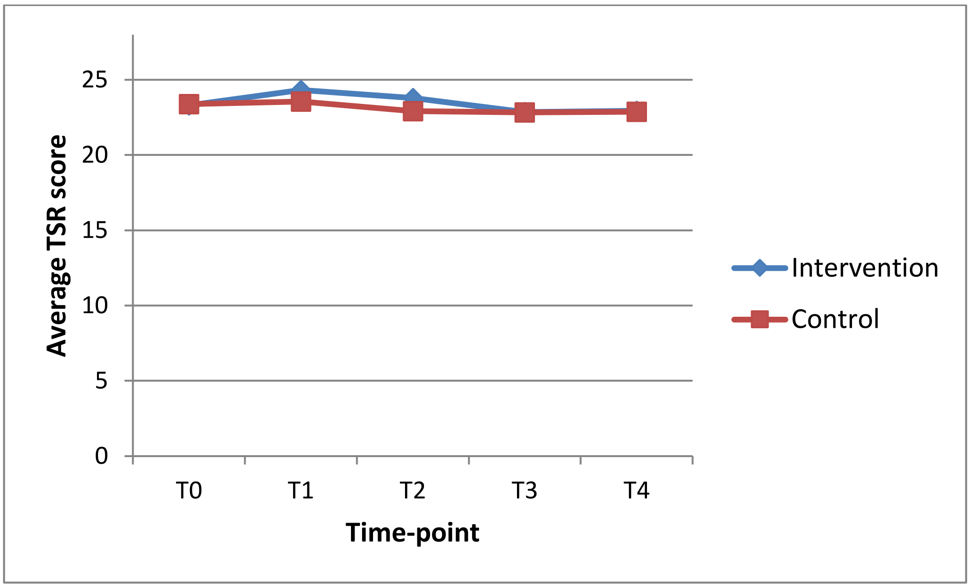
Multilevel modelling for on-task behaviour observed with the Observing Teaching and Pupils in Classrooms tool (OPTIC) during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	1.76 (0.01)***	1.73 (0.01)***	1.76 (0.01)***
Sex	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)
Ethnicity	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
$T1^0$	0.04 (0.01)***	0.04 (0.01)***	0.00 (0.01)
$T2^0$	0.04 (0.01)***	0.04 (0.01)***	-0.01 (0.01)
Intervention		0.06 (0.01)***	0.01 (0.01)
T1*Intervention			0.08 (0.01)***
T2*Intervention			0.09 (0.01)***
Random effects (SE)			
Variance between classes	0.03 (0.01)	0.01 (0.01)	0.01 (0.01)
Variance within classes	0.07 (0.01)	0.07 (0.01)	0.07 (0.01)
Model deviance	758.74	768.11	796.13

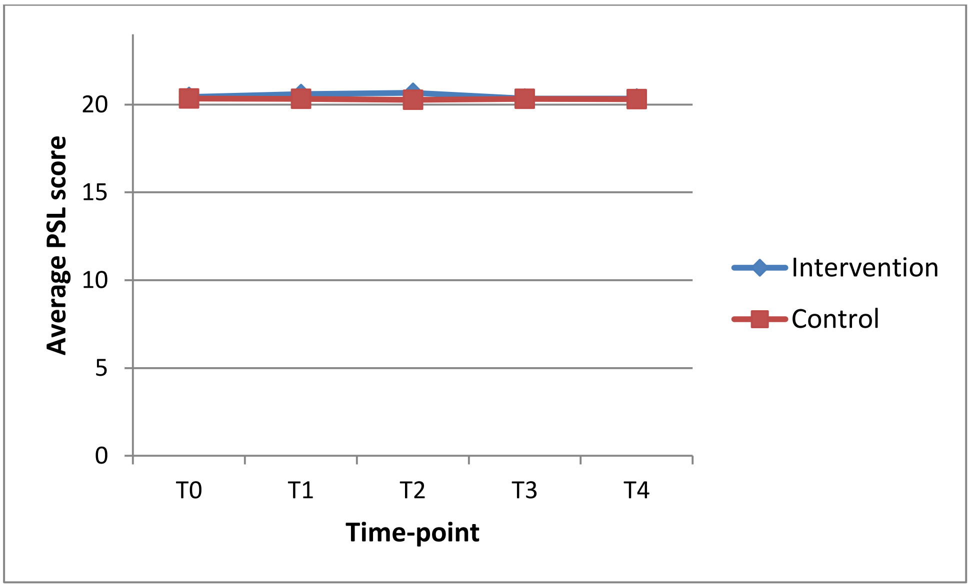
Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** $p \leq 0.001$.

Appendix 8C. Average student engagement scores by intervention group assessed by SEI-E questionnaire, where T1 & T2 represent the Virtual Traveller intervention period

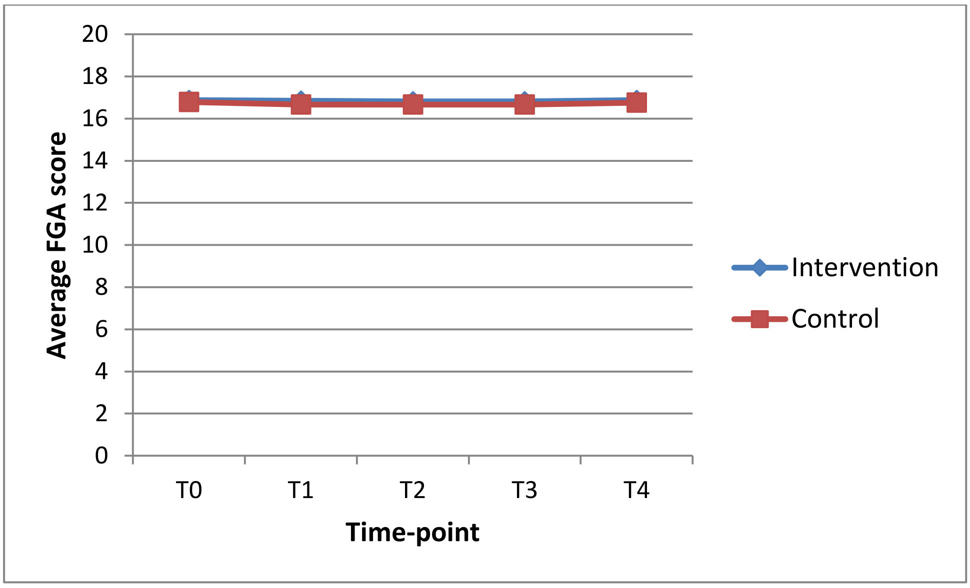
Teacher-Student Relationship (TSR)



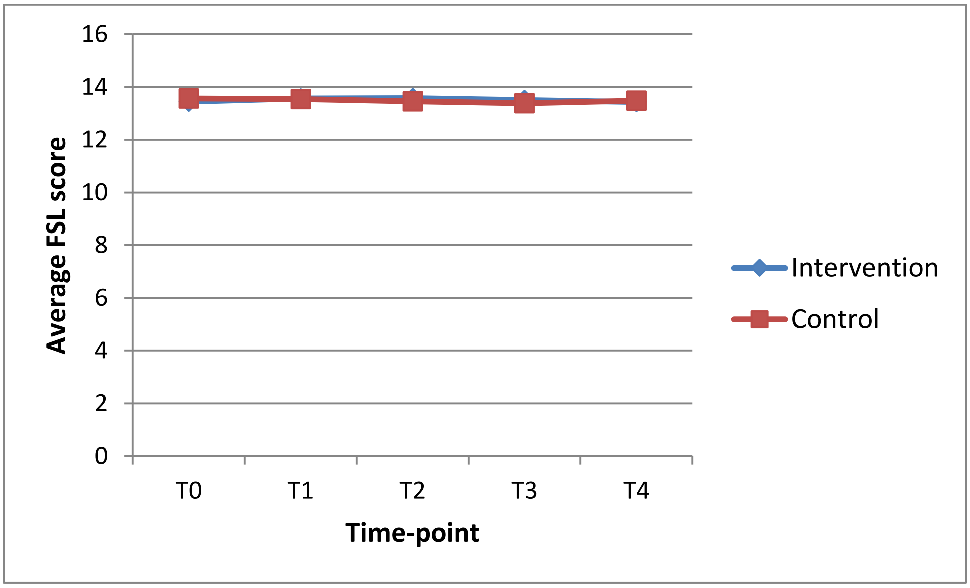
Peer Support for Learning (PSL)



Future Goals and Aspirations (FGA)



Family Support for Learning (FSL)



Notes: TSR, PSL, FSL & FGA are all constructs from the Student Engagement Instrument-Elementary Version (SEI-E); TSR stands for Teacher-Student Relationship (maximum score of 28); PSL stands for Peer Support for Learning (maximum score of 24); FGA stands for Future Goals and Aspirations (maximum score of 20); FSL stands for Family Support for Learning (maximum score of 16).

Appendix 8D. SEI-E sub-scale multilevel modelling for the intervention period

Teacher Student Relationships (TSR)

1) Multilevel modelling for TSR at T4 (3-month follow-up)

The VPC of Model 2 was 0.060, indicating that 6% of variance in TSR at T4 was due to variation between classes and 94% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. Sex added significant explanation to Model 2 (*B*= -0.70 (0.28); 95% CI, -1.06, -0.34; *p*<0.001), indicating that boys scored lower TSR than girls. There was no significant change in model fit between Model 2, Model 1 and the co-variates models, showing that adjusting for intervention and interaction terms did not change on-task behaviour at T4 or any time-point. These findings show that TSR was not significantly affected by the Virtual Traveller intervention.

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	23.68 (0.25)***	23.52 (0.28)***	23.76 (0.34)***
Sex	-0.72 (0.18)***	-0.70 (0.19)***	-0.70 (0.18)***
Ethnicity	0.05 (0.19)	0.06 (0.19)	0.06 (0.19)
$T1^0$	0.60 (0.29)*	0.60 (0.29)*	0.14 (0.41)
$T2^0$	-0.01 (0.29)	0.00 (0.29)	-0.52 (0.41)
$T3^0$	-0.49 (0.29)	-0.49 (0.29)	-0.58 (0.42)
$T4^0$	-0.44 (0.29)	-0.44 (0.29)	-0.55 (0.42)
Intervention		0.28 (0.22)	-0.18 (0.42)
T1*Intervention			0.88 (0.57)
T2*Intervention			1.00 (0.57)
T3*Intervention			0.15 (0.60)
T4*Intervention			0.20 (0.58)
Random effects (SE)			
Variance between classes	0.22 (0.13)	0.18 (0.14)	0.18 (0.14)
Variance within classes	2.85 (0.06)	2.85 (0.07)	2.83 (0.06)
Model deviance	-2400.55	-2399.80	-2397.22

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * *p*≤0.05; *** *p*≤0.001.

2) Multilevel modelling for TSR during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	23.68 (0.26)***	23.41 (0.29)***	23.74 (0.34)***
Sex	-0.62 (0.23)**	-0.57 (0.23)*	-0.58 (0.23)*
Ethnicity	-0.05 (0.24)	-0.03 (0.23)	-0.03 (0.23)
$T1^0$	0.60 (0.28)*	0.61 (0.28)*	0.15 (0.41)
$T2^0$	0.00 (0.28)	0.01 (0.28)	-0.51 (0.41)
Intervention		0.46 (0.23)*	-0.17 (0.40)
T1*Intervention			0.88 (0.56)
T2*Intervention			1.00 (0.56)
Random effects (SE)			
Variance between classes	0.19 (0.20)	3.58 (2.53)	2.81 (2.24)
Variance within classes	2.79 (0.08)	2.79 (0.08)	2.78 (0.08)
Model deviance	-1446.86	-1445.09	-1443.23

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * $p\leq0.05$; ** $p\leq0.01$; *** $p\leq0.001$.

Peer Support for Learning (PSL)

1) Multilevel modelling for TSR at T4 (3-month follow-up)

The VPC of Model 2 was 0.020, indicating that 2% of variance in PSL at T4 was due to variation between classes and 98% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. Sex added significant explanation to Model 2 (*B*= 0.84 (0.19); 95% CI, 0.47, 1.2; $p<0.001$), indicating that boys scored higher in PSL than girls. Ethnicity also added significant explanation to Model 2 (*B*= 0.63 (0.19); 95% CI, 0.26, 1.01; $p<0.001$), indicating that white pupils scored lower in PSL than non-white pupils. There was no significant change in model fit between Model 2, Model 1 and the co-variates models, showing that adjusting for intervention and interaction terms did not change on-task behaviour at T4 or any time-point. These findings show that PSL was not significantly affected by the Virtual Traveller intervention.

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	19.67 (0.25)***	19.47 (0.27)***	19.49 (0.34)***
Sex	0.82 (0.19)***	0.83 (0.19)***	0.84 (0.19)***
Ethnicity	0.60 (0.19)**	0.63 (0.19)**	0.63 (0.19)***
$T1^0$	0.10 (0.29)	0.10 (0.29)	0.03 (0.43)
$T2^0$	0.09 (0.29)	0.09 (0.29)	-0.04 (0.42)
$T3^0$	-0.06 (0.30)	-0.06 (0.30)	0.02 (0.43)
$T4^0$	-0.07 (0.30)	-0.07 (0.30)	-0.01 (0.43)
Intervention		0.33 (0.19)	0.30 (0.42)
T1*Intervention			0.14 (0.59)
T2*Intervention			0.26 (0.59)
T3*Intervention			-0.15 (0.59)
T4*Intervention			-0.12 (0.59)
Random effects (SE)			
Variance between classes	0.17 (0.15)	0.06 (0.32)	0.06 (0.31)
Variance within classes	2.91 (0.07)	2.91 (0.07)	2.91 (0.07)
Model deviance	-2422.77	-2421.46	-2421.12

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); ** *p*≤0.01; *** *p*≤0.001.

2) Multilevel modelling for PSL during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	19.69 (0.27)***	19.42 (0.31)***	19.50 (0.37)***
Sex	0.79 (0.25)***	0.83 (0.25)***	0.83 (0.25)**
Ethnicity	0.58 (0.25)*	0.62 (0.25)*	0.62 (0.25)*
$T1^0$	0.10 (0.30)	0.11 (0.30)	0.03 (0.43)
$T2^0$	0.09 (0.30)	0.10 (0.30)	-0.04 (0.43)
Intervention		0.43 (0.25)	0.30 (0.43)
T1*Intervention			0.14 (0.60)
T2*Intervention			0.26 (0.60)
Random effects (SE)			
Variance between classes	0.13 (0.28)	2.69 (2.16)	2.67 (2.16)
Variance within classes	2.98 (0.09)	2.97 (0.09)	2.98 (0.09)
Model deviance	-1484.08	-1482.60	-1482.51

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); * *p*≤0.05; ** *p*≤0.01; *** *p*≤0.001.

Future Goals and Aspirations (FGA)

1) Multilevel modelling for FGA at T4 (3-month follow-up)

The VPC of Model 2 was 0.6433, indicating that 64.33% of variance in FGA at T4 was due to variation between classes and 35.67% was due to variance within classes. Significance of the intercept in all models indicates that all explained more variance than comparative single-level models. Sex added significant explanation to Model 2 (B= -0.89 (0.17); 95% CI, 0.47, 1.2; p<0.001), indicating that girls scored higher in FGA than girls. There was no significant change in model fit between Model 2, Model 1 and the co-variates models, showing that adjusting for intervention and interaction terms did not change on-task behaviour at T4 or any time-point. These findings show that FGA was not significantly affected by the Virtual Traveller intervention.

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	17.22 (0.22)***	17.17 (0.25)***	17.22 (0.31)***
Sex	-0.90 (0.17)***	-0.89 (0.17)***	-0.89 (0.17)***
Ethnicity	0.16 (0.17)	0.17 (0.17)	0.17 (0.17)
$T1^{0}$	-0.09 (0.27)	-0.09 (0.27)	-0.16 (0.39)
$T2^{0}$	-0.12 (0.27)	-0.12 (0.27)	-0.18 (0.39)
$T3^{0}$	-0.10 (0.27)	-0.10 (0.27)	-0.17 (0.39)
$T4^{0}$	-0.03 (0.27)	-0.03 (0.27)	-0.07 (0.39)
Intervention		0.07 (0.17)	-0.02 (0.38)
T1*Intervention			0.13 (0.54)
T2*Intervention			0.13 (0.54)
T3*Intervention			0.15 (0.54)
T4*Intervention			0.09 (0.54)
Random effects (SE)			
Variance between classes	8.42 (6.75)	3.29 (2.11)	4.78 (3.58)
Variance within classes	2.65 (0.06)	2.65 (0.06)	2.65 (0.06)
Model deviance	-2330.18	-2330.09	-2330.04

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** p≤0.001.

2) Multilevel modelling for FGA during intervention period (T2 as outcome)

Multilevel modelling for Future Goals and Aspirations (FGA) sub-scale of the Student Engagement Instrument - Elementary version (SEI-E) during intervention period (T2 as outcome)

	Co-variates	**Model 1**	**Model 2**
Fixed effects (SE)			
Intercept	17.23 (0.24)***	17.20 (0.28)***	17.24 (0.33)***
Sex	-0.90 (0.22)***	-0.89 (0.22)***	-0.89 (0.22)***
Ethnicity	0.12 (0.22)	0.13 (0.22)	0.13 (0.22)
$T1^0$	-0.09 (0.27)	-0.09 (0.27)	-0.16 (0.39)
$T2^0$	-0.12 (0.27)	-0.12 (0.27)	-0.18 (0.39)
Intervention		0.06 (0.22)	-0.03 (0.39)
T1*Intervention			0.13 (0.54)
T2*Intervention			0.13 (0.54)
Random effects (SE)			
Variance between classes	2.13 (1.53)	1.94 (1.49)	2.75 (8.67)
Variance within classes	2.69 (0.08)	2.68 (0.08)	2.68 (0.08)
Model deviance	-1422.32	-1422.29	-1422.26

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** $p \leq 0.001$.

Family Support for Learning (FSL)

1) Multilevel modelling for FSL at T4 (3-month follow-up)

The VPC of Model 2 was 0.095, indicating that 9.95% of variance in FSL at T4 was due to variation between classes and 90.05% was due to variance within classes. Significance of the intercept in all models indicates that all explained significantly more variance than comparative single-level models. Ethnicity added significant explanation to Model 2 (*B*= -0.49 (0.12); 95% CI, -0.73, -0.26; $p<0.001$), indicating that white pupils scored higher in FSL than non-white pupils. There was no significant change in model fit between Model 2, Model 1 and the co-variates models, showing that adjusting for intervention and interaction terms did not change on-task behaviour at T4 or any time-point. These findings show that FSL was not significantly affected by the Virtual Traveller intervention.

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	13.81 (0.17)***	13.84 (0.19)***	13.92 (0.23)***
Sex	-0.14 (0.12)	-0.14 (0.12)	-0.15 (0.11)
Ethnicity	-0.49 (0.12)***	-0.50 (0.122)***	-0.49 (0.12)***
$T1^0$	0.05 (0.18)	0.05 (0.18)	-0.03 (0.26)
$T2^0$	0.04 (0.18)	0.04 (0.18)	-0.08 (0.26)
$T3^0$	-0.05 (0.18)	-0.05 (0.18)	-0.19 (0.27)
$T4^0$	-0.04 (0.18)	-0.04 (0.18)	-0.08 (0.27)
Intervention		-0.05 (0.17)	-0.19 (0.29)
T1*Intervention			0.15 (0.36)
T2*Intervention			0.24 (0.36)
T3*Intervention			0.27 (0.37)
T4*Intervention			0.08 (0.37)
Random effects (SE)			
Variance between classes	0.20 (0.09)	0.20 (0.09)	0.20 (0.08)
Variance within classes	1.81 (0.04)	1.81 (0.04)	1.81 (0.04)
Model deviance	-1959.85	-1959.81	-1959.45

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** $p \leq 0.001$.

2) Multilevel modelling for FSL during intervention period (T2 as outcome)

	Co-variates	Model 1	Model 2
Fixed effects (SE)			
Intercept	13.79 (0.17)***	13.83 (0.20)***	13.90 (0.23)***
Sex	-0.10 (0.15)	-0.10 (0.15)	-0.11 (0.15)
Ethnicity	-0.49 (0.15)***	-0.50 (0.15)***	-0.50 (0.15)***
$T1^0$	0.05 (0.18)	0.05 (0.18)	-0.03 (0.26)
$T2^0$	0.04 (0.18)	0.04 (0.18)	-0.09 (0.26)
Intervention		-0.07 (0.17)	-0.19 (0.27)
T1*Intervention			-0.03 (0.26)
T2*Intervention			-0.09 (0.26)
Random effects (SE)			
Variance between classes	0.12 (0.14)	0.11 (0.15)	0.11 (0.15)
Variance within classes	1.81 (0.05)	1.81 (0.05)	1.81 (0.05)
Model deviance	-1191.15	-1191.07	-1190.86

Notes: ^{0} indicates comparison of scores between given time-point and T0 (baseline); *** $p \leq 0.001$.