Motor abilities in individuals with Williams Syndrome and individuals with Down Syndrome, and how they relate to spatial skills, anxiety and activities of daily living.

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I, Leighanne Amy Mayall, 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.

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Abstract

This thesis aimed to examine the motor profile of individuals with Williams Syndrome (WS) and individuals with Down Syndrome (DS), and the impact of impaired motor performance in these individuals on other domains. Previous research into motor abilities in these groups has shown poor fine and gross motor ability in children with WS and DS. This research determined the motor profile of each group, and then used this to investigate associations between motor abilities and: physical activity; spatial cognition (mental rotation and block construction); anxiety; and activities of daily living. Motor deficits in both individuals with WS and individuals with DS were observed, with both groups performing at the level of typically developing 4- to 5-year-olds. Both WS and DS groups presented with the same motor profile of relative strength in Upper Limb Control and a particular weakness in Balance. There was no relationship between participation in physical activity and motor ability in any group. Associations were found between fine motor ability and block construction in all groups, but only the WS group showed any associations between mental rotation and motor ability. There were no correlations between anxiety and motor ability in either the WS or DS group, but there were associations between motor ability and daily living ability in both the WS and DS groups. Overall, motor deficits were found in individuals with WS and individuals with DS, and some associations between motor ability and small-scale spatial skills and daily living were found in both these populations.

Impact statement

To investigate the aims in this thesis, a cross-syndrome comparison was used, which allowed investigation into whether the difficulties that individuals with WS and individuals with DS experience in regards to their motor, spatial, anxiety and daily living ability are characteristic of each disorder, or whether certain difficulties are common to both groups, and may therefore reflect their learning difficulties generally.

The current research not only aimed to further research into motor abilities in both WS and DS (WS: Tsai, Wu, Liou & Shu, 2008; Wuang & Tsai, 2017; DS: Alesi et al., 2018; Jobling, 1998; Malak et al., 2015; Spano et al., 1999). Further to this, this is the first study, to our knowledge, that provides an in-depth investigation into the motor profile in these populations. This has implications for intervention studies to improve motor abilities by providing professionals with information about which areas individuals with WS and DS are likely to have most/least difficulty with. It also provides information to new parents of children with WS or DS about the specific areas of motor ability that their son or daughter may struggle with, and they can then seek specific help and put things in place for the future.

As will be discussed in Chapter 5, an association between motor skills and everyday functioning has been observed in individuals with motor difficulties (e.g. Dunford et al., 2005; Magalhaes et al., 2011; Summers et al., 2008). In support of this, it was found in this thesis that motor ability was associated with a novel practical daily living task, providing evidence that improving motor ability may have a significant impact on independence and daily life of individuals with WS and individuals with DS. To investigate this, a novel practical daily living assessment (P-DLT) was designed and implemented, specifically to be used with individuals with WS and individuals with DS, taking into account parent reported strengths and difficulties in the two groups activities of daily living. This P-DLT could be used or adapted for future research into daily living and independence in these populations.

Alternately, if the P-DLT was adapted, it could be used with other populations with neurodevelopmental disorders/learning difficulties. There is not, to this authors knowledge, another practical daily living assessment that could be used easily to assess activities of daily living with a large group of people. The only other daily living assessment that this author is aware of is the Assessment of Motor and Process Skills (AMPS, Fisher and Bray Jones, 2006), which is used by occupational therapists to assess performance on activities of daily living. However, this is designed to be used on an individual basis for assessment and cannot be easily adapted for research purposes with large numbers of individuals (for more information, see Chapter 5, section 5.1.3).

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Chapter 1

Literature review and introduction to thesis

1.1.Introduction

The successful development of motor skills in humans is essential to everything that we do; from feeding ourselves, dressing ourselves and being able to move ourselves independently around our environments. Without adequate acquisition of motor skills, independent living becomes difficult, if not impossible. Two populations who show difficulties in the mastery of their motor skills are individuals with Williams Syndrome (WS) and individuals with Down Syndrome (DS). WS is a rare genetic neurodevelopmental disorder characterised by significant deficits in visuospatial skills, with relative strengths in verbal abilities (Mervis, Morris, Bertrand & Robinson, 1999). Visuospatial skills can be defined as the ability to represent, analyse, and mentally manipulate objects. DS in comparison, is the most common genetic neurodevelopmental disorder, and is characterised by a relative strength in visuospatial abilities, but with poorer verbal abilities (Wang, 1996). The overall aim of this thesis was to expand on the current research into motor abilities in individuals with WS and individuals with DS, and what these motor abilities are associated with.

The first experimental chapter of this thesis (Chapter 2) investigated motor abilities in individuals with WS and individuals with DS. This research expanded on current research in two ways. First, it included adult participants. This allowed the experimenter to determine the adult end-state of motor competence in these groups, and to see if the reported motor difficulties experienced in children with WS and DS persist into adulthood. Second, it examined the motor profile for individuals with WS and DS, which allowed the experimenter to investigate potential strengths and difficulties in motor ability for each group. More details

on what is currently known about motor abilities in WS and DS are provided in sections 1.3.6 and 1.3.14.

The second experimental chapter (Chapter 3) focused on the potential association between motor ability and small-scale spatial skills in individuals with WS and individuals with DS. The association between motor abilities and spatial skills has been well established in young typically developing infants and toddlers (e.g. Adolph, Bertenthal, Boker, Goldfield & Gibson, 1997; Bai & Bertenthal, 1992; Clearfield, 2004). As visuo-spatial abilities are considered to be the weakest area of cognitive performance in individuals with WS (see section 1.3.5), and motor ability is also severely impaired, it is interesting to determine whether these two impairments are related to one another in this group. Cross-syndrome comparison with DS, for whom motor, but not spatial ability (see section 1.3.13), is considered an area of relative weakness, facilitated the interpretation of the extent to which findings are syndrome-specific to WS. The research in Chapter 3 added to the current motor and spatial literature as it was the first study to examine the association between motor abilities and small-scale spatial skills in either WS or DS.

Chapter 4 focused on the potential association between anxiety and motor ability. Anxiety is a well-researched area in WS literature, with studies showing high levels of anxiety in the majority of the population tested (see section 1.3.7; for DS, see section 1.3.15). In typically developing, clinically anxious individuals, research has shown an association between high anxiety and poorer motor ability (e.g. Dewey, Kaplan, Crawford & Wilson, 2002; Erez, Gordon, Sever, Sadeh & Mintz, 2004; Kristensen & Torgersen, 2007). It may be that the poorer motor abilities shown in individuals with WS are associated with their high levels of anxiety. This was the first investigation of the association between anxiety and motor ability in either WS or DS populations.

The final experimental chapter (Chapter 5) focused on the relationship between motor ability and daily living skills. Having good adaptive behaviour and daily living skills is essential to independence, e.g. personal care and looking after the home. For an overview of what is currently known about daily living ability in WS and in DS, see Chapter 5. There is an obvious link between motor abilities and daily living skills, and there has been a significant amount of research showing that individuals with developmental co-ordination disorder (DCD) have poorer daily living ability than their typically developing, chronologically age matched peers (for a review, see Magalhaes, Cardoso & Missiuna, 2011). The current research is novel in several ways. First, it is the first to use a practical daily living assessment as well as parent report of daily living ability. Second, it is the first study to examine the relationship between motor ability and daily living ability in individuals with WS and individuals with DS.

1.2.Typical development of motor abilities

Before considering motor abilities in WS and in DS in detail, it is important to have a good understanding of what is understood about motor abilities in typical development. The process by which typically developing individuals gain mastery of motor skills is considered to be one of the first and most important areas of research into infant development (Gesell, Thompson & Amatruda, 1938; McGraw, 1943). Of particular interest is the age by which infants achieve certain motor milestones, and the psychological implications of successful motor skill acquisition. The consideration of typical motor development is important as it will allows examination of whether the deficits seen in WS and DS are a simple delay, or if motor skill acquisition in WS and DS is in fact different from typical development.

From birth, typically developing infants begin their cognitive development by means of interacting with their environment through motor acts, such as reactions to interesting stimuli by orientating the head, and spontaneous movements (Berthental, 1996). These kinds

of motor acts are the earliest manifestation of the extensive motor development that an individual will experience over their lifetime (O'Brien & Hayes, 1995). These simple movements will, over time, evolve into more complex motor behaviours by aiding the acquisition of new motor skills, such as sitting unsupported, standing and eventually, walking (Burton & Miller, 1998). The acquisition of new motor abilities further enables new learning opportunities. For example, better head stability helps to facilitate oculomotor control and visuospatial abilities such as depth perception (Bushnell & Boudreau, 1993), which are thought to facilitate the child's cognitive development (Piek, Dawson, Smith & Gasson, 2008; Son & Meisels, 2006), and are essential for activities of daily living (Watkinson, Dunn, Cavaliere, Calzonetti, Wilhelm & Dwyer, 2001). In this way, gross motor skills that are acquired in the first few months of life facilitate other motor and cognitive skills in later childhood in both typical development and in individuals at risk of developmental delay.

1.2.1. The motor system

The human motor system is a complex system comprised of different brain areas, which must work together to carry out motor acts. In order to successfully carry out goal-directed movements, the primary motor cortex (M1) must first receive and process different information from the four lobes of the brain: the parietal lobe provides M1 with information about the body's position in space; the frontal lobe provides information about the goal to be attained and the appropriate strategy; the temporal lobe provides memories of past motor strategies; and the occipital lobe provides visual information about the environment and the object to be manipulated (Crossman & Neary, 2015).

1.2.2 Typical motor development

Motor development was the first topic in the scientific study of infant development (Shaffer & Kipp, 2010). Most notable is the early research of Gesell, Thompson and Amatruda (1938) and McGraw (1943) who, amongst other things, were first to hypothesise

about motor milestones and why infants pass through each of them at certain time points (Table 1). In their research both authors concluded that the emergence of motor skills are associated with early brain maturation. This research is still heavily cited in textbooks and paved the way for more in-depth psychological research into motor development.

Table 1. Table indicating average age (months) that typical infants reach motor milestones: Taken from "Child and Adolescent Developmental Psychology: Eighth Edition" Shaffer & Kipp (2010).

Motor Skill	Age (months) when 50% of infants have mastered the skill	Age (months) when 90% of infants have mastered the skill
Lifts head 90 degrees when lying on stomach	2.2	3.2
Rolls over	2.8	4.7
Supported sitting	2.9	4.2
Unsupported sitting	5.5	7.8
Assisted standing	5.8	10.0
Crawling	7.0	9.0
Assisted walking	9.2	12.7
Unsupported standing	11.5	13.9
Walks	12.1	14.3
Can build a simple tower using blocks	13.8	19.0
Can climb steps	17.0	22.0
Kicks a ball	20.0	24.0

1.3. Williams Syndrome (WS) and Down Syndrome (DS)

1.3.1 Overview of the WS genotype and phenotype

Williams syndrome (WS) is a rare genetic neurodevelopmental disorder caused by a *de novo* microdeletion on one copy of the WS critical region (chromosome 7q11.23), that is characterised by psychological, neurophysiological and neuroanatomical features (Hocking, Bradshaw & Rinehart, 2008). Approximations estimate the prevalence of WS to be between 1 in 7,500 births (Strømme, Bjømstad & Ramstad, 2002) and 1 in 20,000 (Morris, Demsey, Leonard, Dilts & Blackburn, 1988). Individuals diagnosed with WS have well documented elfin-like physical features. Pre-mature greying of the hair occurs in many adults with WS,

and a slouched posture often develops over time. Typically, infants with WS have a lower birth weight and postnatal growth tends to be slower (Donnai & Karmiloff-Smith, 2000). However, puberty often occurs earlier in this population (Cherniske, Sadler, Schwartz, Carpenter & Pober, 1999) which is thought to contribute to a shorter height. These individuals show some cognitive strengths, such as good facial recognition (Bellugi, Lichtenberger, Jones, Lai & St George, 2000). Indeed, these individuals show a particular concern for social stimuli, and are particularly fascinated by faces (Jarvinen et al., 2015).

1.3.2. Genes in WS

Research using animal knock-out models and individuals with WS with only partial deletions within the WS critical region (WSCR) have helped gain insight into what role specific individual genes from the WS deleted region play in expression of the disorder (e.g. Meng et al., 1998; Osborne, 2010). However, only the ELN gene, which is responsible for the production of elastin, has been explicitly linked to specific phenotypic expression in WS (Osborne, 2012; Pober, 2010). The ELN gene is associated with cardiovascular disease, specifically supravalvular aortic stenosis and with connective tissue abnormalities, such as joint problems (Curran, Atkinson, Ewart, Morris, Leppert & Keating, 1993; Metcalfe et al., 2000).

There is some evidence to suggest that LIMK1 plays a role in the visuospatial deficits reported in WS (Frangiskakis et al., 1996; Morris et al., 2003), though there is conflicting evidence that suggests that the deletion of only one copy of LIMK1 was not sufficient to account for visuospatial deficits in WS (Gray, Karmiloff-Smith, Funnell & Tassabehji, 2006). The gene GTF2I has been associated with the intellectual disability seen in WS (Morris et al., 2003). Morris et al. (2003) investigated five families with deletions of LIMK1 spanning various sections of the Williams Syndrome critical region (WSCR). None of the individuals tested had the full phenotypic expression of WS, though they all presented with some aspects

of the WS profile, and none had a deletion of GTF2I. None of the individuals tested showed intellectual difficulties once the impact of visuospatial abilities had been taken into account. The authors suggest that the good cognitive functioning may be due to the sparing of the GTF2I gene at the telemetric end of the WSCR. This is supported by evidence from Botta et al. (1999) who found intellectual disability in a child with GTF2I deletion (though note the small sample of only one participant). Dai et al. (2009) found evidence that GTF2I is associated with aspects of social behaviour in WS, and that, in a participant with spared GTF2I, normal cognitive functions were observed.

Schneider et al. (2012) investigated the role of GTF2IRD1, which is deleted in WS, in motor abilities using mice knock-out models. They discovered that the mice who had had the GTF2IRD1 gene knocked-out showed decreased spontaneous motor activity, deficits in motor co-ordination, gait abnormalities and reduced strength, compared to mice with intact GTF2IRD1. This suggests the possible role of GTF2IRD1 in the motor abilities of individuals with WS. Additionally, Barak et al. (2019) also used mice models to investigate the potential role of the deletion of GTF2I in WS. The authors found that selective deletion of the GTF2I gene in mice caused fine motor deficits and neuroanatomical deficits, along with increased anxiety and sociability. However, Kopp, McGullough, Maloney and Dougherty (2019) investigated the role of GTF2I and GTF2IRD1 using mouse models either with a complete deletion of the full WSCR or partial deletion of only the GTF2I and GTF2IRD1 genes. The authors found that the mice with the complete deletion showed deficits across several behavioural domains including motor functioning, social communication and conditioned fear responses that were not present in the mice with only the GTF2I and GTF2IRD1 gene mutations. However, caution should be taken when interpreting these animal models when considering human subjects. One study by Serrano-Juarez et al. (2018) investigated the cognitive, behavioural and adaptive profiles of 18 individuals with WS aged

7-18 years, four with GTF2IRD2 deletion and eight without this deletion. It was found that, individuals with the GTF2IRD2 deletion presented with more impaired performance on tasks measuring visuospatial skills and more behavioural problems, particularly related to social cognition. However, note here that only four participants with the GTF2IRD2 deletion were included in this study, which limits the generalisability of the results.

1.3.3. Neurophysiology in WS

Overall cerebrum size reductions have been found in 13%-18% of individuals with WS studied in comparison to typically developing controls (Reiss et al., 2000; Sampaio, Sousa, Férnandez, Vasconcelos, Shenton & Gonçalves, 2008), while the size of the cerebellum (one of the main areas of the brain responsible for motor execution; Crossman & Neary, 2015) appears reduced in only 7%-10% of individuals studied (Osorio et al., 2014; Reiss et al., 2000). Data examining the total volume of the cerebellum in WS has been inconsistent, with some authors finding an increase in cerebellar volume relative to controls and overall brain size in WS (Jones, Hesselink, Courchesne, Duncan, Matsuda & Bellugi, 2002; Reiss et al., 2000), and others finding no differences in volume in comparison to typical controls (Chiang et al., 2007; Jernigan, Bellugi, Sowell, Doherty & Hesselink, 1993). Overall, these studies suggest that the absolute volume of the cerebellum in WS is comparable to healthy matched controls, but that there is a slight increase in the relative volume of this structure, when the overall volume reduction of the cerebrum is considered.

It has been reported by Jernigan et al. (1993) and Reiss et al. (2000) that the basal ganglia of individuals with WS is reduced in size and volume compared to typical chronological age matched control participants. The basal ganglia plays a key role in the control of movement, and so it is possible that this reduction in size could be detrimental to individuals in this population with reference to carrying out motor acts successfully.

In comparison, after adjustment to normal brain volume, it seems that the frontal lobes,

anterior cingulate, fusiform gyrus and superior temporal gyrus, are all relatively well preserved in WS, compared to the occipital and parietal lobes, the basal ganglia, thalamus and the midbrain, which are all considerably smaller than average in WS. Chiang et al. (2007) also found relative preservation of the amygdala and right fusiform gyrus.

Nir and Barak (2021) reviewed research into white matter abnormalities in WS and how these abnormalities may contribute to the WS behavioural profile and motor deficits. Overall, it was found that individuals with WS have, on average, less grey matter and white matter volume in the parieto-occipital, anterior cingulate cortex, corpus collosum, cingulate gyrus, fusiform gyrus, hippocampus, amygdala, cerebellar peduncles, basal ganglia and internal capsule (Avery, Thornton-Wells, Anderson & Blackford, 2012; Campbell et al., 2009; Green et al., 2016; Haas et al., 2014; Tomaiuolo et al., 2002).

Gagliardi et al. (2018) investigated abnormalities in the structural and functional connections of the brains of 10 individuals with WS aged 17-28 years and a group of 19 control subjects aged 16-30 years. The authors used 3T brain MRI scans which included anatomical, functional and structural (DTI) sequences. The authors examined the Fractional Anisotropy (FA) values of each group in various brain regions. FA is a value between 0 and 1, with 0 showing isotropic diffusion and 1 being diffusion occurring only along one axis. The participants with WS also completed the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1991) and parents were asked about the presence of psychiatric difficulties (mainly anxiety) in their son or daughter using the Kiddie-Sads Present and Lifetime Version (K-SADS-PL; Kaufman & Schweder, 2004). The control subjects were assessed using Cattell's Culture Fair Intelligence Test (Cattell & Cattell, 1960), the Child Behavioural Checklist and the 19 Youth Self Report or Adult Behaviour Checklist (Achenbach & Edelbrock, 1991). The authors found that the WS group showed a lower FA than the control group in both subcortical (white matter of the parieto-occipital region bilaterally) and deep regions

(cerebellum, corpus callosum, and posterior limbs of the internal capsules). They also found that the WS group showed asymmetrical involvement of parieto-occipital regions and lower FA in the right hemisphere. A lower FA in these regions have been found to be associated with language, motor, visuospatial and face processing abilities (37-39). Further, Gagliardi et al. (2018) found that the density of structural connections between the supplementary motor and occipital areas in the right hemisphere was negatively correlated with anxiety. However, no associations were found between connectivity and cognitive abilities.

There are, however, some limitations to this research. Firstly, the sample of individuals with WS consisted of those able to cope with the MRI scan and the noise associated with this. Therefore, some individuals were originally recruited and later excluded due to them not being able to take part in the MRI process. As a result, the individuals tested represent a subgroup of individuals with WS who are highly motivated and enthusiastic to take part in research as well as, perhaps, having fewer sensory sensitivities to noise than most of the population (e.g. Dilts et al., 1990; Einfeld, Tonge & Florio, 1997; Klein et al., 1990; Levitin, Cole, Lincoln & Bellugi, 2005; Leyfer et al., 2006; Pober & Dykens, 1996; Udwin & Yule, 1990). Another limitation is the relatively large age gap between participants from adolescents to adults. This age gap does not take into account the late development of frontal regions, and this should be considered in future research.

1.3.4. Cognition in WS

Research into the cognitive profile of WS began with the use of standardized test batteries (Bellugi, Wang & Jernigan, 1994; Wang & Bellugi, 1994), with all studies finding that individuals with WS fall well below their chronological age on all subtests, with a general consensus that verbal abilities are significantly better than non-verbal abilities in this population (Mervis, Morris, Bertrand & Robinson, 1999).

Historically, within-subject variability in WS shows a large range in IQ with some

studies reporting a range from <40 to 104 (Mervis, Morris, Bertrand & Robinson, 1999). Pezzino, Marec-Breton and Lacroix (2017) conducted a review of the neuropsychological profile of individuals with WS. They found that, overall, studies have shown that verbal IQ is higher than non-verbal IQ in individuals with WS (Boddaert et al., 2006; Searcy et al., 2004), and that there is less heterogeneity in non-verbal IQ (Searcy et al., 2004). Research has also suggested that intellectual levels are relatively stable in WS (Searcy et al., 2004).

Where language development is concerned, the literature cites that individuals with WS are largely unimpaired (Karmiloff-Smith et al., 2003; Carrasco et al., 2005), and research has shown that language abilities appear to be a strength in the cognitive profile of individuals with WS in comparison to other skills (Alloway & Gathercole, 2006; Bellugi et al., 2000; Brock, 2007; Martens, Wilson, & Reutens, 2008; Porter & Coltheart, 2005; Porter & Coltheart, 2006; Rhodes, Riby, Fraser, & Campbell, 2011; Rowe & Mervis, 2012). However, studies have found that early language development is delayed in WS by approximately 2 years compared to typically developing children, although language development does appear to follow a similar trajectory to mental age-matched peers (Bellugi et al., 2000; Laing et al., 2002; Martens et al., 2008). One explanation for this delay is that children with WS have been found to use less gestures than their mental age-matched peers, which has been associated with language development in typical development (Laing et al., 2002). However, later research by Mastrogiuseppe and Lee (2017) have shown that, in their sample of 11 individuals with WS (mean age=23.16 years), individuals with WS produced more gestures than the mental age-matched control children (aged 4-7 years). In this study, the WS group were more likely to use gesture only communication and also used more representative-ironic gestures (e.g. to show motion, shape, action, etc).

It has also been found that individuals with WS have more short-term memory difficulties when it comes to tasks involving recall than recognition (O'Hearn et al., 2009;

Rhodes, Riby, Park, Fraser & Campbell, 2010), and other studies have shown that, in comparison to both chronological and mental age-matched typically developing peers, individuals with WS struggle more on tasks related to spatial as opposed to visual short-term memory tasks (Vicari, Bellugi & Carlesimo, 2006).

Some research has indicated that individuals with WS exhibit attentional and executive deficits which decrease in adolescence (Farran & Jarrold, 2003; Carrasco et al., 2005; Rhodes et al., 2010). In comparison to chronological age matched peers, individuals with WS show deficits on tasks of selective, divided and sustained attention (Farran & Jarrold, 2003; Menghini et al., 2010; Costanzo et al., 2013; Greer, Riby, Hamilton & Riby, 2013). However, individuals with WS have been found to show better sustained attention in comparison to their mental age-matched peers (Atkinson, Braddick & Breckenridge, 2010). Individuals with WS have also been shown to have deficits in flexibility and attentional set-shifting that extend to the visuomotor domain (Mervis, Robinson, Rowe, Becerra, & Klein-Tasman, 2003; Menghini et al., 2010; Rhodes et al., 2010; Hocking et al., 2013). Further, individuals with WS have been shown to have problems with inhibition (Vicari, Bellugi, & Carlesimo, 2006; Jarrold, Baddeley & Phillips, 2007; Porter, Coltheart, & Langdon, 2007; Kittler et al., 2008; Sampaio et al., 2008; O'Hearn et al., 2009; Menghini et al., 2010; Rhodes et al., 2010; Costanzo et al., 2013; Hocking et al., 2013).

Miezah, Porter, Batchelor, Boulton and Veloso (2020) tested 49 individuals with WS aged 6-39 years on a neuropsychological test battery (Woodcock Johnson III Tests of Cognitive Abilities, Australian Adaptation; Woodcock, McGrew & Mather, 2001). Overall, the findings of the study support previous research in that the individuals with WS showed strengths in auditory processing and phonemic awareness. As a group, the WS individuals scored most poorly on processing speed, attention and executive functioning. However, unlike previous findings, visuospatial performance was not found to be a weakness overall.

The authors also examined individual differences in the performance on each task and found considerable heterogeneity. For example, on the fluid reasoning task, individual scores ranged from being in the severe intellectual impairment range (2% of the sample) to the average range (5% of the sample), indicating performance across a wide spectrum of strengths and weaknesses. So, while, for the group as a whole, auditory processing and phonemic awareness were strengths, some individuals were still scoring in the moderate intellectual impairment range.

Abreu and Schonen (2009) examined the performance of 10 children with WS (mean age=114.8 months), nine children with ASD (mean age = 64.33 months) and 96 typically developing children (aged 48 to 186.96 months) on five computer generated motion coherence tasks. When individual differences were examined in the WS group, it was found that not all children presented with the same strengths and weaknesses, and two children in the sample were found to perform within the typical or mild deficit range on all tasks. As a group, it was found that individuals with WS do not appear to present with difficulties in single dot detection. However, the WS group performed significantly below control children on the 'collision task' and on the three motion coherence tasks ('direction change', 'dot %' and 'form from motion').

Porter and Coltheart (2005) examined the cognitive heterogeneity of 31 individuals with WS aged 5-43 years using the Woodcock-Johnson Test of Cognitive Ability-Revised (Woodcock, 1997). The authors found that the most homogeneous skills in WS were phonological processing and phonological short-term memory, with 50% of the sample showing scores at their Basic Cognitive Ability level (BCA) on these tasks. However, although the overall group mean scores suggest strengths in auditory processing skills, some individuals tested scored below their BCA level indicating that this is a weakness for some

individuals. Similarly, when processing speed (a weakness for the group) was examined, this was found to be a relative strength in some individuals' cognitive profile.

Sauna-aho, Bjelogrlic-Laakso, Siren, Kangasmaki and Arvio (2019) examined cognition in 25 adults with WS (age at baseline 19-68 years) in a 20-year longitudinal study. To do this, the authors used the WAIS, WISC (Wechsler, 1949, 1955) and WPPSI (Weschler 1995) along with the Leiter International Performance Test (Leiter & Arthur, 1940) and the Bayley Scales of Infant Development (Bayley, 1993). It was found that the mean verbal IQ of the group remained stable from early adulthood up to 40 years of age, after which it declined, whereas non-verbal (performance) IQ kept on improving from early adulthood until age 50 when it began to decline. This indicates that the verbal functions of individuals with WS both develop and decline earlier than non-verbal functions. The authors also present scatter plots to show the change in individual participants performance over time. This, as in previous research into cognitive abilities, showed a wide range of scores, with some individuals receiving a FSIQ of <40 and others receiving a FSIQ of >70. However, the authors do not comment on the heterogeneity of the sample.

This evidence shows that the WS cognitive profile is highly variable, with individuals presenting with cognitive weaknesses, such as poor visuospatial skills, and relative strengths, such as language and face processing.

1.3.5. Small scale spatial skills in WS

Small-scale spatial ability can be defined as the ability to mentally represent and transform two- and three-dimensional images that can typically be seen from a single vantage point (Wang and Carr, 2014). The difficulties that individuals with WS show in regards to their visuospatial ability have been well documented in the literature, with studies finding deficits in drawing and handwriting ability (Bellugi et al., 1988/1994/1999; Hudson & Farran, 2011; Wang, Doherty, Rourke & Bellugi, 1995), visuospatial construction (e.g. Hoffman, Landau &

Pegani, 2003), mental rotation (Broadbent, Farran & Tolmie, 2014), visual search tasks (Pani, Mervis & Robinson, 1999) and perspective taking (Broadbent et al., 2014), to name a few.

Studies that have explored visual processing have revealed impaired performance on tests that have visuospatial elements (Farran & Jarrold, 2003; Farran, Jarrold, & Gathercole, 2001; Hoffman et al., 2003; Vicari, Bellucci, & Carlesimo, 2003; Farran, 2005; Landau, Hoffman, & Kurz, 2006; Dilks, Landau, & Hoffman, 2008; O'Hearn et al., 2011). It has been found that individuals with WS perform similarly to chronological age-matched typically developing controls on visual perception tasks (Vicari, Bellugi & Carlesimo, 2006), but perform worse than mental age-matched typically developing peers on spatial tasks. Further, it has been found that individuals with WS perform more favourably on visual imagery tasks than on visuospatial tasks (i.e. block tapping, drawing and copying, line orientation and hierarchical forms) (Bellugi et al., 2000; Hoffman et al., 2003; Karmiloff-Smith et al., 2004; Vicari, Bellugi, & Carlesimo, 2006).

In addition to this, some studies have shown that, despite the relatively well-preserved language skills of individuals with WS, this population have a deficit in their spatial language and struggle to describe spatial locations as well as their age-matched peers (Bellugi et al., 2000; Jarrold, Baddeley, Hewes, & Phillips, 2001; Vicari et al., 2003; Searcy et al., 2004).

Foti et al. (2020) investigated visuospatial abilities in 15 individuals with WS (mean age=18.1 years) and 15 mental age-matched typically developing children (mean age=6.5 years) using a Radical Arm Maze tabletop task. The task required individuals to find 8 ladybirds in the 'maze' on a free-choice and forced choice experiment. The authors measured how many times individuals returned to a previously searched location and the longest sequence of correctly visited arms on each condition. It was found that, on both the free and forced choice tasks, the WS group obtained lower scored and made more errors (more trips to previously searched locations) than the control group. In the free choice task, there was no

difference between the longest sequence of correctly visited arms between the WS and control group. However, in the forced choice trial, the WS group were found to have a shorter sequence of correct searches than the control group. Overall, the WS group made more spatial working memory errors than the control group. However, for all participants, the free-choice task was given to participants before the forced-choice task, which may have influenced performance on the forced-choice task due to familiarization and practice effects.

Saj, Heiz, Calster and Barisnikov (2020) examined visuospatial bias in line bisection in 15 individuals with WS aged 10-41 years, 15 chronologically age-matched individuals (mean age=21.9 years) and 15 mental age-matched children (mean age=6.8 years). Participants were given a sheet of paper with a line drawn horizontally and asked to bisect the line down the middle using a vertical line. The results showed that the WS group showed a left bias (i.e. the WS group consistently made the mark on the line too far to the left of the central point), whereas the control groups showed no bias towards either the left or the right of the line. The WS group also made more errors than the chronologically age-matched control group in bisecting the line down the center point.

There are two dominant hypotheses that have been put forward to explain why individuals with WS show difficulties in their visuospatial cognition: the local processing bias hypothesis and the dorsal stream deficit hypothesis. The local processing bias hypothesis refers to the notion that information can be processed at the global (whole picture) or local (individual parts) level. It has been previously reported that individuals with WS focus mainly on the local elements of a task, ignoring the global picture (Bellugi et al., 1988;1994;1999). This leads to increases in errors, for example individuals with WS focus on individual elements when asked to draw an object rather than on the object as a whole.

However, Pani, Mervis and Robinson (1999) reported evidence against 12 individuals with WS (mean age=30.90 years) showing a local processing bias when completing a visual

search task. When asked to find the letter (either a T or F) in the array both the chronologically age matched typically developing adults (N=12), and the WS group showed a pattern of performance that indicates global organisation in visual perception, suggesting perhaps that, rather than a local bias, individuals with WS are finding it equally as difficult to disengage from the global image as typically developing individuals.

Block construction tasks, such as the Block Design task (The Wechsler Intelligence Scale for Children, Wechsler, 1949) and the Pattern Construction task (The British Ability Scales, Elliott, Smith & McCulloch, 1996), represent what is argued to be the weakest area of visuo-spatial performance in WS (Klein & Mervis, 1999). Block construction tasks require the individual to construct designs using three-dimensional coloured blocks to recreate a two-dimensional image. On these tasks, individuals with WS perform approximately at the second percentile, demonstrating a similar mastery to a typically developing 4-year-old (Bellugi et al., 1999; Hoffman et al., 2003). Block construction tasks involve two stages: first, perceptually segmenting the image into its composite parts, and second, integrating these separate parts to make a whole image, though only the second stage is thought to be impaired in WS (Bellugi et al., 1994). This stage draws on both local and global processing, and, potentially, mental imagery, which is a property of the dorsal visual stream.

Farran, Jarrold and Gathercole (2001) used two block construction tasks to investigate the causes of poor block construction in 21 individuals with WS aged 9-38 years, and 21 typically developing control children aged 5-7 years. Results suggested that individuals with WS do not have a local bias at the perceptual level as segmentation did in fact aid block design performance to the same extent as in the TD children, though this group still showed poorer performance than the typically developing non-verbal mental age matched control group. This suggests that individuals with WS may struggle more with integration as opposed to segmentation, a hypothesis which is supported by Bellugi, Sabo and Vaid (1988) who

found that a group of WS participants showed difficulty integrating correctly chosen individual blocks into a whole image.

Farran and Jarrold (2004) developed this research and attempted to investigate the two dominant hypotheses put forward to explain the WS cognitive profile (local processing vs. dorsal stream) using a block construction task. The first experiment focused on investigating the local bias hypothesis; participants had to match squares to a whole image (they saw a whole image of squares put together separated by red lines and saw individual images of squares and had to point to which image went in each quadrant). It was reported that the non-verbal mental age matched TD children (N=22, mean age=6.6 years) were more accurate in their responses than the WS group (N=22, mean age=21.3 years). Overall, these findings cast doubt on the local processing hypothesis as the WS group were not better than the TD group when the images were separated into local elements to make the task easier.

The second of Farran and Jarrold's (2004) experiments focused on investigating the dorsal stream hypothesis (Atkinson, King, Braddick, Nokes, Anker & Braddick, 1997). The human visual system can be split into two pathways: the ventral stream, which is thought to process information about the identity of objects (the 'what' stream), and the dorsal stream, which is thought to process the locations of objects in space (the 'where' stream). It is thought by many researchers that individuals with WS have a dorsal stream deficit (e.g. Atkinson et al., 2003; Galaburda et al., 2002; Nakamura et al., 2001; Paul et al., 2002), and that this dorsal stream deficit is leading to the problems that individuals with WS show in regards to their visuospatial abilities. Farran and Jarrold (2004) presented participants with two different sized objects (abstract shapes) simultaneously and asked if they are the same or different regardless of any differences in size. This task tested the individuals' ability to use size transformation abilities, which like mental rotation tasks, activate the dorsal pathway. It was found that the 22 WS participants (mean age: 21.3-years) behaved comparably to non-

verbal ability matched typically developing participants (N=22) on size transformation, indicating not only that individuals with WS can perform mental image transformations when assessed with this task, but also that they can complete the task to the same level as typically developing peers matched on non-verbal ability. Therefore, we can assume that this ability is available to WS during block construction and therefore should not hinder their performance; providing evidence against the dorsal stream hypothesis.

Farran and Jarrold (2004) show that the impaired dorsal stream is not sufficient to explain deficits in visuospatial skills in WS. While it is likely that both a local processing bias on some tasks (e.g. drawing skills, Wang et al., 1995) and an impairment in the dorsal stream (Atkinson et al., 1997) in individuals with WS is likely to play a role in visuospatial abilities, these differences cannot account for problems with visuospatial skills entirely. This thesis, therefore, investigated whether poor motor ability in WS was having an effect on visuospatial skills in Chapter 3.

1.3.6. Motor abilities in WS

There is evidence to suggest that individuals with WS present with motor deficits from birth. This is evidenced through research into motor milestone development in WS. Martin, Snodgrass and Cohen (1984) reported findings from parent surveys investigating physical and cognitive development in WS. They investigated two motor milestones in 41 children with WS, and report that this group reached the motor milestone of sitting unsupported at 10.5-months and waking unsupported at 23.4-months. The authors did not report any typical control group data, however, data from the World Health Organization (WHO Multicentre Growth Reference Study Group & de Onis, 2006) suggest that infants typically reach the sitting unsupported milestone at around 3.8 to 9.2-months, and typically children will walk unsupported at around 8.3 to 17.6-months.

Carrasco, Castillo, Aravena, Rothhammer and Aboitiz (2005), using parent report, state

that children with WS often reach motor milestones much later than chronological aged matched typically developing children. However, the data on motor milestones is limited in WS, as these authors only examined three motor milestones (head support, sitting without support, and walking without support). They found that while some children with WS were reaching these motor milestones at the same rate as their typically developing peers of the same age, many took much longer to achieve the milestone.

In line with Carrasco et al. (2005), individuals with WS in Farran, Bowler, Karmiloff-Smith, D'Souza, Mayall and Hill (2019) sample were reported to have often shown substantial delays in reaching their motor milestones. This comprised a list of 12 motor milestones (e.g., sitting without support, walking with assistance) and parents were asked what age in months their child was when these milestones were reached. Parents reported that their son/daughter with WS scored in the >99th percentile for all motor milestones that could be compared to the WHO standards (WHO Multicentre Growth Reference Study Group & de Onis, 2006). However, it is important to note the small number of respondents from this data, and so the findings may not be representative of the population as a whole. Parents were asked to fill in the motor milestones questionnaire retrospectively, and given the age range of the participants, many parents noted that they could not remember when their son or daughter was able to reach certain milestones. Further research is required either by collecting concurrent motor milestone data as milestones emerge (although this is difficult due to often late diagnosis of WS), or by asking parents of younger participants with WS for retrospective milestone information.

Sparaci, Stefanini, Marotta, Vicari and Rizzolatti (2012) tested 18 young people with WS aged 5-30 years, 18 mental age-matched typically developing children and 18 chronologically age-matched typically developing children with the aim of investigating individuals understanding of motor acts and motor intentions. The 'what' task asked

individuals to identify whether the person in the clip was just touching an object or whether they were grasping it, and the 'why' task asked individuals to identify why the person in the video was grasping the object (to use or put away). It was found that, in the absence of contextual cues, individuals with WS made more errors in the 'what' task in comparison to all typically developing participants. On the 'why' task, individuals with WS made more errors than the chronologically age matched controls but performed similarly to the mental age-matched controls. The presence of contextual cues in the videos decreased the number of errors for individuals in all groups on the 'why' task. One limitation of this study is that they did not take into account the potential for individuals with WS using different motor strategies to complete tasks. This is relevant because individuals with WS may compensate for their poor motor skills by grasping objects in a different way to improve stability (for example using a whole fist grip rather than a pincer like grip). Also, you could grasp an object in the same way to use it and to put it away, for example, the authors use the example of lifting a mug by the handle to use it, and by the top to put it away. However, you could just as easily grasp the mug by the handle to put it away.

Vivanti, Dissanayake, Fanning and Hocking (2018) investigated motor inference in 22 children with Autism Spectrum Conditions (mean age=3.98 years), 14 individuals with WS (mean age=4.51 years) and 18 typically developing children (mean age=4.3 years). To do this, participants were asked to perform an action (putting a penny into a money box) immediately after observing a "prime action" that was either congruent (putting the penny in the box) or incongruent (the video played in reverse so that the penny appeared to be coming out of the box), and eye-tracking data was recorded. It was found that both the WS and ASD group, in comparison to the control group, did not show slower performance when completing the task after viewing the incongruent video. It was also found that this difference could not be attributed to attention, as the eye-tracking data showed similar eye-gaze to the

target in all three groups. The authors also took into account fine motor skills (as measured by the Mullen Scales of Early Learning; Mullen, 1995) and found that fine motor difficulties did not influence the performance of any group. However, the authors did not provide any information on what scores the individuals with WS obtained on the fine motor measure and only stated that they fell outside of the typical standard range of developmental quotient for the WS and ASD groups.

Individuals with WS have been found to continue to show deficits in their motor abilities in later life. This is supported by empirical evidence for difficulties with fine motor tasks such as finger tapping (Berencsi, Gombos & Kovacs, 2016), where participants are asked to touch their thumb to each finger of one hand (usually the dominant hand) in a given order, as quickly as they can. Finger tapping was found to show wide individual variability in the WS group in comparison to typically developing, mental age matched children. Finger tapping was generally, initially poor in the WS group, and was found to show limited capacity for improvement.

Heiz and Barisnikov (2016) tested 26 individuals with WS aged 6-41 years and 154 typically developing children aged 4-12 years on Beery-Buktenica Developmental Test of VMI (Beery-VMI; Beery, 2004). The authors found that performance of the group of WS individuals was in line with the results of the typically developing 5-year-old children on all three measures of the Beery-VMI (visual motor integration (VMI), visual perception (VP) and motor co-ordination (MC)). Scatter plots of the MC scores in the WS group show a wide variability in performance, however, the authors do not discuss possible heterogeneity in the sample or the potential effects of other individual factors.

Gross motor tasks, such as judging step height and posting cards into a slot (Atkinson, King, Braddick, Nokes, Anker & Braddick, 1997; Cowie, Braddick & Atkinson, 2012) has also been investigated in individuals with WS. In these studies, gross motor skills have been

shown to be poorer in comparison to chronologically age-matched controls. Atkinson et al. (1997) used a Postbox task with 15 individuals with WS aged 4-14 years and a group of 30 chronologically age matched children and adults aged 4 to 20-years. In this task participants were asked to post a card through a slot which was orientated at various rotations (0, 45, 90 and 135 degrees). In a matched task, participants were asked to pose the hand of a mannequin to the correct orientation to post the card. The authors found that the individuals with WS showed difficulties with both the card posting task and with posing the mannequin's hand to the correct orientation task, and the authors credit these difficulties to dorsal stream deficits. It has been suggested by Atkinson et al. (1997) that the reported difficulties in the dorsal stream of individuals with WS not only affected their spatial skills, but also their motor actions, such as walking over uneven surfaces (Withers, 1996). Milner and Goodale (1995) found that a dorsal stream dysfunction leads to difficulties in both the transformation of visual information into motor acts and the control of ongoing movement. Indeed, research undertaken with patients who have dorsal stream damage has demonstrated that the dorsal stream is instrumental for object avoidance during reaching (Chapman & Goodale, 2008; Jax & Rosenbaum, 2009; Schindler et al., 2004). Schindler et al. (2004) reported that individuals with dorsal stream lesions show difficulties deviating between two objects in a reaching task. Behavioural research that has used tasks to investigate the role of the posterior parietal lobe in individuals with WS has shown impairments in visually guided actions when compared to typically developing mental age-matched controls (Atkinson et al., 1997), suggesting atypicality in dorsal stream function controlling movement.

Cowie et al. (2012) investigated the visual control of stepping in 16 individuals with WS (mean age=9.58 years) and 18 typically developing children aged 3-4 years. Individuals were asked to take a single step down from a box of various heights, while their movements were kinematically recorded. The authors found that the individuals with WS did not use the

visual information to control the speed of their leg movement appropriately for the step, which was similar to the pattern shown by the typically developing 3 to 4-year-olds. The authors suggest that these results show that the visuomotor and visuospatial deficits that have been found in WS also effect the motor domain. One limitation of this study is the narrow age range of the control group (3-4 years). The authors used the data collected from a previous study (Cowie, Atkinson & Braddick, 2010) for the control data rather than collecting a new sample of participants. This may be a problem as the WS groups may have been able to perform as well as an older sample of typically developing children on this task, but as there is no data, the authors can only say that the WS group are performing similarly to the 3 to 4-year-olds. Conversely, if an older group of typically developing children had been collected, and the WS group were showing poorer performance than this group, it would have provided information on the upper limits of the WS group's performance on stepping movements.

Deficits in motor skills are to be expected in WS, due in the main to physiological and neuroanatomical changes that cause joint laxity (Carrasco et al., 2005), muscle hypertonia (Chapman, du Plessis & Pober, 1996) and problems with gait (Hocking et al., 2011) in this group.

There have been studies that have investigated a full profile of motor abilities of individuals with WS. Tsai et al. (2008) investigated the motor ability of 11 individuals with WS, using the Bayley scales of infant development (Bayley, 1993) for those who were under 42-months (N=7), and the Bruininks–Oseretsky Test (BOT) short form (Bruininks & Bruininks, 2005) for those over 42-months (N=4). The authors found that all the children with WS showed a significant deficit in both their fine and gross motor abilities. However, the use of different motor tests across participants and the small sample size, make it difficult to draw conclusions from these results.

Wuang and Tsai (2017) investigated motor ability in 38 children with WS aged 6 to 12-years using the Bruininks–Oseretsky Test of motor proficiency, second addition (BOT-2; Bruininks & Bruininks, 2005). The authors found results consistent with Tsai et al. (2008) in that all the children showed impairment on the fine motor measures universally across subtests. However, only 60% of the children scored in the impaired range on gross motor measures, with Running Speed and Agility being, on average, the most impaired area. It was also found that full scale IQ, as measured by the Wechsler Intelligence Scale for Children third edition (WISC-III; Wechsler, 1991), was strongly correlated with fine motor ability, and moderately correlated with gross motor ability (Wuang & Tsai, 2017).

Taken together, these studies suggest that individuals with WS show fine motor impairment in infancy, early childhood, and into later childhood, and there is some evidence to suggest that gross motor ability may also show impairment in infancy and early childhood and on certain gross motor tasks later in childhood (e.g. Running Speed and Agility).

The aim of this thesis is to explore this in detail. We will also investigate whether there are particular strengths and weaknesses in specific areas of fine and gross motor ability.

1.3.7. Anxiety in WS

Anxiety is one of the most persistent and debilitating difficulties in individuals with WS (e.g. Royston et al., 2017). However, there is wide variability in reported prevalence estimates, with reports ranging from 16.5% to 82.2% in research (Stinton et al., 2010; Woodruff-Borden et al., 2010). It is hypothesised that these differences in rates of anxiety are at least in part due to methodological differences in studies (e.g. diagnostic criteria, measures and samples) (Dodd & Porter, 2011; Green et al., 2012).

However, despite these differences in estimates, it is clear that individuals with WS show elevated levels of anxiety in comparison to the general population, with systematic reviews showing that rates of anxiety in the general population are around 7 to 11% (Baxter

et al., 2013; Somers et al., 2006). What is more, while anxiety is a common feature in a number of genetic syndromes (Emerson, 2003), the prevalence rates of anxiety found in WS are often higher than even these populations, for example DS, Fragile X syndrome and Prader-Willi syndrome (Dykens et al., 2005; Pegoraro et al., 2014). Prevalence rates in individuals with Intellectual Disability (ID) of mixed etiologies are estimated at around 3% to 22% (Reardon, Gray & Melvin, 2015). This indicates that the high rates of anxiety in WS are not solely due to the presence of ID, and so these findings suggest instead that there is a specific association between WS and higher prevalence of anxiety, which may be associated with deletions of genes in the WS critical region (Dykens, 2000). This thesis will expand on the above studies in that it will investigate not only parent perspectives of anxiety, but the individual's own perspective of their anxiety on different tasks. More information on anxiety in WS can be found in Chapter 4, section 4.1.2.

1.3.8. Adaptive behaviour and daily living skills in WS

Adaptive behaviour is the attainment of appropriate developmental milestones in abilities that are thought to be associated with everyday demands and independence, such as self-care (Liss et al., 2001; Szatmari, Bryson, Boyle, Streiner & Duku, 2003). Research in WS has shown that this population demonstrates deficits in adaptive behaviour (Howlin, Davis & Udwin, 1998; Mervis & Klein-Tasman, 2000). Gosch and Pankau (1994) found that children with WS obtained significantly lower scores compared to chronologically age matched controls with non-specific ID. Further, Davies, Howlin and Udwin (1997) found that, despite a similar degree of cognitive impairment, individuals with WS were poorer in areas of employment (i.e. reduced rates of employment were found in the WS group) and independence in comparison to adults with other genetic disorders, such as Prader-Willi syndrome and DS.

In addition to a general deficit, individuals with WS show an uneven profile of adaptive functioning as measured by the Vineland Adaptive Behaviour Scales (VABS; Sparrow, Cicchetti & Balla, 1989). Children with WS have better social interaction skills and communication skills in comparison to motor and daily living domains (Greer, Brown, Pai, Choudry & Klein, 1997; Mervis, Klein-Tasman & Mastin, 2001). However, whilst adults with WS still showed relatively well-preserved socialisation skills, results from Howlin et al. (1998) indicate that performance in the communication domain was lower than that of the daily living domain on the VABS. This thesis expanded on the above studies in that it investigated not only parent perspectives of daily living ability, but also a practical assessment of daily living ability. A more in-depth review of the literature on daily living skills in WS can be found in Chapter 5, section 5.1.1.

1.3.9. Overview of the DS genotype and phenotype

Down Syndrome (DS) is the most common genetic neurodevelopmental disorder, with a prevalence of approximately 11.8 in 10,000 live births (Shin et al., 2009). DS occurs when an extra copy of chromosome 21 is present (or critical regions of chromosome 21) (Akhtar & Bokhari, 2020). As in WS, individuals with DS have characteristic facial features, an increased number of health concerns, including congenital heart defects and an increased risk of Alzheimer's disease, and intellectual disability (Epstein, 1989). Global cognitive delays in DS are thought to range from moderate to severe (Carr, 1985). There is a large body of evidence of early onset Alzheimer's disease common in individuals with DS (for a review, see Wisniewski, 1990). Many individuals with DS show hallmark Alzheimer's disease characteristics around age 35 to 40-years. Due to this, all DS participants included in this thesis are under the age of 35 years, as the researcher did not want the potential effects of Alzheimer's to affect the results of this study.

1.3.10. Genes in DS

There are three types of DS. The first is Trisomy 21, which applies to around 95% of individuals with DS (Shin, Siffel & Correa, 2010) and occurs when three copies of chromosome 21 are present in every cell of the body, rather than two. This means that these individuals with DS have 47 chromosomes instead of the typical 46. The second most common type of DS is Translocation, which accounts for around 4% of all cases of DS (Hernandez & Fisher, 1996; Flores-Ramírez et al., 2015; Morris, Alberman, Mutton & Jacobs, 2012). In this type of DS, part of chromosome 21 breaks off during cell division and attaches itself to another chromosome (usually chromosome 14). Therefore, in translocation, the total number of chromosomes is the typical 46, but there is an extra part of chromosome 21, which causes DS in these individuals. Lastly, the least common type of DS, occurring in just 1% of the DS population, is Mosaicism (Papavassiliou, Charalsawadi, Rafferty & Jackson-Cook, 2015). This happens when non-disjunction of chromosome 21 occurs in one of the initial cell divisions, but not all of them. Non-disjunction is the failure of pared chromosomes to split in cell division, leading to both chromosomes to go to one cell, and none to the other cell. This leads to a mixture of two types of cells, some with the typical 46 chromosomes, and others with 47.

The presence of the extra chromosome 21 leads to DS being a very complex genetic disorder. There are thought to be almost 300 genes identified on chromosome 21 (Ensembl, 2007), and an overexpression in any one of these genes could have wide-reaching consequences for development. These genes also have the potential to interact with and influence each other, which again may affect development in important ways.

Previous research supported the idea that only a small number of genes in chromosome 21 were responsible for determining the DS phenotype (Epstein et al., 1991; Korenberg et al., 1991), however, other research has found that this DS 'critical region',

while necessary for producing the typical DS phenotype, is not sufficient to cause the DS phenotype (Olson, Richtsmeier, Leszl & Reeves, 2004), and that other genes must be involved.

De Lagrán et al. (2004) used mouse models to investigate the role of the overexpression of the DYRK1A gene in motor abilities in DS. DYRK1A has been previously found to be expressed in the cerebellum, motor nuclei of the brainstem and the spinal cord (Martí et al., 2003), implicating it in the role of controlling motor functions. It was found by de Lagrán et al. (2004) that the mice with the overexpressed DYRK1A gene showed significant deficits in motor learning and showed differences in movement organisation in comparison to mice without the overexpressed gene. This research supports clinical observations of motor behaviour in DS and supports suggestions that the DYRK1A gene is playing a role in motor dysfunction in this population.

Feki and Hibaoui (2018) conducted a review of the literature examining the role of the DYRK1A gene in DS. Many studies have used mouse models (20-24), and these studies have shown that, in mice with an altered DYRK1A gene, there have been neurodevelopmental delays, motor abnormalities, learning deficits, increases in anxiety and an impaired reactivity to stress (Ahn et al., 2006; Altafaj et al., 2001; Benavides-Piccione et al., 2005; Fotaki et al., 2002; Guedj et al., 2012). However, there have also been studies in human participants with DYRK1A gene abnormalities (resulting from deletions, translocations, frameshifts). These studies have found that, individuals with DYRK1A gene abnormalities present with intellectual disabilities, speech and motor delays, gait disturbances and short stature (Bronicki et al., 2015; Courcet et al., 2012; Ji et al., 2015; Luco et al., 2016; Møller et al., 2008; Oegema et al., 2010; Redin et al., 2014; Ruaud et al., 2015; Valetto et al., 2012; Yamamoto et al., 2011). This research lends further evidence to the idea that the DYRK1A gene

abnormalities may play a role in the motor difficulties that individuals with DS experience, alongside cognitive difficulties.

1.3.11. Neurophysiology in DS

White, Alkire and Haier (2003) and Menghini, Costanzo and Vicari (2011) employed VBM to investigate the integrity of several structures on the adult DS brain. White et al. (2003) noted significant decreases in the volume structures such as the cerebellum, which is a region integral to motor control (Crossman & Neary, 2015); the cingulate gyrus, which is important for a number of functions, such as emotional regulation (Devinsky, Morrell & Vogt, 1995); and the left hippocampus, which plays a major role in memory and the regulation of behaviour (Crossman & Neary, 2015). Decreases in the volume of white matter in the inferior brainstem have also been reported, a structure which carries information from the brain to the spinal cord and is instrumental in permitting movement of the limbs and trunk of the body (Crossman & Neary, 2015). This decrease in white matter in the brainstem, along with the smaller structure of the cerebellum may be impacting motor abilities in individuals with DS.

Menghini et al. (2011) used VBM to examine the brains of 12 adolescents with DS aged 12-19 years and 12 typically developing individuals aged 12-18 years, along with a series of neuropsychological assessments. Consistent with previous research, Menghini et al. (2011) found reductions in grey matter, white matter and total brain volume of individuals with DS in comparison to control subjects. Menghini et al. (2011) further reported reduced grey matter volume in the posterior cerebellum and lateral and medial temporal lobes, specifically in the right inferior temporal gyrus, fusiform gyrus and the right hippocampus. Similar to White et al. (2003), these are structures that are involved in memory and motor control, and researchers such as Vicari (2006) have suggested that changes in the size of the cerebellum in individuals with DS may have a major role in the hypotonia and motor

dysfunction present in this disorder. Increases in grey matter density was also noted in the insula, basal ganglia and right parahippocampal gyrus. As noted in the in the WS brain section, the basal ganglia is another area that is important for the control of motor acts (Crossman & Neary, 2015) and so it is likely that changes in the density of this structure in DS is likely to impact it's function.

In contrast to the WS data, there has been some promising evidence to suggest that there is good preservation of grey matter in the parietal lobes in DS (Jernigan et al., 1993; Pinter et al., 2001), showing preservation of posterior parietal-occipital cortical grey matter. This is particularly interesting considering the differences in the neurocognitive profile of individuals with WS or DS in regards to their visuospatial skills (for more, see Chapter 3).

In DS, research has shown that there are significant changes in the size of the cerebrum in DS from the 6th month of life (Rondal & Perera, 2006), and that regressions of motor development are also observed at this time (Teipel et al., 2004). Neuroimaging studies have also shown reductions in size of the cerebellum in DS relative to chronologically age matched, typically developing peers, and reductions in both the white and grey matter of this structure (Baxter et al., 2000; Pinter et al., 2001; Roubertoux et al., 2005). Cerebellar hypoplasia, which is a neurological condition where the cerebellum is either not fully developed or smaller than typical, is thought to be responsible for deficits in axial control, movement fluency, balance, muscle hypotonia and co-ordination in children with DS (Sveljo, Ulic, Koprivesk & Lucic, 2014).

Patkee et al. (2020) examined early alterations in cortical and cerebellar regional brain growth in DS using in vivo foetal and neonatal MRI. The sample consisted of 30 foetuses with DS (age at time of MRI 21-35 weeks), 21 neonates with DS (age 36-46 weeks) and 52 control foetuses (aged 22-38 weeks). The researchers found that, foetuses and neonates with DS were found to have significantly smaller whole brain volumes than the control foetuses in

the second and third trimester as well as postnatally. However, it was also discovered that cortical volumes in DS only started to deviate from the control subjects in the third trimester. Reduced cerebellar volume was noted in the DS group in the second trimester in comparison to the control subjects.

Lee et al. (2020) used DTI to examine the cerebellar networks in 15 individuals with DS aged 6-24 years and 15 age and sex matched typically developing control subjects. The authors found that the individuals in the DS group showed marked hypoplasia of cerebellar afferent systems. Further, there was evidence of prominent grey matter hypoplasia in the medial frontal regions, the cerebellum and the inferior olives in the DS group in comparison to the control subjects. However, there were very few differences in FA or mean diffusivity between the DS and control subjects, which suggests that white matter structural tissue abnormalities are not a relevant feature of the DS neuroanatomical phenotype during childhood and young adulthood. There were, however, widespread reductions in white matter volume in the DS group in comparison to the control subjects.

However, despite these differences in the structure and function of the cerebellum in DS, the basal ganglia have been reported to be relatively well preserved in this population (Aylward et al., 1997; Pinter et al., 2001; Raz et al., 1995). Pinter et al. (2001) hypothesised that this was due to the early development of the basal ganglia. Embryologic data support this theory, as it has been found that there are no differences in either the structure or function of the DS brain until after the third trimester, which is after the majority of basal ganglia development is complete (Pinter et al., 2001).

1.3.12. Cognition in DS

We saw in the WS cognitive profile that individuals with WS typically show relative strengths in their verbal ability and severe deficits in their visuospatial ability (e.g. Morris et al., 2003). In comparison, the opposite profile exists for individuals with DS. That is, this

population show relative strengths in their non-verbal ability, and relative weaknesses in their auditory and verbal abilities (Wang, 1996). Research has shown that, in comparison to their typically developing peers, individuals with DS present with a lower IQ and also show a progressive decline in IQ relative to chronological age from the first year of life (i.e. the gap between mental age and chronological age widens) (Patterson, Rapsey & Glue, 2013). As previously mentioned, individuals with DS present significant difficulties with expressive language, and expressive language has been found to be more impaired than receptive language in DS (Chapman, Hesketh & Kistler, 2002). Additionally, individuals with DS have been found to show difficulties with phonology, grammar and syntax (for a review, see Grieco et al., 2015).

There is some evidence to suggest that children with DS are skilled at imitation tasks that require the use of short-term memory skills (Milojevich & Lukowski, 2016; Roberts & Richmand, 2015). However, when long-term memory has been examined, it has been found that children with DS show poorer performance than control subjects matched for mental age (Milojevich & Lukowski, 2016). Additionally, working memory deficits have been well-documented in individuals with DS (for a review, see Baddeley & Jarrold, 2007). For example, Carney et al. (2013) found that in their study of 25 children and adolescents with DS (aged 10-18 years), both verbal and visuospatial working memory was impaired.

Executive functions have also been examined in DS. Cross sectional research into executive functions in DS suggest that these skills remain relatively stable over time, although specific strengths and difficulties within executive functions vary (Lee et al., 2015; Loveall, Conners, Tungate, Hahn & Osso, 2017). For example, difficulties in planning and goal-directed action have been found to be fairly consistent in DS (e.g. Lanfranchi, Jerman, Dal Pont, Alberti & Vianello, 2010; Lee et al., 2015; Loveall et al., 2017). However, the study of inhibitory control in DS has provided more mixed results. Some studied shave found

that, when matched with typical children of the same mental age, children and adolescents with DS do not show any problems with inhibition (Carney, Brown, & Henry, 2013; Cuskelly, Jobling, Gilmore, & Glenn, 2006; Lee et al., 2011; Pennington et al., 2003). However, other studies suggest that children and adolescents with DS show deficits in their ability to inhibit (Borella, Carretti, & Lanfranchi, 2013; Lee et al., 2015). These differences in outcomes across studies are potentially due to the different measures used, as some studies gathered data from parent reports and some from teacher reports. It has been found by Daunhauer et al. (2014) that parents are more likely to report problems with inhibition in their children with DS than teachers are. Additionally, studies have found that the performance of children, adolescents and adults with DS is poorer than that of mental age-matched controls on tasks of cognitive flexibility (Carney et al., 2013; Costanzo et al., 2013; Lanfranchi et al., 2010; Rowe, Lavender, & Turk, 2006), although other studies have found comparable performance between children with DS and mental age-matched controls (Daunhauer et al., 2014; Lee et al., 2011).

Pezzuti et al. (2018) investigated cognitive strengths and weakness in 128 participants with DS aged 7 to 16 years using the Italian version of the WISC-IV (Wechsler, 2012). To avoid floor performance, the authors used weighted scores from 1-19 to examine performance of the DS participants. They found that individuals with DS, as a group, scored most poorly on the Working Memory Index and Processing Speed Index, where the majority of the group received a weighted score of 1. The group was found to perform best on the Similarities task, where only 27% of participants received a weighted score of 1, and the mean weighted score was 3.16. a wide variability in IQ was found, with some individuals (82% of the sample) scoring <40 and others (18% of the sample) scoring between 40 and 62. However, despite this discrepancy in scores, the authors did not examine any individual differences in the sample.

Thomas et al. (2020) employed a multi-level approach to explore individual differences in 84 infants and young children with DS aged 6.9 to 63.4 months. Children completed the MacArthur-Bates Communicative Development Inventories (Fenson, 2007) and the Mullen Scales of Early Learning receptive and productive language subscales (Mullen, 1995). It was found that, overall, children with DS experienced both expressive and receptive language delay. However, for both expressive and receptive vocabulary, there were individuals who fell withing the normal range (e.g. one child with a receptive vocabulary of 81 words at 8.4 months) and other cases where children fell below the mean and presented with particular deficits in language (e.g. a child with an expressive vocabulary of 4 words at 36.6 months). This research highlights the importance of considering individual differences and heterogeneity when working with groups with neurodevelopmental conditions.

1.3.13. Small scale spatial skills in DS

In contrast to WS, small scale spatial skills are not a specific area of weakness in DS. Indeed, better visuospatial abilities in comparison to verbal abilities are one of the key features of the DS cognitive profile (for reviews, see Chapman & Hesketh, 2000; Davis, 2008; Moldavsky, Lev & Lerman-Sagie, 2001; Silverman, 2007). However, much of this research has focussed on visuospatial skills being a strength in comparison to their poor verbal abilities. It is, therefore, possible that while visuospatial abilities in DS are significantly better than verbal abilities, they may not be a strength when compared to chronological age. Indeed, there is some evidence to suggest that there may actually be deficits in some areas of spatial ability in individuals with DS (e.g. Hodapp et al., 1992; Lanfranchi, Cornoldi & Vianello, 2004; Pennington, Moon, Edgin, Stedron & Nadel, 2003).

Studies investigating visuospatial construction are limited in the DS literature, potentially because of the idea that visuospatial skills are not an area of weakness in this population, and provide mixed results. On block construction tasks, both Vicari et al. (2004)

and Lee, Pennington and Keenan (2010) reported that their DS groups performed similarly to typically developing, verbal mental age matched controls on block construction. However, Bihrle (1990) and Cornish, Munir and Cross (1999) found that their DS groups performed more poorly than the typically developing controls. However, Bihrle (1990) did not report mental ages of their participants, so it may be that the groups were not well matched, and Cornish et al. (1999) used a control group with a year higher mental age than their DS group, though the authors reported that this difference was not significant.

Couzens, Cuskelly and Haynes (2011) assessed over 200 participants with DS longitudinally from age 4 to 24 years on the Stanford-Binet Intelligence Scale (SB:IV; Thorndike, Hagen, & Sattler, 1986) and found that the task with the largest within-group variance was block construction. At the time of the first test (age 4 years), there were no significant differences between the range of scores. However, as individuals aged, the rate of block construction development varied significantly between individuals, with some people making more improvements than others.

However, most research reports no significant differences between the performance of individuals with DS and individuals with ID (Hodapp et al., 1992; Kittler et al., 2004) or individuals with Fragile X Syndrome (Cornish et al., 1999; Hodapp et al., 1992) on this task. As expected, when compared, DS groups have been found to perform better on block construction than WS groups (Bihrle, 1990; Edgin et al., 2010; Klein & Mervis, 1999; Vicari et al., 2004). Overall, these studies suggest that individuals with DS do not have a particular strength in block construction tasks, and that performance is highly variable in this population.

On mental rotation tasks, even less research exists. Uecker, Obrzut and Nadel (1994) conducted the first study of mental rotation in 56 individuals with DS (mean age=8.4 years) 22 typically developing children (mean age=9.2 years) and 24 individuals with a learning

disability (mean age=10.3 years). The authors found that their DS group performed significantly worse than the control group. However, the two comparison groups used in this study had significantly higher mental ages than the DS group, so accurate comparisons cannot be made as the differences seen in mental rotation performance may have been due to differences in overall cognitive ability.

However, Hinnell and Virji-Babul (2004) tested a group of 7 DS individuals (mean age=29.8 years) and a group of 9 mental age matched typically developing control participants (mean age=7.2 years) on a mental rotation task, and they also found that the DS group performed significantly more poorly than the control group. Though the DS group did perform more poorly than the control group, they did appear to show the typical pattern of mental rotation, with response time increasing with angle of rotation. However, as this was a pilot study, only 7 individuals with DS and 9 controls were tested which limits the generalisability of the results. In contrast, Vicari, Bellucci and Carlesimo (2006) found that there were no significant differences between 15 individuals with DS (mean age=19.8 years) and four groups of 15 mental age matched typically developing children on mental rotation using a larger sample size than Hinnell and Virji-Babul (2004). From this evidence, it appears that mental rotation is also not a particular strength in the DS cognitive profile, and some evidence suggests that there is, in fact, a deficit in mental rotation ability in this group. However, both of these studies focused on adult participants with DS, so we do not know from these studies whether children with DS would perform better or worse than mental age-matched control participants.

More recently, Meneghetti, Toffalini, Carretti and Lanfranchi (2018) explored mental rotation ability and everyday life spatial activities in 48 individuals with DS (mean age=14.11 years) and 48 mental age-matched typically developing children (mean age=5.5 years). The results from the mental rotation task showed that the DS group performed worse than the

typically developing control group. However, both groups showed decreased accuracy with increases in rotation, indicating that the DS group were able to understand the task, as if the DS group had shown poor performance regardless of degree of rotation, it would indicate that they were simply not understanding the task rather than having a specific deficit in their mental rotation ability.

Doer, Carretti, Toffalini, Lanfranchi and Meneghetti (2021) aimed to examine developmental trajectories in spatial visualisation and mental rotation in 87 individuals with DS aged 7 to 53 years. It was found that, chronological age was linearly associated with spatial visualisation performance. However, while mental rotation performance was found to increase from the 7- to 14-year-olds, development then plateaus, and performance gradually decreased between age 14 and 53 years. However, this study used a cross-sectional design, and a longitudinal method would have been a better way to measure changes in visuospatial ability over time. This study also did not have a control group of typically developing children to compare the developmental trajectories to with respect to either developmental or chronological age level. However, this study suggests that there are, perhaps, differences in the performance of individuals with DS over different visuospatial tasks at different ages. Therefore, making the claim that visuospatial abilities generally are a relative strength for individuals with DS may not be accurate as some aspects of visuospatial skills seem to be easier than others to master for these individuals.

While it appears that the claims that visuospatial abilities are a strength in the DS cognitive profile are, perhaps, exaggerated, it is clear that individuals with DS are still performing more favourably than individuals with WS on visuospatial tasks. This is hypothesised to be due to the preservation of grey matter in the parietal lobes of DS individuals (Jernigan et al., 1993; Pinter et al., 2001). As mentioned above in section 1.4.1, the parietal lobe is thought to be particularly important for visuospatial ability, with evidence

coming from lesion studies (Black & Bernard, 1984; Piercy, Hecaen & Ajuriaguerra, 1960) and from functional neuroimaging studies of visuospatial tasks (Jonides et al., 1993).

1.3.14. Motor abilities in DS

Neuromuscular abnormalities have been noted in the DS population, which likely impact motor functioning. These include muscle hypotonia, slower response times during movement and the perseverance of primitive reflexes with age (Frith & Frith, 1974; Knight, Atkinson & Hyman, 1966; Molnar, 1978; Rarick & McQuillan, 1977; Davis & Scott Kelso, 1982). Molnar (1978) have further found that children with DS (N=53), aged 10-25 months, showed a delay, and wider variability in the age they develop correct postural adjustments in comparison to typical development. Molnar (1978) speculated that these deficits in muscle response patterns may be due to a reduction in the connections and number of neurons in areas such as the basal ganglia, motor cortex, brain stem and cerebellum, and also poorer myelination of descending brain stem and cerebral neurons.

Early motor milestones have been found to be delayed in DS, though some research suggest that this delay is not significant (e.g. Melyn & White, 1973). For example, Melyn and White (1973) found that DS children achieved rolling between 5 and 6.4 months (typically achieved between 3 and 5-months; Gladstone et al., 2010) and sitting independently between 8.5 and 11.7-months (typically achieved between 4.5 and 7-months; Gladstone et al., 2010), showing only a slight delay. However, as motor skills become more complex, the delays in reaching motor milestones increases. For example, Melyn and White (1973) also found that DS children crawl between 12.2 and 17.3-months, which is typically achieved between 6 and 10-months (Gladstone et al., 2010). Other research by Malak, Kostiukow, Krawczyk-Wasielewska, Mojs and Samborski (2015) found that in their sample of 79 children with DS aged 3 to 6-years, none of the children had developed all gross motor functions assessed using a measure known as the Gross Motor Function Measure-88 (Russell, Rosenbaum,

Wright & Avery, 2013). This measure grouped gross motor functions into five sections: lying and rolling, sitting, crawling and kneeling, standing, and walking, running and jumping. (see also: Russell et al., 1998; Connolly, Morgan, Russell & Fulliton, 1993). Further, only 10% of the children with DS under 3-years were able to achieve a standing position, which supports earlier research by Pereira, Basso, Lindquist and da Silva (2013). The majority of the children in Malak et al.'s. (2015) study did not start walking until they were older than 3-years (see also: Melyn & White, 1973; Palisano et al., 2001), whereas it has been shown that typically developing children usually learn to walk sometime between 8 and 17.5-months of age (WHO Multicentre Growth Reference Study, 2006), again providing evidence that as motor skills become more complex, children with DS fall further behind their typically developing peers in motor milestone acquisition.

It is hypothesised that walking may be particularly difficult for children with DS as it requires good balance, and also because of the frequently reported problems with muscle hypotonia and joint laxity in DS (Skallerup, 2008; Agiovlasitis, McCubbin, Yun, Mpitsos & Pavol, 2009). Problems with early postural control, balance, motor speed and fluency of movement have been observed from an early age in DS (Cardoso et al., 2015; Mazzone, Mugno & Mazzone, 2004). In contrast to these early gross motor skills, early fine motor skills (such as drawing) are typically characterised by a greater speed of movement, but deficits in accuracy compared to typically developing controls (Schott, Holfelder & Mousouli, 2014; Vimercati et al., 2015). Evidence from Palisano et al. (2001), in their sample of 121 children with DS aged 1-month to 6-years, suggests that DS infants follow the same sequence of motor milestone acquisition as their typically developing peers, but that atypical movement patterns are used by DS children to maintain postural stability, for example sitting with legs spread wide and walking with a wide base (Lydic & Steele, 1979). Overall, these studies into the earlier motor skills of children with DS suggest that this population is falling

behind their typically developing peers when acquiring their motor milestones, and this may have an impact on their later motor development.

Kim, Kim, Kim, Jeon and Jung (2017) gathered information about gross motor milestone achievement of 78 infants with DS in South Korea. They found that, on average, children with DS had head control by 6.1 months, were able to turn over by 8.76 months, were sitting independently by 12 months, crawling by 18.1 months, cruising by 22.3 months and were not walking independently until 28 months. The authors also examined the effect of operational history (i.e. those children who had needed to undergo operations in the early stages of development) and found that operational history had a negative relationship with motor development. However, when type of operation was looked at, there was no difference between operation type on motor development. The results of this study are in line with previous research from western samples (Europe and the United States), indicating that this delay in motor milestone achievement is present across cultures.

Herrero et al. (2017) examined the motor repertoire of 47 3 to 5-month-olds with DS by examining their Motor Optimality Score (MOS). It was found that there was a lot of variability in the movements of these infants with DS. For example, it was found that 30% of the sample presented with normal fidgety movements, 12.5% showed abnormal fidgety movements (i.e. movements with greater speed, amplitude and jerkiness), and 27.5% showed no fidgety movements. Further, 25.5% of the infants were found to present with an age-adequate movement repertoire, 42.5% showed a lack of movement and 32% presented with age-inadequate movement. The most frequent normal movement patterns observed were visual scanning (68% of the sample normal), side-to-side movements of the head (47%), foot-to-foot contact (30%), hand-to-mouth (25.5%) and kicking (21%). However, movements such as smiling, fiddling, hand regards, swipes, hand-to-hand contact, arching and leg lifting were observed in less than 10 individuals. However, the authors did not measure muscle tone in

these infants with DS, and low muscle tone could have contributed to movements such as arching, leg lifting and movements to the midline.

There has been some research into later motor abilities in DS. Alesi, Battaglia, Pepi, Bianco and Palma (2018) assessed the gross motor abilities of 18 children with DS, with a mean age of 8.22-years, and compared them to chronological age-matched children with borderline intellectual functioning (BIF) and typically developing children. They found that the children with DS showed significantly lower scores on gross motor tasks compared to both BIF and TD children on all locomotion and object control tasks assessed.

Similarly, Spano et al. (1999) found that 22 children with DS (aged 4 to 14-years) scored below the 5th percentile on the M-ABC (Sudgen & Henderson, 1992). Spano et al. (1999) further found that the ability to move an object in space (e.g. to hit a target) was a relative strength, however, when the body must be adjusted in space to retrieve a moving object, performance was much poorer and showed little improvement with age. It was also observed that both static and dynamic balance were much poorer in individuals with DS in comparison to typically developing controls, though there was a wide variability in scores on these items. This difficulty in balance may be due to the differences in the structure and function of the cerebellum reported in section 1.3.2. (Baxter et al., 2000; Pinter et al., 2001; Roubertoux, Bichler & Pinoteau, 2005). However, it was noted that some of the children included in the study had undertaken early interventions to improve their motor skills, so these results should be viewed with caution as there was no analysis to see whether the scores of these individuals influenced the group mean or whether these individuals were scoring differently at all.

Jobling (1998) investigated motor skills in a sample of 99 school aged children with DS over four age groups (group 1: 10.17 to 10.75-years, group 2: 12.17 to 12.83-years, group 3: 14.08 to 14.75-years, group 4: 16.0 to 17.17-years). She found that motor ability does

appear progress over childhood between the ages of 10 and 16-years in DS, but that this development was slower than in typical development. Jobling (1998) reported that, after 12-years of age, children with DS showed much slower progress of motor skills on the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP, Bruininks & Bruininks, 2005), and that certain subtests of the BOTMP showed faster progress across time than others, though this progress was still slower than would be expected for their chronological age. Specifically, bilateral co-ordination, response speed, upper-limb control and dexterity showed a significant increase between 10 and 12-years of age, whereas all other subtests did not show an increase from age 10 until 14 or 16-years of age. The most significant delays in motor abilities assessed from the BOTMP were response speed, bilateral co-ordination and balance. Indeed, as in other studies (Capio et al., 2018; Rigoldi et al., 2011; Wang et al., 2012) balance was found to be the most difficult subtest for the children with DS and was the lowest level of motor ability tested, which is again potentially due to the smaller size of the cerebellum in individuals with DS (Baxter et al., 2000; Pinter et al., 2001; Roubertoux, Bichler & Pinoteau, 2005).

Capio et al. (2018) investigated the association between fundamental movement skills and balance of 20 children with DS, with a mean age of 7.1-years. They found that children with DS showed significantly lower scores on locomotor and object control tasks in comparison to chronologically age-matched control children, which is consistent with previous findings (Capio & Rotor, 2010; Schott & Holfelder, 2015). In addition to this, Capio et al. (2018) examined specific strengths and weaknesses in these fundamental movement skills and found that children with DS showed a relative strength in simpler skills, such as catching, and weaknesses in more complex object control skills, which are thought to be more difficult to train than locomotor skills (Morgan, Delbarre & Ward, 2013) (see also, Palisano et al., 2001). This was also suggested in the infant research into motor milestone

acquisition in DS, showing that children with DS show relatively good mastery of simple motor actions, but as the task becomes more complex, they fall further behind their typical peers (e.g. Connolly et al., 1993; Malak et al., 2015; Pereira et al., 2013; Russell et al., 1998). However, it should be noted that none of the DS group tested in Capio et al. (2018) study were overweight, which is not in line with the population of individuals with DS as a whole (Basil et al., 2016; Nordstrøm, Hansen, Paus & Kolset, 2013; Wong, Dwyer & Holland, 2014), and therefore these results might not apply to individuals with DS who are of a higher BMI.

Rigoldi et al. (2011) investigated balance in 37 children (mean age 9.2-years), 58 teenagers (mean age 16.7-years), and 45 adults (mean age 37.3-years) with DS by analyzing center of pressure during standing. These authors found antero-posterior and medio-lateral center of pressure displacement in both children and adults with DS compared to 39 chronologically age-matched controls, suggesting less stable balance in DS. Center of pressure refers to the location of the individual on the surface they are standing on, averaged down to a single point where their weight is primarily distributed. Similarly, adolescents with DS have been found to show larger center of pressure velocity and displacement in comparison to typically developing controls (Villarroya et al., 2012). Shift in center of pressure is an indirect measure of postural sway. Wang et al. (2012) found that balance skills are associated with both fine and gross motor skills in 23 children with DS with a mean age of 14.4-years, and that better gross motor skills were associated with smaller center of pressure displacement during static standing. Overall, balance has been found to be a particular area of difficulty for individuals with DS (Capio et al., 2018; Jobling, 1998; Rigoldi et al., 2011; Wang et al., 2012), and this has been related to center of pressure displacement in this population (Rigoldi et al., 2011).

Abd El-Hady, Abd El-Azim and El (2018) investigated correlations between cognitive function, gross motor skills and health-related quality of life in 70 children with DS aged 8 to 12-years, who were then split into two groups (8-10 years) and 10-12 years). The authors used the Gross Motor Function Measure-88 (SMFM-88) to evaluate gross motor skills and the Rehacom system, version 5 to assess cognitive functions. The authors found a weak correlation between gross motor abilities and cognitive functions. However, Abd El-Hady et al. (2017) do not report whether the gross motor skills of the children in their sample was below average or any other details on the motor functioning of the sample.

Tsao, Moi, Velay, Carvalho and Tardif (2017) examined the handwriting abilities of 24 children and adults with DS aged 10 to 40 years, 24 mental age-matched children (aged 3-9 years) and 24 chronologically age-matched individuals (aged 9-38 years). The authors assessed the participants' spontaneous writing by asking them to write out single letters of the alphabet. Letters were split into easy letters (e.g. e, s and a) and difficult letters (e.g. b, f and g). The results showed that the DS group showed similar performance to the mental age-matched group on stroke length, duration, number of pauses and speed, but were below the chronologically age matched group. All participants, regardless of group, showed longer stroke length, were slower and took more pauses when writing the 'difficult' letters as opposed to the 'easy' letters. However, the authors did not measure fine motor abilities of any participants, so it is unclear whether poor fine motor skills contributed to the poor performance of the DS group or whether other factors were responsible. Additionally, the authors did not examine the effect of age in the DS group, which may have played a role considering the wide age range of participants tested.

As in the WS literature, the current thesis expanded on the above research by examining both a child and adult population of individuals with DS. This allowed us to investigate the hypothesis that these early motor difficulties will persist into adulthood in DS.

The thesis also allowed us a more in-depth investigation on the particular strengths and difficulties in the motor profile in individuals with DS.

1.3.15. Anxiety in DS

While many individuals with DS present with mental health difficulties, namely depression (Collacott, Cooper & McGrother, 1992; Cooper & Prasher, 1998), this population does not tend to suffer from high levels of anxiety. Compared to other clinical groups, individuals with DS present with lower levels of anxiety and rarely reach the clinical level (Graham et al., 2005; Haveman, Maaskant, van Schrojenstein Lantman, Urlings & Kessels, 1994; Einfeld, Tonge, Turner, Parmenter & Smith, 1999). There is some evidence of anxiety in younger individuals with DS (Dykens, Shah, Sagun, Beck & King, 2002), however these rates are not found in older individuals. Overall, these findings are mixed with some studies showing similar rates of anxiety to the general population (Graham et al., 2005; Haveman et al., 1994; Einfeld et al., 1999) and others reporting similar levels to populations with intellectual difficulties (Dykens et al., 2015). However, there is limited research into anxiety in DS, and more research is needed in this area before any firm conclusions can be formed. This thesis expanded on the above studies in that it investigated not only parent perspectives of anxiety, but the individual's own perspective of their anxiety on different tasks. More details into what is currently known about anxiety in DS can be found in Chapter 4, section 4.1.4.

1.3.16. Daily living skills in DS

Research into daily living skills in individuals with DS have highlighted that these individuals present with difficulties across their lives. Deficits in functional skills have been found from a young age in DS (Dolva, Coster & Lilja, 2004; Dykens, Hodapp & Evans, 1994; Leonard, Msall, Bower, Tremont & Leonard, 2002; van Duijn, Dijkxhoorn, Scholte & van Berckelaer-Onnes, 2010), with children and young people scoring consistently in the

impaired range of functioning on the Vineland Adaptive Behavior Scales, Interview Edition (VABS; Sparrow, Balla & Cicchetti, 1984). These difficulties in daily living skills have also been found to persist into adulthood (Carfi et al., 2019; Holland, Hon, Huppert, Stevens & Watson, 1998; Matthews et al., 2018), as well as longitudinally (Carr, 1975, 1995, 2000, 2003, 2012; Carr & Collins, 2014, 2018).

As in the research in WS, research into adaptive functioning in DS shows an uneven profile, with individuals with DS presenting with generally poorer communication skills in comparison to their daily living and socialisation skills. However, this is unsurprising considering the deficit in language abilities that is commonly found in individuals with DS (e.g., Silverstein et al., 1982; Wang, 1996). More details on daily living skills in DS will be given in Chapter 5.

1.3.17. Summary

Overall, these studies suggest that both individuals with WS and individuals with DS show deficits in their motor abilities in comparison to typically developing, chronologically age-matched controls. There have been studies that have investigated motor abilities in WS (Tsai et al., 2008; Wuang & Tsai, 2017), all of which found deficits in the motor abilities of infants and children with WS. More research has been carried out to investigate motor abilities in DS, however much of this work has focused on early development of motor milestones in this population (e.g. Connolly et al., 1993; Malak et al., 2015; Russell et al., 1998). These studies consistently found that motor milestone development was delayed in infants with DS. There has been slightly more research into motor abilities of children and adults with DS in comparison to WS. Research by Alesi et al. (2018) and Spano et al. (1999) both found severe deficits in motor abilities in children and adolescents with DS.

What these studies do not take into account are other potential differences (beyond the presence of a neurodevelopmental disorder) that may affect motor development. For

example, parents of children with a neurodevelopmental condition may be more protective of their child than parents of typically developing children due to the increased level of vulnerability in these individuals (e.g. Fisher, Moskowitz & Hodapp, 2013; Jawaid et al., 2012). It is also possible that parents of children with neurodevelopmental disorders may be more likely to complete tasks for their child rather than letting them explore and develop strategies to complete tasks themselves due to differing parenting styles compared to neurotypical populations (e.g. Phillips, Conners & Curtner-Smith, 2017).

However, research has not investigated motor abilities in adults with WS, and adult research in DS is limited (e.g. Rigoldi et al., 2011). Due to this, this thesis included adolescent and adult populations with WS and DS in order to better examine whether these early motor deficits persisted into later life, and to examine relative strengths and weaknesses in the motor profile in these two populations.

1.4. Conclusions and thesis directions

The first aim of this thesis was to investigate the motor profile of strengths and weaknesses in individuals with WS and individuals with DS. The second aim was to investigate whether these motor abilities affected small scale spatial skills in these populations, as an association between motor abilities and small scale spatial skills have been found in the typically developing population (e.g. Clearfield, 2004) and spatial abilities have been shown to be a particular area of difficulty in the WS population (e.g. Farran et al., 2001; 2004). Thirdly, we investigated the potential impact of anxiety on motor ability in WS and in DS, again as associations have been found between high anxiety and motor difficulties in typically developing populations (e.g. Dewey, Kaplan, Crawford & Wilson, 2002; Erez, Gordon, Sever, Sadeh & Mintz, 2004; Kristensen & Torgersen, 2007) and anxiety has been found to be particularly high in individuals with WS, even in comparison to other populations with neurodevelopmental disorders (Papaeliou et al., 2012; Stinton, Elison & Howlin, 2010;

Woodruff-Borden, Kistler, Henderson, Crawford & Mervis, 2010). Lastly, this thesis outlined the design and implementation of a Daily Living Task and investigated how poor motor ability is impacting these skills.

Chapter 2

Motor profile and Physical Activity in individuals with WS and DS

2.1. Introduction

2.1.1. Factors that may affect motor ability in WS and DS

Reduced motivation is a factor that may make the individuals less likely to want to engage with everyday motor acts. One example of this, is that individuals with WS or DS may be less motivated to join in with a team sport or game in the playground, because of negative experiences of bullying, and negative past experiences of not being able to perform physical activities, when they have tried to take part in the past. Additionally, individuals with WS or DS may be less likely to join a sports club or gym, as they may not feel comfortable with a new group of people or feel confident using unfamiliar sports equipment (as may be found in a gym), further reducing motivation.

Another factor that may affect motor ability in WS and DS is cognitive ability. Smits-Engelsman and Hill (2012) measured the IQ and motor abilities in a group of 460 children (aged 4-13 years) both with and without motor difficulties. These authors found that individuals with lower IQ's were significantly more likely to show motor difficulties, although both typical and atypical motor abilities were seen across all IQ levels. Overall, 19% of the variance in motor skills was explained by IQ scores, and for each standard deviation lower in IQ, a mean loss of 10 percentile motor points was found. A limitation of this study is that the researchers used a number of different motor and IQ measures over the course of the data collection. This may have led to some tasks or assessments of motor or IQ being easier or more difficult than others. However, both the motor and IQ tests used in the study were standardised for the population studied and the range of tasks was split similarly across the 'normal' IQ, borderline learning disability and mild learning disability groups, so if one assessment was easier than another, a relatively equal number of people in each group were

asked to complete this assessment. Additionally, the motor assessment used was always the M-ABC (Henderson & Sugden, 1992), but the authors changed to the more recent version (M-ABC2; Henderson, Sugden & Barnett, 2007) during the course of data collection. Therefore, there were few differences in the actual tasks that participants were asked to perform.

2.2. Associations between involvement in physical activity and motor abilities in typical development.

In early childhood, children acquire fundamental motor skills, which are composed of locomotor skills (e.g. running, jumping, skipping, etc.) and object control skills (e.g. throwing, kicking, rolling, etc.) (Haywood & Getchell, 2005). These skills are thought to provide the foundation of future engagement in physical activity, and develop more complex, context-specific motor skills (Clark & Metcalfe, 2002). Stodden et al. (2008) suggest that, in younger children, the amount of physical activity a child engages in will influence motor skill development by promoting neuromotor brain development. However, in older children, motor competence will affect the level of physical activity the child engages in. Ulrich (1987) report that motor proficiency is associated with participation in sport, and that the mastery of early motor skills plays a significant part in determining later motor skills. This has been investigated in typical development, for example Barnet, Morgan, van Beurden and Beard (2008) aimed to investigate whether there is an association between child motor skills and activity level as adolescents. Barnet et al. (2008) assessed 1021 children from 18 primary schools on a battery of motor assessments. Of the 1021 students, 276 were followed up to secondary school and given the Adolescent Physical Activity Recall Questionnaire (Kowalski, Crocker & Donen, 2004). The authors also found that time spent doing physical activity was correlated with object control proficiency in childhood (12.7% of the variance), and that those with better object control skills in childhood were 20% more likely to

participate in more vigorous activity in adolescence. These findings suggest that there is an association between better motor skills and willingness to engage in physical activity. Wrotniak, Epstein, Dorn, Jones and Kondilis (2006) found similar results when they evaluated 8 to 10–year-olds motor competencies and physical activity. They discovered that children's motor proficiency was significantly correlated with the time they spent taking part in moderate to vigorous physical activity (8.7% of the variance). However, in all these studies, it is impossible to say if motor ability is influencing sports involvement (i.e. those with better motor ability will be more likely to take part in sports), or whether sports involvement is improving motor ability (i.e. those who practice motor skills more though sports will thereby gain greater mastery over motor abilities).

Oja and Jorimae (2002) investigated 294 typically developing children aged 6-years. Interestingly, in this younger population, it was found that girls were more physically active than boys when playing indoors. There were no significant differences between the sexes in time spent physically active outdoors. Although, this could be explained by girls being more involved in additional indoor aerobic exercises compared to boys in this sample. Children with the highest physical activity levels performed better on fine motor skills such as drawing, suggesting that physical activity could have the potential to improve fine motor skills.

Fisher et al. (2005) measured the physical activity of 394 primary school aged children using accelerometers. They also measured the children's motor skills using the Movement Assessment Battery for Children (M-ABC) (Sugden & Henderson, 1992). Total movement skills score from the M-ABC was significantly correlated with time spent doing physical exercise as measured by the accelerometer. The authors hypothesise that limited engagement with physical activity could hinder motor development, as children who took part in the least physical activity had the lowest scores on the M-ABC. However, as above,

we cannot be sure here of direction of the effect from this data, i.e. we cannot say whether poor motor skills are leading to less engagement in physical activity, or whether less engagement in physical activity is leading children to have less opportunity to practice their motor skills. Indeed, it is likely that this is a bi-directional effect.

However, Harter and Connell (1984) suggest that how competent a child believes themselves to be will influence their continued engagement with the activity. Stodden et al. (2008) built on this idea and suggested that if the child has poorer motor competence, their perception of their own competence will be lower.

2.3. Physical activity and motor ability in WS, DS, and other neurodevelopmental disorders.

As discussed above in section 2.2, there is a significant association between level of physical activity and motor ability in typically developing children and adolescents, with those who are more involved in sports and exercise receiving higher scores on motor tasks (Barnet et al., 2008; Stodden et al., 2008; Ulrich, 1987). Findings indicate that individuals with WS and individuals with DS have low levels of physical activity (Nordstrøm, Hansen, Paus & Kolset, 2013), which may influence their motor ability or vice-versa, although this is yet to be investigated.

Taking part in regular physical activity improves functional ability (the ability to perform activities of daily living, such as eating and dressing), reduces the risk of health disorders such as cardiovascular disease and diabetes, and enhances independence (Nordic Council, 2005; World Health Organization [WHO], 2010). However, how effective physical activity may be is difficult to assess, as it depends heavily on duration, frequency and intensity of activity (Westerterp, 2009). In groups with intellectual disabilities, walking is the most common and most easily accessible form of exercise (Draheim, Williams & McCubbin, 2002), and is related to level of independence (Cowley et al., 2010) and long-term health outcomes (Rasekaba, Lee, Naughton, Williams & Holland, 2009). It has been reported that

there is a significant low level of physical activity and a significant risk of inactivity in neurodevelopmental disorders such as DS and Prader-Willi Syndrome (PWS) (Butler, Theodoro, Bittel & Donnelly, 2007; Phillips & Holland, 2011; Temple & Stanish, 2009). These authors suggest that as individuals with intellectual disabilities are at a greater risk of developing diseases associated with low physical activity, this indicates a need for well-designed and accessible interventions to promote physical activity in populations with intellectual disabilities. However, there has been little investigation into participation in physical activity in WS. One investigation into physical activity in WS and DS is a study by Nordstrøm, Hansen, Paus and Kolset (2013), who used accelerometers to measure physical activity levels in adults with WS (N=28), DS (N=40) and PWS (N=28) in Norway. The authors found that in all groups, the majority of the day was spent in sedentary activities, and only 12% of the whole sample met the Nordic recommendation for amount of daily physical activity. According to the Nordic Council of Ministers, who published data collected in 2011, 67% of typically developing adults met the minimum recommendation of 3.5 hours of moderate intensity physical activity per week (Rasmussen, 2012). Nordstrøm et al. (2013) found that males in all three groups, WS, DS and PWS, were more active than females, with an average of 2137 more steps per day. There was no association found between body mass index (BMI) and amount of physical activity in any group, although a total of 78% of the whole sample was either overweight or obese, with the WS group having the lowest overall BMI, with an average BMI of 26.6. According to the NHS, a BMI of between 18.5 and 24.9 is considered to be healthy. Higher BMI in this group of individuals with WS was thought to not only be due to lower levels of physical activity, but also due to a poorer diet, consisting of fewer fruits, vegetables and, when living in communities rather than with relatives, were more likely to consume pre-cooked meals and high sugar drinks compared with participants with PWS (Nordstrøm, Paus, Andersen & Kolset, 2015). Although, the use of accelerometers

as a tool for measuring physical activity may be a weakness of this study. While it is thought that accelerometers are a valid and reliable tool for measuring physical activity in adults (Westerterp, 2009), these devices do not take into account the amount of energy expended in an activity (e.g. one individual may be walking for half an hour, and another may be vigorously dancing for half an hour, but the accelerometer would say that the first individual had done more activity because they would have taken more steps). Accelerometers also do not measure activities that do not require movement of the hips, or movement in water (i.e. swimming). Nevertheless, if there is an association between motor ability and involvement in sports and exercise, it may be that increasing involvement in physical activity could have positive effects on improving motor ability as it would give the individual the opportunity to practice motor skills. This has been found to be the case in typical populations (e.g. Barnet et al., 2008; Stodden et al., 2008; Ulrich, 1987)., so it seems likely a similar association would be found in other groups. Alternatively, it may also be the case that interventions to improve motor skills will increase confidence, accessibility and enjoyment of taking part in physical activity, leading to better health outcomes. This potential association between motor skills and physical activity will be investigated in the following study.

In summary, based on the above evidence, it is likely that individuals with WS and individuals with DS do not take part in as much physical activity as their typically developing peers. This may be due to poorer motor ability and lower motivation to take part in physical activity.

2.4. Aims

The aim of this study was to investigate the overall, fine and gross motor abilities of individuals with WS and with DS, and to obtain a full motor profile for individuals with WS and individuals with DS.

The second aim of this study was to investigate whether there is an association between motor ability and physical activity for each of these groups.

2.5. Hypothesis

It was hypothesised that individuals with WS and individuals with DS would perform below their expected level of motor ability, for their chronological age based on the evidence outlined in Chapter 1. It was also hypothesised that this poor motor ability would not be affected by age in the WS or DS groups, and that there would be no association between age and motor ability. It is further hypothesised that individuals with WS and individuals with DS would show an uneven motor profile with relative strengths and difficulties.

It was also hypothesised that individuals with WS and individuals with DS would show low levels of physical activity. It was further hypothesised that level of physical activity would not be related to age in these populations, though there would be an association between age and amount of physical activity in the TD groups.

It was also hypothesised that there would be an association between physical activity, as measured by a Physical Activity Questionnaire, and an individual's motor ability, with individuals who score higher on the motor assessment participating in more sports. However, this questionnaire did not determine the direction of the effect (i.e. whether greater participation in physical activity is leading to better motor skills, or vice-versa).

2.6. Method

2.6.1. Participants

The sample included a total of 36 participants with a positive clinical diagnosis of WS, 29 of whom had a positive FISH test. WS participants were aged 8 to 50-years, and recruited via the Williams Syndrome Foundation, UK. 9/36 participants were under the age of 18 years. The lists of participants provided by the Williams Syndrome Foundation, UK were for the south of England (e.g. London, Brighton, Essex, Surrey, etc.) and the north-west

of England (e.g. Manchester, Liverpool, Lancashire, etc.). Together, these lists totaled 243 individuals with WS who were over the age of 8 at the time of testing. The age of 8 was chosen as the minimum age, as it was thought, based on previous research from the lab, that participants with WS under this age would have difficulty focusing on the tasks, for the required amount of time and would also be more likely to misunderstand the task instructions. As the sample of individuals with WS was an opportunity sample, it was sometimes not possible to ensure that all participants had a positive FISH test, though every effort was made to only recruit participants with a positive FISH test before those without were contacted. Participants were called on the phone and/or emailed (if an email address was provided) to invite them to take part. All participants who it was reasonable for the researcher to logistically access were contacted to take part (39 participants in the north-west of England and 38 individuals in the south of England).

The sample also included 18 participants with DS, aged 12 to 35-years (4 participants under the age of 18 years), recruited via social media (e.g. Facebook and Twitter), phone calls to individuals who have been previously tested in our lab, emails to centers and charities set up for individuals with DS, and word of mouth. The individuals with DS included in this thesis were all under the age of 35 years. This is because, as highlighted in Chapter 1, the risk of Dementia and Alzheimer's is higher in individuals with DS aged over 35 years (for a review, see Wisniewski, 1990). Again, the DS group were an opportunity sample, and while every effort was made to recruit a larger sample of participants, and recruitment took place over a 12-month period, it was difficult to access this group.

A control sample of 40 typically developing (TD) children aged 4 to 7-years was also tested. These were divided into two groups, a TD 4-5-year-old group and a TD 6-7-year-old group, recruited from two primary schools from the Greater London area (Table 2). All participants had normal or corrected to normal vision. The age range of the typically

developing children were chosen to span the hypothesised range of overall motor abilities of the WS and DS groups. A sample of typically developing children was used as, in the BOT2-SF, there is no norms data in the manual and so it is not possible to calculate standard scores for the tasks in the subdomains. Therefore, to examine the motor abilities on specific subdomains in individuals with WS and individuals with DS, a sample of typically developing children was required.

Participants were assessed on their verbal and non-verbal IQ using the British Picture Vocabulary Scale III (BPVS III) (Dunn, Dunn, Styles & Sewell, 2009) and the matrices subtest of the British Abilities Scales III (BAS III) for 20 participants in the WS group (Elliott, Smith & McCulloch, 1996), and the Ravens Coloured Progressive Matrices (RCPM) (Raven, 2003) for 16 participants with WS and all participants with DS. This is due to data being collected at two different time points and, it was discovered that, when participants were tested using the BAS III Matrices, many participants were performing at floor. That is, they were getting a raw score of 2 or 3, and so they got the same ability score. The RCPM is a more sensitive measure and was used once the issue with the BAS III Matrices was apparent. The Williams Syndrome Development study (WiSDom, Van Herwegen, Purser & Thomas, 2019) project was also set up during the course of this thesis, and the protocol that they have set up includes the RCPM. Changing to the RCPM therefore means that the data collected during this thesis can be shared with this project also. Participant details are shown in Table 2. Raw scores for the BPVS III and RCPM were used as the WS and DS groups ages exceeded the maximum age range used to calculate standard score and raw scores are more sensitive. Ability scores were derived from the raw scores of the BAS III, which gave a score based on what item in the assessment each participant began (equivalent to raw scores).

Analysis of variance (ANOVA) were conducted separately for BPVS III and BAS III matrices scores with group (BPVS, 4 levels; WS, DS, TD4-5 and TD6-7. BAS: 3 levels; WS,

TD4-5 and TD6-7) as the between participant's factor. This demonstrated that the WS group performed significantly better on the BPVS III than the TD4-5 group (p<.001), but were not significantly different from the TD6-7 or DS groups (p>.05) (F(3,93)=12.58, p<.001, η^2_p=.295). The WS group performed below both typically developing groups on the BAS III matrices subtest (F(2,57)=16.03, p<.001, η^2_p=.421). For the TD 4-year-old children, percentiles were used from the youngest age (5-years, 0-months) to calculate percentile rank on the BAS-III, as no percentiles were available for this group at a younger age. For the 16 participants with WS who completed the RCPM and all the DS participants, TD comparison data was not available. Age equivalent data, based on the standardized sample from the manual demonstrated a mean age equivalent of 5-years (range:<4-years to 8-years) for the WS group, which also reflects the WS Cognitive Profile. The DS group also scored at an age equivalent of 5-years, which was not expected, as it was hypothesised that the DS group would perform at a higher age than the WS group based on previous research. However, the range of scores in the DS group ranges from <4-years to >11-years, showing that this group had more variability in performance on the task than the WS group (see Table 2).

Table 2. Participant details.

	Group			
	WS (N=36)	DS (N=18)	TD4-5 years (N=20)	TD6-7 years (N=20)
Mean age (years;months) (range age years)	23;9 (8.8-50.7)	24;2 (12.1-35.0)	4;6 (4.0-5.9)	6;6 (6.1-7.7)
Gender F:M	20:16	9:9	11:9	9:11
BPVS-III[1] raw score (Mean, SD)	120.31 (26.66)	103.78 (22.29)	83.30 (14.64)	105.10 (16.26)
BPVS-III[1] Percentile	8th	3rd	78th	60th
BAS-III[2] ability score (Mean, SD) Or *RCPM[3] raw score (Mean, SD)	47.75 (17.95) *17.75 (6.42)	*17.78 (6.42)	66.55 (25.51)	92.20 (21.61)
BAS-III[2] Or *RCPM[3] percentile rank	1st *0.1th	*0.1th	67th	33rd

[1] British Picture Vocabulary Scale, Third Edition
[2] British Abilities Scale, Third Edition (matrices subtest only)
[3] Ravens Colour Progressive Matrices

2.6.2. Design and procedure

Ethical approval was obtained from the UCL ethics committee before testing began. Typically developing participants were tested in a quiet room at their school during the day or, for a small sample of the 4-year-olds, in their own home. WS and DS participants were tested either in a quiet room at the University or in their own home. For the WS individuals and DS individuals, the entire testing session lasted between 1 hour 30 minutes and 2 hours with breaks. For the TD children, testing was completed over four 30-minute sessions for the 4, 5 and 6-year-olds, and two 1-hour sessions for the 7-year-olds. All participants were given

breaks when needed, and for some of the 4 and 5-year-olds, sessions were split into 15-minute sessions to reduce fatigue and maximize motivation.

*Motor ability***.** Motor ability was assessed using the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition short form (BOT2-SF; Bruininks & Bruininks, 2005). This measure was designed for typically developing people aged 3 to 21-years, and was selected because the BOT-2 has high reliability (inter-rater reliability: >.90, test-retest reliability: >.80) and validity (ability to distinguish between clinical and non-clinical groups: clinical groups scored lower than non-clinical groups on three studies reported in the BOT-2 Manual, $p<.001$) (Deitz, Kartin & Kopp, 2007). It is also a comprehensive approach to testing specific motor skills, and it is used clinically by occupational therapists (Deitz et al, 2007). While the whole BOT-2 full assessment would have provided the researcher more information about the motor abilities of individuals with WS and individuals with DS, as well as comparison norms data, it was impractical to consider undertaking the whole assessment with each individual. This was due to time constraints, as the whole BOT-2 assessment is estimated to take an hour to complete per person, and in the context of the other tasks in the battery, would have made the testing battery too long. Although the BOT2-SF standard scores only go up to age 21 years, and some of the sample is over this age, there were no alternative motor assessments available that could be used with both children and adults. However, it may be that the oldest participant (age 50 years) would have had poorer motor abilities due to the effect of age. Therefore, using the maximum age of 21 years to get their standard score may not be accurate. However, Hunter, Pereira and Keenan (2016) found in their study measuring the decline in motor abilities of older adults that notable declines in motor abilities do not, generally, occur until age 60 years, and then begin to accelerate between the ages of 75-80 years of age. It should be noted, however, that this study was conducted with typically developing adults, and it is possible that the rate of motor decline in

WS may happen more quickly. Although, please note that the two oldest participants in the group scored 58 (age 50 years) and 55 (age 39 years) on their overall motor ability, and the mean score for the WS group was 44.86, which indicates that, while age may affect some older people with WS in regard to their motor ability, it did not appear to affect these individuals. Additionally, motor tasks designed for adults may have been too difficult for these groups, and it may have led to floor performance.

The fine motor subtests of the BOT2-SF are: Fine motor precision, which comprised: the Crooked Line Path Task, where participants were asked to draw a line through a path from a picture of a car to a picture of a house; and the Folding Task, where participants were asked to fold a piece of paper on the lines. Fine motor integration, which comprised: the Square Task, where participants were asked to copy a picture of a square by drawing the square on paper with a red pencil; and the Star Task, where participants were asked to copy a picture of a star by drawing it on paper using a red pencil. Finally, manual dexterity was measured with the transferring Pennies Task, where participants had to pick up plastic pennies, move them from one hand to another, and drop them into a pot as quickly as possible.

The gross motor subtests of the BOT2-SF are: Bilateral co-ordination, which comprised: the Tapping Task, where participants were asked to alternatively tap their fingers and feet on the same side of the body at the same time to a rhythm; and the Jumping in Place Task, where participants were asked to put the same arm and leg in front/behind them and then jump to switch the arms and legs around so the other arm and leg were in front. Running speed and agility, which comprised: the Hopping in Place Task, where participants were asked to hop in place on one foot for 15 seconds. Balance, which was the Balancing Task, where they had to balance on a balance beam on one leg for 10 seconds while looking at a red target, placed at eye level, ten feet in front of them; and the Walking on a Line Task, where

they had to walk forward six steps on a line. Upper limb control, which involved: the Dropping and Catching Task, where they had to drop and catch a tennis ball 5 times; and the Dribbling Task, where they had to drop the ball with one hand, and then dribble it with alternate hands 10 times. Finally, Strength, which comprised: the Sit-ups Task, where they were asked to do sit-ups for 30 seconds; and the Push-up Task, where they were asked to do knee push-ups (i.e., where they were asked to adopt a 'hands and knees' position, with the legs bent at the knee, feet crossed) for 30 seconds.

*Physical activity***.** All participants were given an interview style questionnaire regarding their level of physical activity. They were asked, in a typical week, how many times during weekdays they participated in sports (excluding compulsory P.E. as the majority of the WS and DS groups were adults and therefore did not take part in any compulsory exercise) and how many times during the weekend they participated in sports. The experimenter first gave these as open-ended questions, and then gave prompts where needed, such as 'did you do any sports or exercises yesterday?' and 'are you going to be doing anything after school today/over the weekend?'. Participants were also given some examples of types of physical activity to aid recollection if they were struggling, such as 'dancing, playing football, going to the gym, etc.'. In the WS and DS group, parents or carers were often present when these questions were being asked, and they verified whether this information was accurate or not. This was not possible for the typically developing participants as they were not seen in their own homes and there was no contact, apart from the opt-out letter, between the parents and the experimenter. The maximum score for this questionnaire was eight, and this was computed from adding up the number of activities taken part in on weekdays and weekends (max score of 4 for each), with each activity being a separate score, regardless of the length of activity. Participants were given a score of 0 if they did not take part in any physical activity on week days, a score of 1 if they took part in physical activity once on week days, a

score of 2 if they took part in physical activity two or three times on week days, a score of 3 if they took part in physical activity four times on week days, and a score of 4 if they took part in five or more physical activities on week days. Amount of physical activity undertaken on weekends was scored in the same way.

2.7. Results

2.7.1. Analysis and parametric assumptions

Participants completed a motor assessment as described above and reported on the amount of physical activity they took part in. It was found that the data met assumptions of normality for the majority of variables on both the BOT2-SF and the physical activity questionnaire (Kolomorov-Smirnov, $p \geq .05$), and that outliers were not significantly affecting the means of the data when the 5% trimmed mean was looked at. Therefore, parametric tests were conducted.

To consider the general level of motor achievement in WS and DS, a one-way ANOVA was conducted on the total motor raw scores for the BOT2-SF, with Group (WS, DS, TD4-5, TD6-7) as a between participant factor, followed up using Tukey pairwise comparison tests. The mean and SD of all groups (WS, DS, TD4-5 and TD6-7) were used to calculate z-score performance, from the raw scores of performance on each subdomain of the BOT2-SF. Therefore, to determine the motor profile of the WS and the DS group, a one factor ANOVA of the z-scores was carried out on the WS and DS data only with subtest (8 levels: fine motor precision, fine motor integration, manual dexterity, bilateral co-ordination, balance, running speed and agility, upper limb control and strength) as the within-participant factor.

To examine the amount of physical activity that the individuals with WS and individuals with DS took part in, a one-way ANOVA was conducted to compare performance between the groups on level of physical activity involvement (Max. score: 8).

2.7.2. The effect of age on motor performance

Due to the wide age range in the WS and DS groups, correlations were conducted to determine whether age was related to motor performance in these groups. This was done to ensure that the results related to the hypothesis were not being influenced by the wide age range of the participants. As expected, chronological age was not related to motor ability in the WS or DS group, which is in line with previous research showing that chronological age is rarely related to cognitive impairment in groups with intellectual disabilities (Karmiloff-Smith, 1998). However, it should be noted that the WS group were close to significance, which may reflect the wider age range and larger sample in the WS group in comparison to the DS group. There were some much older (e.g. 50 years old) participants in the WS group, and, therefore, these older participants may have poorer motor abilities due to less strength or stamina to carry out the tasks. There were, never-the-less, correlations between chronological age and motor ability in the TD group, which you would expect as motor ability is expected to improve with age. The TD correlation is present in spite of the narrower age range, suggesting a tight trajectory for typical motor development that is absent in the WS and DS groups (Table 3).

Table 3. Correlations between chronological age and raw total motor scores for the WS, DS and TD groups. Critical alpha: $p \leq .05$.

Group	Age X total raw motor score
WS (n=36)	r=.323, *p*=.055
DS (n=18)	r=.032, *p*=.899
TD (n=40)	**r= .803, *p* <.001**

2.7.3. The effect of verbal and non-verbal intelligence on motor ability

Due to research suggesting that intellectual functioning is related to motor ability (Smits-Engelsman & Hill, 2012), bivariate correlations were conducted to examine the potential effect of non-verbal IQ on motor ability. To do this, BAS III or RCPM score was

correlated with the overall raw score on the BOT-2. It was found that there was a significant correlation between motor ability and RCPM score in the WS group (N=16) (Table 4). There were no other correlations between non-verbal measures and motor ability.

Bivariate correlations were also used to examine the potential association between verbal IQ and motor ability. As this constitutes three correlations per group, a bonferroni corrected critical alpha of $p \leq .015$ was used. It was found that there was a significant correlation between BPVS III score and motor ability for the WS (Table 4). There were no other significant correlations.

Table 4. Correlations between verbal and non-verbal IQ and raw total motor scores for the WS, DS and TD groups. Critical alpha: $p \leq .015$.

	WS	DS	TD4-5	TD6-7
Motor ability X RCPM	R=.525, p=.037 (N=16)	R=.442, p=.066	_	_
Motor ability X BAS III	R=.229, p=.201 (N=20)	_	R=.394, p=.086	R=.460, p=.041
Motor ability X BPVS III	**R=.710, p<.001**	R=.233, p=.352	R=.524, p=.018	R=.235, p=.318

2.7.4. BOT2-SF motor performance zones

To determine the motor percentiles of the individuals with WS and individuals with DS, relative to the general population, standard scores were derived from the BOT-2 manual for the TD, WS and DS groups. For participants in the WS and DS groups who were over 21 years (WS N=25, DS N=9), the maximum adult age of 21 years was used to calculate the standard score. Results indicate that most members of the WS group and all member of the DS group were performing in the 'below average' (3rd to 16th percentile) or 'well below average' (<2nd percentile) zone of the BOT2-SF. However, two participants with WS scored in the 'average' zone (17th to 18th percentile). All participants in the TD groups performed in the 'average', 'above average' (83rd to 97th percentile) and 'well above average' (>98th percentile) zones (Figure 1).

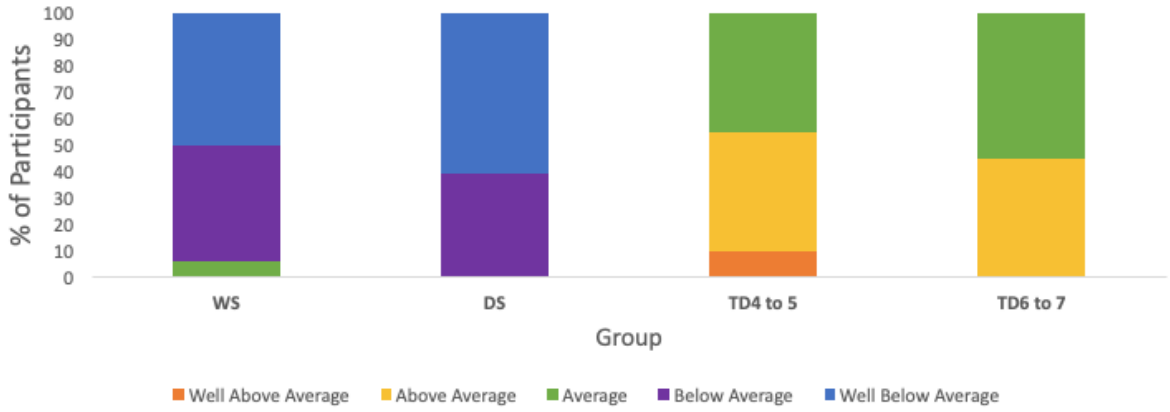

Figure 1. Distribution of BOT2-SF "zones" in the WS, DS, TD4-5 and TD6-7 groups.

2.7.5. BOT2-SF total motor abilities

To consider the general level of motor achievement in WS and DS (Table 5), a one-way ANOVA was conducted, with Group (WS, DS, TD4-5, TD6-7) as a between participant factor, on the total motor raw scores for the BOT2-SF. This demonstrated a main effect of group ($F(3,93)=9.920$, $p<.001$, $\eta^2=.248$). Post-hoc Tukey tests indicated that both the WS and the DS group were performing at the TD4-5 level ($p>.05$ for both), and the WS, DS and TD4-5 group were performing below the TD6-7 level ($p<.05$ for all). Therefore, the WS and DS group are matched as a group to the TD4-5 group in terms of overall motor ability.

Table 5. Mean (SD) participant raw total motor score on BOT2-SF

Group	BOT2-SF[1] mean raw score (SD)
WS (N=36)	44.86 (16.38)
DS (N=18)	45.28 (14.12)
TD4-5-years (N=20)	47.05 (9.83)
TD6-7-years (N=20)	63.45 (6.60)

[1] Bruininks-Oseretsky Test of Motor Proficiency short form, Second Edition

2.7.6. Individual differences in motor abilities

Dot plots were used to investigate the spread of individual differences in each separate group. It can be seen from the dot plots that the WS and DS groups show much wider variability of scores from their mean on total motor ability in comparison to the TD

groups. It can also be seen that the TD4-5 group is showing a wider spread of scores than the TD6-7 group (Figure 2).

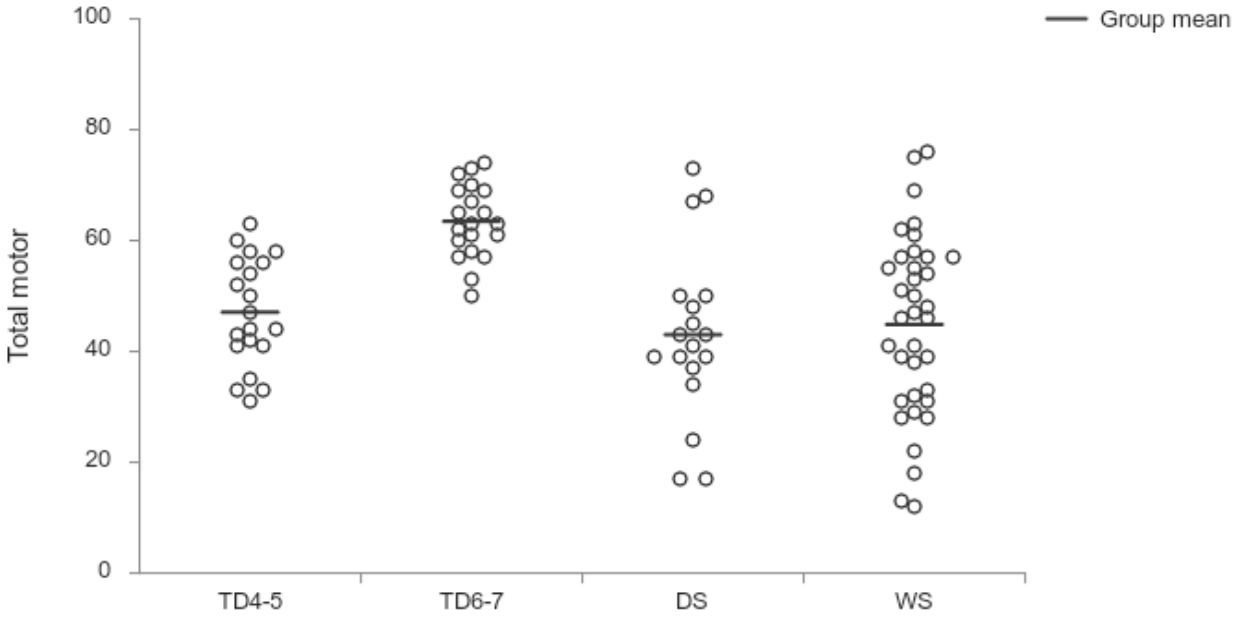

Figure 2. Dot plot to show the distribution of scores on the BOT2-SF for the TD4-5, TD6-7, DS and WS groups

2.7.7. BOT2-SF motor profile

The raw scores for each of the 8 BOT2-SF subdomains, for each of the 4 groups (WS, DS, TD4-5 and TD6-7) are shown in Table 6. T-tests were performed to investigate whether any of the groups were performing at floor or ceiling on any of the BOT2-SF subdomains. T-tests showed that no group were performing at floor on any of the tasks (p<.001 for all). The TD6-7 group performed at ceiling on the Bilateral Co-ordination task (t(19)=-.625, p=.541). The TD6-7 group performed below ceiling on all other subdomains, and all other groups performed below ceiling on all subdomains (p<.05 for all).

Table 6. Mean (SD) raw score for each of the 8 BOT2-SF subdomains for each group.

	Mean (SD, range) BOT2-SF fine motor subdomain			Mean (SD, range) BOT2-SF gross motor subdomain				
	FMP max:14	FMI max:10	MD max:9	BLC max:7	Balance max:8	RSA max:10	ULC max:12	Strength max:18
WS	7.19 (4.10)	5.64 (2.69)	2.67 (.93)	4.64 (2.31)	4.14 (2.62)	5.47 (3.08)	7.47 (2.47)	7.69 (3.15)
DS	6.89 (3.38)	6.56 (2.68)	2.72 (1.18)	5.28 (2.85)	3.94 (1.98)	4.56 (3.13)	6.78 (3.23)	7.67 (2.20)
TD4-5	7.40 (2.48)	8.00 (2.15)	2.80 (.95)	5.60 (1.64)	6.70 (1.46)	6.55 (2.61)	2.50 (2.01)	7.55 (2.69)
TD6-7	11.30 (1.81)	9.55 (.76)	4.00 (.86)	6.90 (.72)	7.65 (.75)	8.15 (1.04)	6.75 (2.63)	9.75 (2.34)

FMP: Fine Motor precision
FMI: Fine Motor Integration
MD: Manual Dexterity
BLC: Bi-lateral Coordination
RSA: Running Speed and Agility
ULC: Upper Limb Control

It is not possible to obtain standard scores for each individual subtest when using the short form of the BOT-2. On account of this, the mean and SD of all groups (WS, DS, TD4-5 and TD6-7) were used to calculate z-scores of performances on each subdomain of the BOT2-SF for the WS and DS group. The use of z-scores enabled the researcher to determine the profile of scores of both the WS and DS group relative to the overall level of motor ability of all groups. ANOVA of the z-scores was carried out for the WS and DS data with subtest (8 levels: fine motor precision, fine motor integration, manual dexterity, bilateral co-ordination, balance, running speed and agility, upper limb control and strength) as the within-participant factor, and group (WS, DS) as the between-participant factor (Figure 6).

There was a main effect of group ($F(3, 90)= 34.442$, $p<.001$, $\eta^2= .534$). This was due to the WS group preforming below the TD4-5 group ($p=.011$) and the TD6-7 group ($p<.001$), and the DS group performing significantly below the TD6-7 group ($p<.001$). There was also a significant difference between the TD4-5 group and the TD6-7 group, with the TD4-5 group performing below the TD6-7 group ($p<.001$). There was also a significant main effect of subdomain ($F(3, 90)= 11.304$, $p<.001$, $\eta^2 =.112$), which is best described in the context of

the significant interaction between subdomain and group (F(3, 90)= 11.914, p<.001, η^2= .284). This relationship was further investigated, and it was found that there was a main effect of group on all subdomains (p<.005 for all). The WS group were performing higher than the TD4-5 group on Upper Limb Control, Fine Motor Integration, Fine Motor Precision, Manual Dexterity, Bi-Lateral Co-ordination, Running Speed and Agility and Strength (p>.005 for all). The WS group were performing below the TD4-5 group on Balance (p<.001). The WS group performed similar to the TD6-7 group on Upper Limb Control (p=.899), and lower than the TD6-7 group on Fine Motor Integration, Fine Motor Precision, Manual Dexterity, Bi-Lateral Co-ordination, Balance, Running Speed and Agility and Strength (p<.005 for all). The DS group were performing higher than the TD4-5 group on Upper Limb Control (p<.001) and lower than the TD4-5 group on Balance (p<.001). The DS group were performing to a similar level to the TD4-5 group on Fine Motor Integration, Fine Motor Precision, Manual Dexterity, Bilateral Co-ordination, Running Speed and Agility and Strength (p>.005 for all). The DS group were performing to a similar level to the TD6-7 group on Upper Limb Control, Bilateral Co-ordination and Strength (p>.005 for all) and were performing below the TD6-7 group on Fine Motor Integration, Fine Motor Precision, Manual Dexterity, Balance and Running Speed and Agility (p<.005 for all).

Post-hoc Sidak tests demonstrated that the WS group showed a particular weakness in Fine Motor Integration, which they scored lower in than all other subdomains, and a relative strength in Upper Limb Control (p<.05 for all). There was a main effect of group on Fine Motor Integration (F(1, 3) = 13.820, p<.001, η^2= .315), with post-hoc tests indicating that the WS group were performing below than the TD4-5 group (p=.002) and the TD6-7 group (p<.001) but were comparable to the DS group (p=.662). The DS group also demonstrated a weakness in Fine Motor Integration, which they scored lower in than all other subdomains except Balance (p<.05). The DS group did not show a significant strength in any subdomain.

It was also investigated whether the WS group showed a strength in Upper Limb Control in comparison to older TD children, so an ANOVA was performed to look for differences between the WS group and the TD6-7 group on Upper Limb Control. This was done to ensure that the range of the typically developing participants was high enough to span the motor ability range of the WS group. The results of the ANOVA showed a main effect of group $F(1, 3) = 17.215$, $p<.001$, $\eta^2= .365$, with po-hoc tests indicating that the WS group were performing at the same level as the TD6-7 group ($p=.719$). The mean raw score on Upper Limb Control for the WS group was 7.47 (SD: 2.63, range: 12.00), for the TD4-5 group it was 2.50 (SD: 2.01, range: 6.00), and for the TD6-7 group it was 6.75 (SD: 2.63, range: 11.00). While the WS group showed a relative strength in Upper Limb Control compared to the TD4-5 year olds (Cohen's $d= 2.32$) and the rest of their own (WS) motor profile, they did not perform significantly better than the TD6-7-year-olds ($p=.895$; Cohen's $d= 0.293$), suggesting that their Upper Limb Control ability is still significantly delayed for their age. The researcher can, therefore, be confident that the chosen age range of the control group does span the whole range of motor abilities in the WS group.

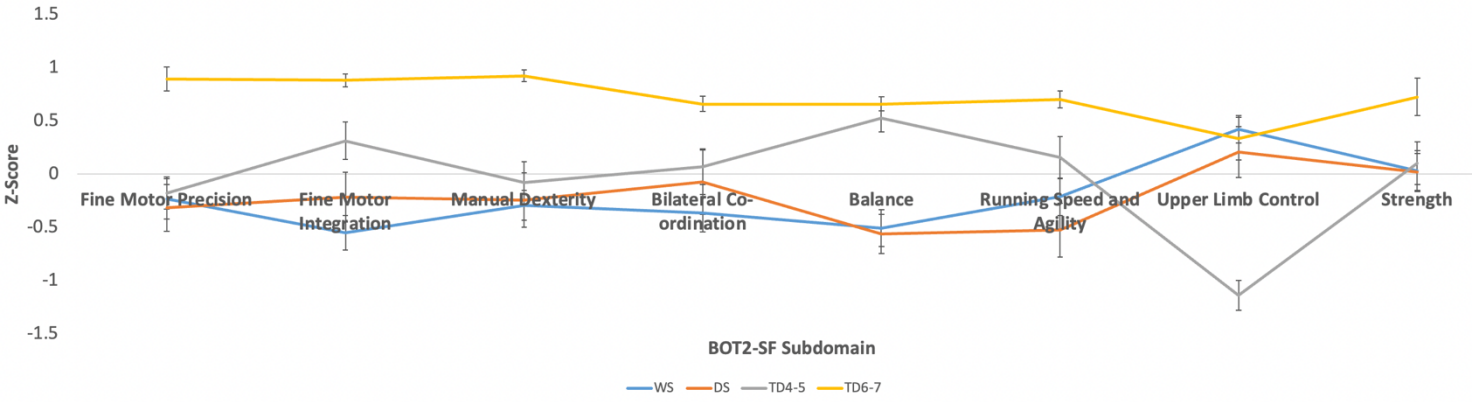

Figure 3. Profile of motor abilities in WS (blue line), DS (orange line), TD4-5 (grey line), TD6-7 (yellow line): z scores based on the mean and standard deviation of all groups.

2.7.8. The effect of age on physical activity participation

Due to the wide age range of the WS and DS groups, correlations were conducted to examine the potential effect of age on levels of physical activity in these groups. Again, this

was to ensure that the wide age range of the WS and DS groups were not significantly influencing the hypothesised participation in physical activity. As expected, there were no significant correlations found between the chronological age of participants in the WS or DS group and the number of physical activities they took part in. As was expected, there was significant correlation found between amount of physical activity and age in the TD group (Table 7).

Table 7. Correlations between chronological age and amount of physical activity in WS, DS and TD. Critical alpha: $p \leq .05$.

Group	Age X physical activity
WS (n=36)	r=-.130, *p*=.448
DS (n=18)	r=-.057, *p*=823
TD (n=40)	**r=.335, *p*=.034**

2.7.9. Physical activity questionnaire

To examine the amount of physical activity that individuals with WS and individuals with DS took part in, a one-way ANOVA was conducted to compare performance between the groups (TD4-5, TD6-7, WS, DS) on level of sports and physical activity involvement (max. score: 8). This highlighted significant differences across the groups ($F(3, 93)= 5.36$, $p=.002$, $\eta^2=.152$). Post hoc Tukey comparisons indicated that the WS group were taking part in a similar amount of physical activity as the TD4-5-year-olds ($p=.882$) and the TD6-7-year-olds ($p=.549$), and less physical activity than the DS group ($p=.006$). The DS group were taking part in more physical activity than the TD4-5 group ($p=.004$), but a similar amount to the TD6-7-year-olds ($p=.445$) There was no significant difference between the amount of physical activity that the TD4-5 and TD6-7 groups took part in ($p=.316$) (Table 8).

Table 8. Mean (SD) participant score on the Physical Activity Questionnaire (Max. score: 8)

	Group			
	WS (N=36)	DS (N=18)	TD4-5 (N=20)	TD6-7 (N=20)
Range	0-6	1-8	0-4	0-6
Average physical activity score	2.31 (1.62)	4.11 (2.40)	2.00 (1.26)	3.10 (2.10)

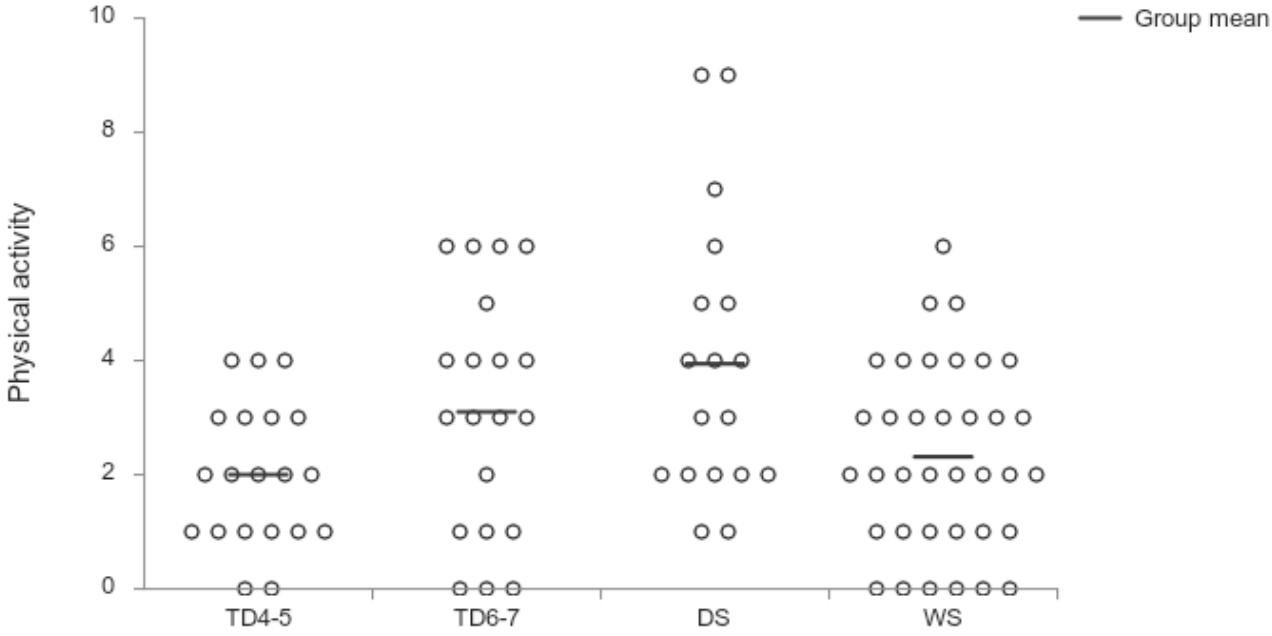

Figure 4. Dot plots to show the distribution of scores for the TD4-5, TD6-7, DS and WS groups on the Physical Activity Questionnaire.

2.7.10. Correlations between motor ability and physical activity

Bivariate correlations between physical activity and motor ability were conducted. As shown in Table 9, there were no significant correlations between motor ability and physical activity in any group.

Table 9. Two tailed correlations between fine and gross motor ability and physical activity involvement in the WS, DS and TD groups. Critical alpha: $p \leq .05$.

	WS (n=36)	DS (n=18)	TD4-5 (n=20)	TD6-7 (n=20)
Motor X physical activity	r=.169, *p*=.325	r=.027, *p*=.916	r=.239, *p*=.311	r=.380, *p*=.098

2.8. Discussion

This chapter examined motor abilities in individuals with WS, individuals with DS and typically developing children, and how these motor abilities are related to participation in physical activity. The hypothesised motor deficits were observed in the WS and DS groups, with these groups scoring at the level of a 4 to 5-year-old typical child. Importantly here, it is not the case that individuals with WS and individuals with DS perform motor tasks in the same way as typically developing 4-5-year-old children but that, statistically, the overall motor score of the WS and DS groups is not different from the TD4-5 group. Individuals with WS and individuals with DS showed a relative strength in Upper Limb Control, a subtest that required the participant to drop and catch, and also to dribble a tennis ball. Note, however, that both the WS and DS group performance in this subdomain was still only at the level of a typically developing 6 to 7-year-old. Both the WS and DS group showed a particular weakness in Fine Motor Integration, a task that required participants to copy a picture of a square and copy a picture of a star by drawing them on paper with a red pencil. Both individuals with WS and individuals with DS show cerebellar abnormalities, which although different in each group, are both likely to influence motor skills (WS: Jernigan & Bellugi, 1990; Jernigan et al., 1993; Jones et al., 2002; Reiss et al., 2000; DS: Baxter et al., 2000; Pinter et al., 2001; Roubertoux, Bichler & Pinoteau, 2005; Sveljo et al., 2014), alongside other factors which are discussed further below. In addition, the WS group showed a weakness in Balance, which, as discussed in the introduction chapter, are also thought to be influenced by the cerebellum (Crossman & Neary, 2015).

The hypothesis that individuals with better motor abilities would also be involved in more physical activity (or vice versa) was not supported in any group. This will be discussed in more detail below.

2.8.1. Motor abilities in WS and DS

It was demonstrated that the fine and gross motor difficulties observed in children with WS (e.g. Tsai et al., 2008; Wuang & Tsai, 2017) and in children with DS (e.g. Connolly et al., 1993; Malak et al., 2015; Pereira et al., 2013; Russell et al., 1998) were also present in the current study. Overall, individuals with WS and individuals with DS demonstrated motor performance broadly at the level of a TD4 to 5-year-old, and as discussed above, the profile of motor ability for these two groups was atypical, indicating that there is not a simple delay in motor ability. This is not to say that these individuals with WS and individuals with DS are performing motor acts in the same way as a TD4-5-year-old, but rather that their scores, on this test, from this sample were not significantly different from those of a TD4-5-year-old. It may be that these individuals with WS and individuals with DS use different methods to complete motor tasks (e.g. Atkinson, King, Braddick, Nokes, Anker & Braddick, 1997; Braddick & Atkinson, 2013; Newman, 2001), take more breaks during tasks, have lower motivation, misunderstand instructions more easily, etc. These factors should be considered in future studies when conducting research into the motor abilities of individuals with WS and individuals with DS. These factors were not measured in this thesis, though future studies could film the individuals performing these tasks, and then record information such as how many breaks were taken halfway through tasks, when an ineffective method was used, etc.

Individual differences were examined within each group, and it was found that both the WS and DS groups had a wider spread of scores than either of the TD groups. This indicates that populations with WS and with DS have more variability in motor ability than in typical populations. It was also found that the TD4-5 group showed a wider variability of scores than

the TD6-7 group, this may suggest that motor development is occurring at a more rapid rate in these younger participants, and that motor learning is slowing down by age 6-7 years.

The severity of motor problems suggests that motor ability in WS and DS could be affecting other aspects of the individuals' lives. For example, if you are less confident with your movement, then you may also be less likely to want to independently perform tasks of daily living, such as getting dressed independently, or cooking a meal, an area of functioning that individuals with WS (Dilts, Morris & Leonard, 1990; Greer, Brown, Pai, Choudry & Klein, 1997; Gosch & Pankau, 1994; Mervis, Klein-Tasman & Mastin, 2001; Udwin, 1990) and individuals with DS (e.g. Dykens et al., 1994; Lin et al., 2015; Leonard et al., 2002) are known to struggle with. This will be investigated in Chapter 5.

Like the WS (Mervis et al., 1999), and the DS (Wang, 1996) cognitive profile, the motor profile for individuals with WS and individuals with DS was highly varied across tasks. For example, as noted in the Introduction chapter of this thesis (Chapter 1), individuals with WS and individuals with DS have a 'spiky' profile of cognitive abilities. It was found that both the WS and DS group showed a particular weakness in Fine Motor Integration, and the WS group presented with a relative strength in Upper Limb Control.

One explanation for the similarities in these two populations in their motor profile, may be the presence of learning difficulties. A relationship has been observed between cognitive ability and motor ability in other populations with intellectual disability (Smits-Engelsman & Hill, 2012). In a study by Smits-Engelsman and Hill (2012), IQ explained 19% of the variance in motor ability in groups with and without motor difficulties. Further, for each standard deviation lower in IQ, a mean loss of 10 percentile points was observed. It has been found that IQ for individuals with WS typically ranges from 55 to 62 (Greer et al., 1997; Mervis et al., 1999), and IQ for individuals with DS has been reported to be on average 50, ranging from 30 to 70 (Mégarbané et al., 2013). Using this information, it can be predicted

from Smits-Engelsman and Hill (2012), that the motor percentile for individuals with WS and individuals with DS should be around the 10th percentile, which on the BOT2-SF motor zones would put them in the 'below average' zone, which 18/36 (50%) of the WS participants fell into, and 11/18 (61%) participants with DS fell into. Additionally, 16/36 of the WS group and 7/18 of the DS group tested in the current study fell into the 'well below average' zone, which is below the 2nd percentile, indicating that some individuals with WS and DS may be performing lower than would be predicted for their cognitive abilities. It may therefore, be the case that having a learning difficulty would lead to this motor profile in other populations. When examined, it was found that there was a correlation between non-verbal and verbal IQ and motor ability in the WS group, but not in the DS group. This suggests that intellectual functioning may be affecting motor performance in the WS group, and those with a higher verbal and non-verbal ability may be better at acquiring motor skills.

It should be noted that there are other similarities that individuals with WS and individuals with DS share. For example, motor deficits in both the WS and the DS group may be partially due to atypicallities of the cerebellum, which are often reported in these populations (WS: Jernigan et al., 1993; Osorio et al., 2014; Reiss et al., 2000; Wang et al., 1992; DS: Baxter et al., 2000; Pinter et al., 2001; Roubertoux, Bichler & Pinoteau, 2005; Sveljo et al., 2014). However, the atypicallities of the cerebellum are different for each group. For individuals with WS, a slight increase in the relative volume of the cerebellum is reported, when the overall volume reduction of the cerebrum is considered (Jernigan et al., 1993; Osorio et al., 2014; Reiss et al., 2000; Wang et al., 1992). In individuals with DS, the opposite differences have been found; that is, individuals with DS are thought to have reduced density in both white and grey matter of the cerebellum (Baxter et al., 2000; Pinter et al., 2001; Roubertoux, Bichler & Pinoteau, 2005; Sveljo et al., 2014). The cerebellum is one of the main structures of the brain responsible for motor control, and, therefore, changes to

this structure, whether this be an increase or decrease in volume are likely to have an impact on motor skills. Another similarity in both individuals with WS and individuals with DS is the high incidence of hypotonia (WS; Chapman, du Plessis & Pober, 1996; Morris, 2005; DS: Almeida et al., 2000; Frith & Frith, 1974; Latash, Wood & Ulrich, 2008; Rarick & McQuillan, 1977; Shumway-Cook & Woollacott, 1985). Hypotonia is defined as an abnormally low level of muscle tone. Indeed, research has suggested that one possible reason for poor motor ability in both individuals with WS and individuals with DS is the presence of hypotonia (e.g. Morris, 2005; Latash et al., 2008). To test whether the presence of learning difficulties generally would lead to this motor profile, the study would need to be repeated with a population who had learning difficulties, but no cerebellar abnormalities or hypotonia.

However, it should be noted that, in comparison to the TD groups, both the WS and DS groups showed a large amount of heterogeneity of their scores. For example, while the group mean for the WS group on their overall motor score was 44.86, some individuals were achieving scores of up to 76, whereas others were achieving as low as a score of 12. Similarly, in the DS group, the mean score was 45.28, however some participants were achieving scores of up to 67 and as low as 17. This indicates that motor abilities are more of a difficulty for some individuals with WS and DS than others.

2.8.2. The association between motor ability and physical activity

Motor ability was associated with participation in physical activity in typically developing children for fine motor abilities, but not for gross motor abilities. This has some consistency with previous studies (e.g., Barnet et al., 2008; Wrotniak, Epstein, Dorn, Jones & Kondilis, 2006) who found associations between fine and gross motor ability and participation in physical activity in school aged children. Although, as causation cannot be implied from cross-sectional correlations, it is impossible to say whether it is the case that better motor abilities lead to increases in participation in sports, due to better motor mastery,

or whether the opposite relationship is occurring, and this relationship is likely to be bidirectional.

There were not any significant correlations between motor ability and participation in physical activity in the WS or the DS group. This may be due to lack of opportunity. Many individuals with WS and individuals with DS are often not afforded the same opportunities to join sports groups as their typically developing peers, as they may not have lived in an area that provides suitable sports groups for their age and level of ability. It is not possible to discuss the potential bi-directionality of any effect of physical activity on motor ability in WS or DS as there was no correlation between either fine or gross motor ability and physical activity in either group.

2.9. Limitations

As discussed in the methods section of this chapter, the short form of the BOT-2 was used to collect motor data. This was due to time constraints, as the whole BOT-2 assessment is estimated to take an hour to complete per person. However, more information about specific strengths and weaknesses of the motor profile in WS and in DS could have been collected from using the full version of the BOT-2. Using the whole version of the BOT-2 would have also allowed the researcher to use the standard scores for each subdomain of the BOT-2 to investigate these strengths and weaknesses in motor ability, instead of having to rely on using a TD sample.

Additionally, it was found that the TD6-7 group scored at ceiling on the Bilateral Co-ordination task, which indicates that this task was too easy for this group. As the BOT-2 is designed for individuals up to 21 years, the fact that this task was too easy for the 6–7-year-olds in the current study may indicate that there is a problem with the task itself, in that the task is not an accurate measure of Bilateral Co-ordination. This may have, in turn, influenced

the motor profile for all groups, in that, any strength in the Bilateral Co-ordination may have been affected by the ease of the task itself rather than showing actual ability.

This study also did not investigate *how* the motor abilities of individuals with WS and individuals with DS were impaired. We have seen from that data that individuals with WS and individuals with DS were performing broadly at the level of the TD4-5-year-old group. Although, we do not know why motor abilities were poorer and whether these individuals used different strategies to complete tasks. Future research should consider this to get a better picture of how individuals with WS and individuals with DS are completing motor tasks and what new, more effective strategies could be taught to these individuals to enable them to complete motor tasks more effectively.

The physical activity questionnaire was not piloted. This was mostly due to time limits and difficulties recruiting participants. As only one individual (the experimenter) was recruiting and collecting data at this time, it was not feasible to conduct a pilot study for the physical activity questionnaire. Further, it may also be the case that the young age of the typically developing children (4 to 7-years) may have reduced the variability in physical activity scores, as they may have not been in as many sports clubs as older children due to having less choice and independence because of their young age. This, in turn, would weaken any correlations.

This study included a control group of typically developing children aged 4-7-years. This age range was chosen to span the expected motor ability of the WS and DS groups. However, there is no 'ideal' control group for this study (Jarrold & Brock, 2004). If an age-matched control group had been used, this group would have, mostly, consisted of adults. These typically developing adults would have likely scored at ceiling on the majority, if not all, of the BOT-2 tasks. Although, a strength of using an age-matched control group would be that the physical activity questionnaire information may have been more valuable as it would

be comparing, in most cases, adults to other adults. It is likely that typically developing adults would not take part in the same amount or types of physical activity as typically developing children. Therefore, it may have been helpful to compare the physical activity scores of the WS and DS participants to an age-matched control group.

2.10. Summary and future directions

In summary, the results from this study support previous findings that individuals with WS and DS show deficits in both total motor ability and in specific areas of their motor profile, particularly in Fine Motor Integration. Harter (1987) found that people's actions are highly motivated by a need to avoid situations where they would have to show their low ability to other people, which may lead to a cycle where initial failure leads to withdrawal from the failed activity, which in turn leads to less opportunity to practice and master the skill (Schoemaker & Kalverboer, 1994). It was observed during testing that many of the WS and DS participants showed some discomfort or embarrassment during certain motor tasks, particularly the Hopping, Push-up and Sit-up tasks, and in some cases declared that they were not able to complete the task for the required amount of time, despite performing the task correctly. This suggests that factors such as motivation and negative past experiences lead these individuals to be less likely to take part in physical activity, due to fear of 'not being good enough'. Indeed, Schoemaker and Kalverboer (1994) found that when children with poorer motor co-ordination were told that they would be taking part in physical activity, they were more anxious than their peers with better motor co-ordination. Skinner and Piek (2001) found that 8 to 14-year-olds with Developmental Co-ordination Disorder (DCD) showed increased levels of trait and state anxiety and lower self-esteem than their typically developing peers, and such traits have also been reported in adults with DCD (Hill & Brown, 2013). Given the poor motor ability in individuals with WS and individuals with DS shown

in this chapter, it is possible that these groups may feel more uncomfortable and therefore also wish to avoid situations where they would be required to perform motor tasks.

Chapter 3

Motor Abilities and Small Scale Spatial Skills

3.1. Introduction

The following chapter focuses on the potential relationship between motor ability and small scale spatial skills in WS, DS and typical development. A strong relationship between spatial skills and motor skills has been found in typically developing infants and toddlers (Schwarzer et al., 2013), with young children who have more mastery of how they choose to move around the environment, be it crawling or walking, showing significantly better spatial skills (Clearfield, 2004). Individuals with WS, however, show particular difficulty in spatial tasks, with visuospatial skills being classed as the weakest area of performance in the WS population within their cognitive profile (e.g. Farran et al., 2001/2004). While it has been shown that individuals with DS show better visuospatial abilities than individuals with WS (Edgin, Pennington & Mervis, 2010; Jarrold et al., 1999; Klein & Mervis, 1999, Wang & Bellugi, 1994), it is not the case that spatial abilities are a strength in DS, or that they are performing at the typical level (e.g. Hodapp et al., 1992; Lanfranchi, Cornoldi & Vianello, 2004; Pennington, Moon, Edgin, Stedron & Nadel, 2003). This, combined with the severely impaired motor ability in both groups (reported in Chapter 2), raises the question of how much the difficulties that individuals with WS and individuals with DS face in their spatial skills are associated with their poor motor ability. This will be investigated in this chapter. The following sections detail current knowledge of spatial and motor competence in WS and DS and the relationships between these domains.

3.1.1. A summary of spatial skills in WS and in DS

It is clear from the evidence outlined in Chapter 1, section 1.4.2, that individuals with WS show a particular deficit in their visuospatial abilities within their cognitive profile (e.g. Bellugi et al., 1994, 1999; Broadbent et al., 2014; Hudson & Farran, 2011; Pani et al., 1999;

Wang et al., 1995). This deficit is likely due, at least in part, to structural and function differences in the parietal lobe in individuals with WS, specifically, in the dorsal stream (Gaser et al., 2006; Kippenhan et al., 2005; Meyer-Lindenberg et al., 2004; Schmitt, Watts, Eliez, Bellugi, Galaburda & Reiss, 2002; Van Essen et al., 2006). In contrast, it is thought that individuals with DS show better visuospatial abilities than individuals with WS (Brock & Jarrold, 2005; Cardoso-Martins, Peterson, Olson & Pennington, 2009; Carretti, Lanfranchi & Mammarella, 2013; Edgin et al., 2010; Frenkel & Bourdin, 2009; Jarrold & Baddeley, 1997; Jarrold et al., 1999/2002; Lanfranchi, Cornoldi & Vianello, 2004; Lanfranchi, Jerman & Vianello, 2009; Numminen, Service, Ahonen & Ruoppila, 2001; Pennington et al., 2003; Rowe et al., 2006; Visu-Petra, Benga, Incaş & Miclea, 2007; Vicari, Carlesimo & Caltagirone, 1995; Vicari et al., 2006). Overall, this evidence suggests that both individuals with WS and individuals with DS have difficulties in processing visuospatial information.

It can be seen from past research (WS: Tsai et al., 2008; Wuang & Tsai, 2017; DS: Alesi et al., 2018; Capio et al., 2018; Jobling, 1998; Malak et al., 2015; Rigoldi, Galli, Mainardi, Crivellini & Albertini, 2011; Russell et al., 1998; Spano et al., 1999; Wang et al., 2012), and from data in Chapter 2, that both individuals with WS and individuals with DS show deficits in their motor abilities. Taken together with the above evidence of visuospatial difficulties in both these populations, it is possible that there is an association between motor abilities and spatial abilities in these populations.

3.1.2. Associations between spatial skills and motor abilities in typical development

Strong relationships have been found between mental rotation performance and motor abilities, and this association has been shown using both imaging and behavioural studies. For example, Bai and Bertenthal (1992) found that, on the A-not-B task, infants who could crawl could accurately reach for a hidden toy after it had been moved to another location, whereas matched infants who could not yet crawl reached for the location the toy was in

before it was rotated (see also: Kermoian & Campos, 1988). These findings suggest that crawling, particularly active crawling, by infants positively impacts the development of spatial abilities. Similarly, Clearfield (2004) investigated whether the onset of walking would provide further improvements to spatial skills. Clearfield (2004) found that infants with the least locomotor experience (new crawlers) were less likely to be successful at navigating a maze to find their hidden mothers. As locomotor experience increased, so did success on the trials. This has also been shown in more recent studies. For example, Schwarzer, Freitag, Buckel and Lofruthe (2013) indicated that, in their mental rotation study where infants were put in front of a screen and presented with two images which were either the same or mirror images at different rotations, 9-month-old crawling infants looked longer at a non-matching image, indicating that they could mentally rotate the original image. In comparison, same age non-crawling infants showed no difference in the looking times to the matching and non-matching image. Similarly, Frick and Möhring (2013) found that 8 to 10-month-olds who had mastered assisted walking were significantly better at a mental rotation task than were age matched infants who could not yet walk. Overall, these findings suggest a strong relationship between motor abilities and spatial skills in infancy, and perhaps suggests that one of the reasons that individuals with WS show such severe deficits in their spatial skills (e.g., Broadbent, Farran & Tolmie, 2014; Farran & Jarrold, 2003; Farran, Jarrold, & Gathercole, 2001) is low motor ability (although, see Farran, Bowler, Karmiloff-Smith, D'Souza, Mayall & Hill, 2019).

Associations between better motor co-ordination and better mental rotation abilities have been reported in 5 to 6-year-old TD children (Jansen & Heil, 2009), and improving motor skills (juggling) has been found to improve mental rotation skills (Jansen, Lange & Heil, 2011). Frick, Daum, Walser and Mast (2009) asked children and adults to perform a mental rotation task while simultaneously rotating their own hand (using a handle) either in

the same direction as the rotation they have viewed (clockwise or anti-clockwise), or in the opposite way. They found that, in the 5 and 8-year-olds, there was an effect of direction of rotation of the hand on response time on the mental rotation task, with participants being faster when rotating the handle in the same direction as the required mental rotation. However, this was not true for the 11-year-olds or adults, suggesting that the ability to dissociate visuospatial processes and motor processes gets better with age (see also Sack, Lindner & Linden, 2007, Wexler et al., 1998). Studies of mental rotation of hands found that individuals found it more difficult to mentally rotate pictures of hands that were presented in awkward or impossible positions (Cooper & Shepard, 1975; Sekiyama, 1982). This suggests that people find it easier to select the correct rotation if they can imagine their own body moving in that way.

Associations between motor abilities and mental rotation have also been shown in more recent studies. For example, Schwarzer et al. (2013) indicated in their mental rotation study that 9-month-old crawling infants looked longer at the non-matching image, indicating that they were able to mentally rotate the original image, whereas same age non-crawling infants showed no difference in the looking times to the matching and non-matching image. However, the design of this research does not allow the experimenter to know whether the infants achieved the task using mental rotation strategies or whether they used an alternative strategy, such as structural description, to enable matching without having to use mental rotation. This research also does not specify how crawling ability is related to mental rotation skills. It may be that once infants are able to independently explore their environment they become naturally more motivated to explore objects, and in this case, it would be the experience of object manipulation and exploration that is aiding mental rotation, rather than crawling ability itself. Similarly, Frick and Möhring (2013) found that 8 to 10-month-olds who had mastered assisted walking (i.e. walking while holding a parent's hands or using a

walker) were significantly better at a mental rotation task than were age matched infants who could not yet walk. This was also the case when the authors examined the age at which the infants learnt to crawl, with earlier crawlers showing superior performance on the task than later walkers. However, parents were asked to report on the exact age that motor milestones were reached retrospectively, and so these times may not be accurate. Though it should be noted that, as the infants included in this study were still very young, it is likely that parent's memories of the events, particularly one as salient as walking, would still be good, making it more likely that the results are accurate.

It has been shown that both passive and active movement aids spatial memory. Bremner (1978) conducted a study where infants were given the task of searching for a desirable toy, and found that infants were better able to accurately search for a toy when they were rotated around the table (active) compared to when the table itself was rotated (passive). It was also the case that infants who were able to independently crawl around the table were better able to find the hidden toy than infants who were passively moved (Acredolo, Adams & Goodwyn, 1984; Benson & Uzgiris, 1985), which is thought to be because when the infant is passively moved it is not essential for them to pay attention to where they are going or how they are getting there as their movement is under external control, whereas when the infant moves independently, they must monitor their movements to ensure they reach their target location and do not collide with other objects in the environment. This relationship between improvement in encoding spatial locations and motor development is also the case in spatial tasks that do not require any movement.

Clearfield (2004) investigated whether the onset of walking would provide further improvements to spatial skills. It has been shown that as infants become more proficient crawlers, their spatial skills improve. However, when infants progress to walking, the spatial skills that they have learnt are disrupted. Clearfield (2004) tested the relation between

locomotor experience and place learning in infants who were either new crawlers, experienced crawlers or new walkers. The infants' task was to successfully navigate a complex environment to find their hidden mothers using their different locomotor skills and environmental cues (e.g. flags, cameras and lights). They found that the infants with the least locomotor experience (new crawlers) were less likely to be successful at the task of finding their hidden mothers. As locomotor experience increased in the four groups, so did success on the trials; this was true for both crawlers and walkers, i.e. infants with less than 7 weeks of crawling experience failed more trails than crawlers with more crawling experience (this was also the trend for walkers, but it did not reach statistical significance). It was also found that older infants took less time to begin movements towards their mothers once they had been released, however there was no difference in the duration of searching dependent on locomotor experience. Further, Adolph, Bertenthal, Boker, Goldfield and Gibson (1997) found that infants in their sample could judge the steepness of a slope as accurately as experienced crawlers, but could not judge the same steepness as accurately when they progressed to being new walkers. This suggests that the transition to walking affects the infants perceptual learning and exploratory behaviour. Overall, these findings suggest that locomotor experience is correlated with success on a hidden goal spatial task, with more experienced movers having more success on spatial tasks. It also lends support to the notion that the way that infants can successfully navigate an environment is at least partly tied to the experience they have at the way they move through it: i.e. the new walkers were poorer at the task than the experienced crawlers.

Associations between spatial skills and motor brain areas have also been shown. Motor cortex activation has been found during mental rotation tasks (Wraga, Thompson, Alpert & Kasslyn, 2003), and the same brain areas are active (intraparietal sulcus) after juggling training (Draganski, Gaser, Busch, Schuierer, Bogdahn & May, 2004) as observed during a

mental rotation task (Jordan, Heinze, Lutz, Kanowski & Jäncke, 2001). Deutsch, Bourbon, Papanicolaou and Eisenberg (1988) also showed that solving mental rotation tasks lead to higher cerebral blood flow in areas of the brain associated with motor processes. In the current study, participants completed two block construction tasks and two mental rotation tasks. For each of these, a purer spatial condition, and one that also taps into motor ability was employed. This design was used because, while it is the case that spatial tasks in general activate motor brain areas, it may be that spatial tasks that involve an added motor element activate more motor brain areas, such as the cerebellum. For example, Vingerhoets, De Lange, Vandemaele, Deblaere and Achten (2002) conducted a mental rotation task using fMRI where participants were asked to mentally rotate tools and hands. There was also a control condition with the same stimuli, but these were not rotated, and participants were just asked to determine whether the two pictures matched or not. It was discovered that the cerebellum was activated, the left cerebellum showed significantly greater activation in the tools condition as opposed to the hands condition, and the premotor cortex was unilaterally (LH) active in the tools condition. The authors hypothesise this to be because tracts in the brain decussate (the left hemisphere processed information from the right side of the body, and vice-versa), so in the tools condition they would be imagining manipulating the tool with their right hand, and so the left hemisphere would process the information. Dekker et al. (2011) investigated the role of the dorsal and ventral stream in object recognition of scrambled and un-scrambled objects, half of which were tools (objects that could be grasped and used with your hands), half were animals. Dekker et al. (2011) found that there was an increased dorsal stream involvement for the images of tools over animals which were more likely to be processed by the ventral stream. It has been suggested that the reported difficulties in the dorsal stream of individuals with WS not only affects their spatial skills, but also their motor skills (Atkinson et al., 1997; Chapman & Goodale, 2008; Schindler, Rice,

McIntosh, Rossetti, Vighetto & Milner, 2004). Therefore, in this study, an image of a jug was selected for the tool condition of the mental rotation task, which is hypothesised to activate motor brain areas and the dorsal stream, and a chicken was chosen as the non-tool mental rotation condition image, as it is hypothesised that the use of an animal image will elicit less activation of motor brain areas. However, it should be noted that this study did not measure brain activation and these images have been selected based wholly on previous research as one is hypothesised to be associated with motor brain areas (jug) and the other is not (chicken). Also, while the jug condition is hypothesised to have stronger associations to motor brain areas, the predominant mechanism for both conditions is still spatial.

3.1.3. Associations between motor ability and spatial ability in atypical populations

Insights can be gained on the associations between spatial skills and motor ability from other atypical populations such as Spinal Muscular Atrophy (SMA), Autism Spectrum Disorder (ASD), Developmental Delay (DD), and Cerebral Palsy (CP).

SMA is a rare neuromuscular disorder caused by degeneration of the anterior horn cells of the spinal cord. Children with SMA are unable to walk or crawl, though normally reach the sitting motor milestone, and have normal IQ. Interestingly, it has been shown that in this population, despite having no method of self-generated exploration of their environment, these children often show similar spatial cognition and superior spatial language in comparison to chronologically age matched typically developing children (Riviere & Lecuyer, 2002, 2003). Riviere and Lecuyer (2003) attribute this good visuospatial ability to having better inhibition ability in comparison to typically developing peers when tested using an A-not-B task, i.e. they are able to inhibit the natural response to return to location A during searching, and instead search at the correct location B. Oudgenoeg-Paz and Riviere (2014) hypothesise that this superior spatial ability is due to these children's superior language. As children with SMA are unable to manipulate their environment themselves, they become

skilled in using complex spatial language in order to get their caregivers to manipulate it for them. However, the authors note that readers should be cautious about drawing conclusions about the relationship between motor and spatial development in SMA children, as it has been shown that there are significant differences in the mechanisms underlying brain and cognitive development in atypical populations compared to typically developing peers (Karmiloff-Smith et al., 1998).

Another example of the relation between motor abilities and visuospatial cognition in an atypical group can been seen in individuals with ASD and in individuals with Developmental Disability (DD). ASD is a neurodevelopmental disorder, characterised by difficulties in social communication and interaction, repetitive behaviour and restricted interests (American Psychiatric Association, 2013). Hellendoorn et al. (2015) investigated the association between fine motor abilities, visuospatial cognition and language ability, all assessed using The Mullen Scales of Early Learning (Mullen, 1995). They also investigated exploration of objects assessed using an observation coding scheme, which was developed for the study, in a group of individuals with ASD (mean age: 27.10-months) and a group with DD's (mean age: 17.99-months). They discovered that fine motor skills were related to visuospatial cognition and language ability in both the ASD group and the DD group. The findings from this study suggest that there is a strong association between fine motor ability and visuospatial ability in ASD and DD, as there is in typical development.

Cardillo, Erbi and Mammarella (2020) investigated spatial and motor abilities in 36 children with ASD and 39 typically developing children aged 8-16-years. Participants were assessed on tasks of spatial perspective taking, visuospatial working memory, fine and gross motor skills, visuo-constructive abilities, visual imagery and mental rotation. It was found that there was a predictive effect of fine motor skills on perspective taking in both groups, but that gross motor ability was only predictive in the TD group. However, these authors only

used a manual dexterity task to measure fine motor ability, and a balance task to measure gross motor ability. The perspective taking task also asked the participants to “imagine that they are at the flower and facing the tree”, etc. This use of language may have also affected performance in the ASD group, as it is known that individuals with ASD often show difficulties with tasks involving imagination (American Psychiatric Association, DSM-5, 2013). The possible effect of this use of language was not investigated in this study, and so it is not possible to know whether the use of language may have influenced the results.

Salowitz, Eccarius, Carson, Schohl and Stevens (2013) investigated visuo-spatial guidance of movement during gesture imitation and mirror drawing in 13 children with ASD and 14 typically developing control children aged 11-16 years. It was found that children with ASD were less accurate than controls in imitation of movement and hand orientation. The authors suggest that visuospatial information processing deficits may contribute to motor co-ordination deficits in autism. This was based on the finding that significant errors on the mirror drawing task were correlated with hand orientation and hand shape in imitation. However, in this study neither fine nor gross motor skills were measured directly, so the reader should be cautious of making any conclusions regarding direct associations between motor abilities and spatial abilities from this data.

Belmonti, Cioni and Berthoz (2015) investigated anticipatory control and spatial cognition in locomotion in 15 individuals with Cerebral Palsy (CP) aged 5-23 years and 26 typically developing individuals aged 4-35 years. It was found that individuals with CP who did not show spatial perceptual disorders also had more success on gross motor tasks. However, the authors do not provide much detail on the methods of this task or how gross motor ability was measured as this finding was part of a larger study.

In summary, the association between small scale spatial skills and motor abilities has been found not only in typically developing populations, but also in populations with

neurodevelopmental disorders, such as ASD, DD and CP. This lends evidence to the potential association between spatial skills and motor abilities in other neurodevelopmental disorders such as WS and DS. The studies above have their own limitations, for example not outlining how fine and/or gross motor ability were assessed (Belmonti et al., 2015; Salowitz et al, 2013) or only one kind of skill to represent fine or gross motor skills as a whole (Cardillo et al., 2020). The current study will use a range of standardised measures to assess motor abilities alongside two different kinds of small scale spatial skills.

3.2. Aims

The aim of the current study was to investigate if individuals with WS, individuals with DS and typically developing participants would perform differently on two small scale spatial tasks. Small-scale spatial ability can be defined as the ability to mentally represent and transform two- and three-dimensional images that can typically be seen from a single vantage point (Wang and Carr, 2014). Each task (block construction and mental rotation) had one condition with a clear motor element, and one condition with the motor element removed as much as possible. The two versions of each task were used to better investigate the potential association between motor abilities and small-scale spatial skills in populations with WS, DS and in typically developing children. One version of the block construction task was designed as a typical block construction task, i.e. the participants use the plastic 3D blocks to make the patterns themselves. The other version of the task was designed to partially remove the motor element of the task by having the participant tell the experimenter which block would go where, and having the experimenter move them. Similarly, for the mental rotation task, one version of the task was designed as a typical mental rotation task where participants were asked to mentally rotate pictures of chickens and choose the matching chicken by pressing a button on a computer. The other condition was designed the same way, but participants were asked to mentally rotate pictures of jugs instead. The second aim was to explore the potential

association between motor ability observed in Study 1 (Chapter 2), and the small scale spatial skills of the samples.

3.3. Hypotheses

It was hypothesised that the WS group would perform below all other groups on all small scale spatial tasks. It was further hypothesised that the WS and DS groups would perform better on the non-motor tasks as they have poor motor ability.

On the mental rotation tasks, it was hypothesised that the WS and DS groups would be less accurate than the TD groups, and that all groups would show decreased accuracy with increases in rotation. It was further hypothesised that, with increases in rotation, participants from all groups would show longer response times.

Finally, it was hypothesised that there would be a correlation between motor ability and small-scale spatial skills in all groups - i.e. those who have better motor skills will perform better on spatial tasks.

3.4. Method

3.4.1. Participants

The sample of this study are the same TD and DS participants who took part in Chapter 2, along with a subsample of participants with WS from Chapter 2. The sample includes a sample of 20 participants with WS (mean age: 27.1-years; 16 with a positive FISH test), 18 participants with DS (mean age: 24.2-years), 20 typically developing 4-5-year-olds (mean age: 4.6-years), and 20 typically developing 6-7-year-olds (mean age:6.6-years). There are fewer WS participants in this chapter than in Chapter 2 as data was collected at two different time points and, therefore, some of the participants included in Chapter 2 did not complete the block construction or mental rotation tasks. This was due to time demands on the researcher.

3.4.2. Design and procedure

Block Design

Participants were given a manual and non-manual version of a block design task. The manual task was modelled after the WISC-4 Block Design task (Wechsler, 2012), where participants were given a 2D image, and asked to construct a 3D model using identical plastic blocks, with six faces, two of which were solid red, two were solid white and two were half red and half white, split by a diagonal line down the middle. The patterns increased in difficulty from two patterns made using two blocks, nine patterns made from four blocks, and finally two patterns made from nine blocks. The discontinue rule used in the WISC-4 (Wechsler, 2012) Block Design was employed (i.e. discontinue after three consecutive scores of 0) for both the manual and non-manual conditions. Unlike on the WISC-4 Block Design, all participants started at item one, and the first two items had two trials, in order to make sure that participants understood the instructions. There was also a time limit in which the participants must complete the task (Table 10).

Participants were also given a non-manual block construction task where the experimenter manipulated the blocks for the participant. Participants were shown a numbered grid and asked which of the block faces should go in each segment of the grid to complete the pattern (Image 1). The order in which participants completed each condition was counterbalanced. The 2D designs used for the two conditions were mirror images of each other (set A and B), and the order that the participants received each set was counterbalanced (i.e. participant 1 would complete the Manual task with set A, then the Non-Manual task set B, participant 2 would complete the Non-Manual task set A, then the Manual task set B, and so on). This controlled for the possibility that one set of images would be easier than the other, and helped control for practice effects. Before testing began, the experimenter asked the participants to name each letter in turn and to name each number in turn. As previously

mentioned, the first two trials of each condition were practice trials, which enabled the experimenter to make sure that all participants had fully understood the instructions. Participants were asked whether they understood the instructions and were also asked to explain what they had to do to the experimenter. Participants were also encouraged to ask any questions if they did not understand.

Table 10. Time limit for each trial on both the manual and non-manual block construction tasks.

Design	**Time Limit**
1	30 sec
2	30 sec
3	45 sec
4	45 sec
5	45 sec
6	45 sec
7	1 min 15 sec
8	1 min 15 sec
9	1 min 15 sec
10	1 min 15 sec
11	2 min
12	2 min
13	2 min

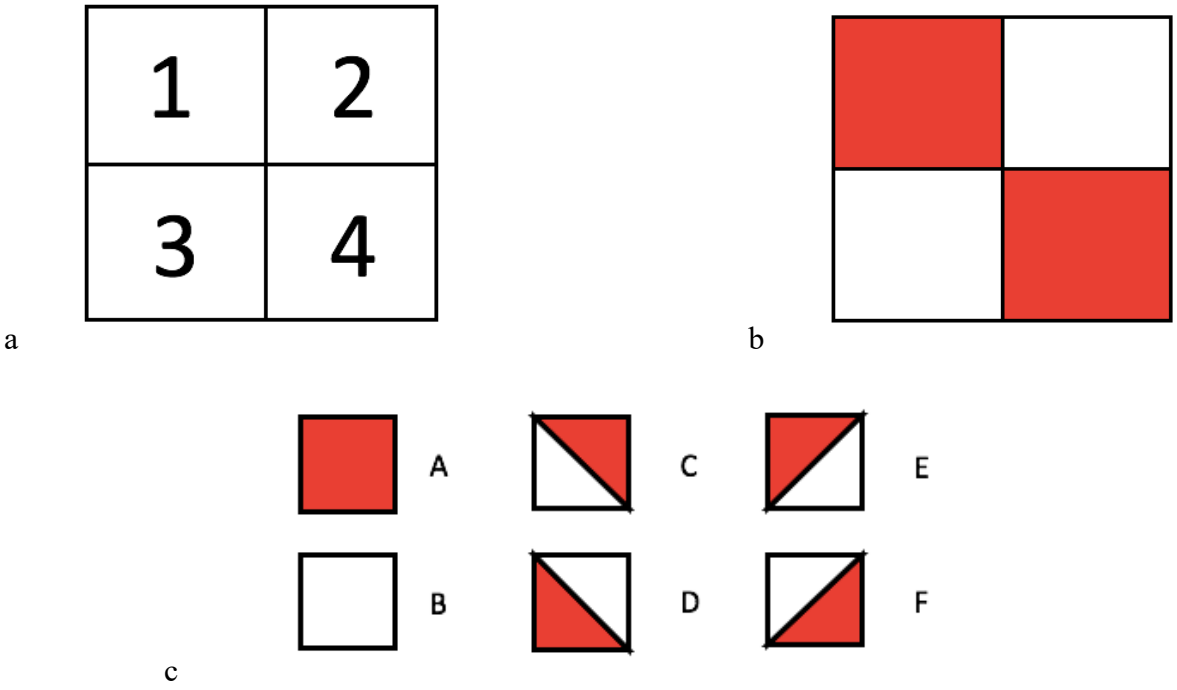

Image 1. a) example of the 4-square grid in which participants were asked to create the patterns; b) example pattern 4B used alternatively for the manual and non-manual block design task; c) labelled block faces shown to participants for the non-manual block design task.

Mental Rotation

Participants were asked to view two images of either the chicken or the jug at the bottom of the screen, and one chicken or jug at the top of the screen at varying degrees of rotation from upright. The images were presented on a 13" laptop computer. The participants were asked to choose which of the two images at the bottom of the screen matched the one at the top. The incorrect image at the bottom of the screen was a mirror image of the correct image. The participants indicated their response by pressing either the 'A' key, if they believed the correct response was the image on the left, or the 'L' key if they believed the correct response was on the right. These keys were made easier to see on the keyboard by the use of bright stickers, and the experimenter made sure that the participants understood which button to press before testing began in the practice trials.

The mental rotation task consisted of four practice trials, which were there to make sure that the participant understood the instructions of the task, followed by 20 experimental trials

(4 x 0º trails, 4 x 30º trials, 4 x 60º trials, 4 x 90º trials, and 4 x 120º trials). This study used degrees of rotation up to 120º as trials that require more rotations than these have been shown to produce chance performance in WS (Broadbent, Farran & Tolmie, 2014; Farran et al., 2001; Stinton, Farran & Courbois, 2008). This allowed the researcher to better capture true mental rotation performance in the groups. For half the trials the correct response was on the left, for half it was on the right. There were two versions (A and B) of each condition (tool and animal), and the order that the participants completed the conditions were counterbalanced, as was task version.

The image of a jug was chosen for the active 'motor' element of the task, and the chicken chosen for the 'non-motor' element of the task because, as shown by Vingerhoets et al, (2002) that images of 'tools' (i.e. objects that people use for a functional purpose) activate the motor cortex of the brain more strongly than images of 'non-tools' (e.g. things that you would not imagine manipulating with your hands, for example, animals). Further, Dekker et al. (2011) found that there was an increased dorsal stream involvement for the images of tools over animals which were more likely to be processed by the ventral stream. Therefore, for this study, the images of the jug and chicken were chosen as they both have the same prominent axis (vertical), and both images were scaled to the same size, and presented in the same positions on the screen before presentation

3.5. Results

3.5.1. Analysis and parametric assumptions

Participants completed two block construction and two mental rotation tasks, along with the motor assessment outlined in Chapter 2. As mentioned in Chapter 2, the motor data were normally distributed for the majority of variables (Kolomorov-Smirnov, $p \geq .05$), and there were no outliers effecting the means of the data when the 5% trimmed mean was looked at. For the block construction tasks, it was also found that for the majority of variables data

met assumptions of normality (Kolomorov-Smirnov, $p \geq .05$), and there were no outliers effecting the means of the data when the 5% trimmed mean was looked at. Therefore, parametric tests were conducted on both the motor and block construction data. Specifically, participant performance on the manual and non-manual block construction tasks was investigated using mixed ANOVA in which pairwise group comparisons were examined using Tukey pairwise comparison tests.

In contrast, the mental rotation accuracy and the mental rotation response time data were not normally distributed for over half the variables (Kolomorov-Smirnov, $p \leq .05$), however as there is no non-parametric alternative to a mixed ANOVA, parametric tests are reported. All main effects and interactions were then explored non-parametrically using Wilcoxon Signed Ranks tests, Mann-Whitney tests, Friedman tests and Kruskal-Wallis tests as appropriate, and only reported when results were different from parametric equivalents.

For correlational analyses which involved the mental rotation data, Spearman correlations were used to investigate bivariate correlations. Partial correlations were also required, which controlled for Chronological Age. As it is not possible to conduct partial correlations non-parametrically, residuals were created using linear regression to control for the effect of age. Spearman correlations could then be conducted using these residuals. Power analyses can be found in Appendix B.

3.5.2. Manual vs non-manual block construction

Table 11. The mean (SD) performance of the four groups (WS, DS, TD4-5 and TD6-7) on manual and non-manual block construction

	WS	DS	TD4-5	TD6-7
Manual block construction	15 (11.03)	19.78 (13.46)	22.05 (11.56)	35.25 (7.25)
Non-manual block construction	7.69 (7.99)	15.06 (13.20)	13.65 (11.79)	31.10 (12.45)

A 2-factor mixed ANOVA was conducted to examine the differences between the manual and non-manual conditions. The within participant factor was condition (2 levels: manual and non-manual), and the between participant factor was group (4 levels: WS, DS, TD4-5 and TD6-7). The dependent variable was accuracy. Results indicate a main effect of group ($F(1, 74)=17.53$, $p<.001$, $\eta^2=.415$), with post-hoc Tukey tests showing that both the WS and DS groups were performing at a similar level to the TD4-5 group ($p>.05$ for both), and below the TD6-7 group ($p<.05$ for both). There were no significantly differences between the TD4-5 and TD6-7 group ($p>.05$). There was also a main effect of task ($F(1, 74)=26.68$, $p<.001$, $\eta^2=.265$) due to higher scores on the manual condition than the non-manual condition, however there was no interaction between task and group ($F<1$).

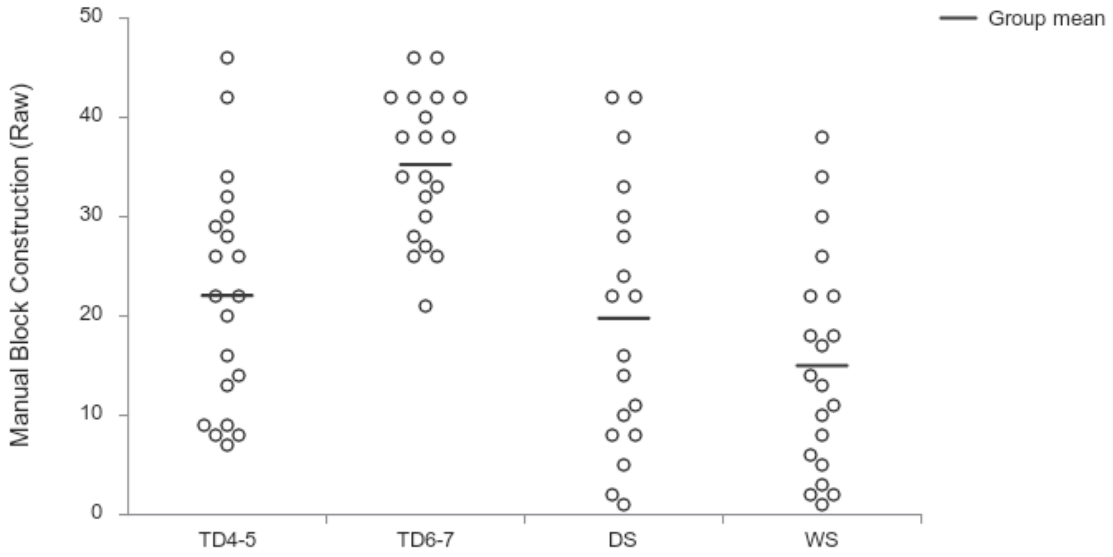

Figure 5. Dot plots to show the mean and spread of scores on the Manual Block Construction task for the TD4-5, TD6-7, DS and WS groups.

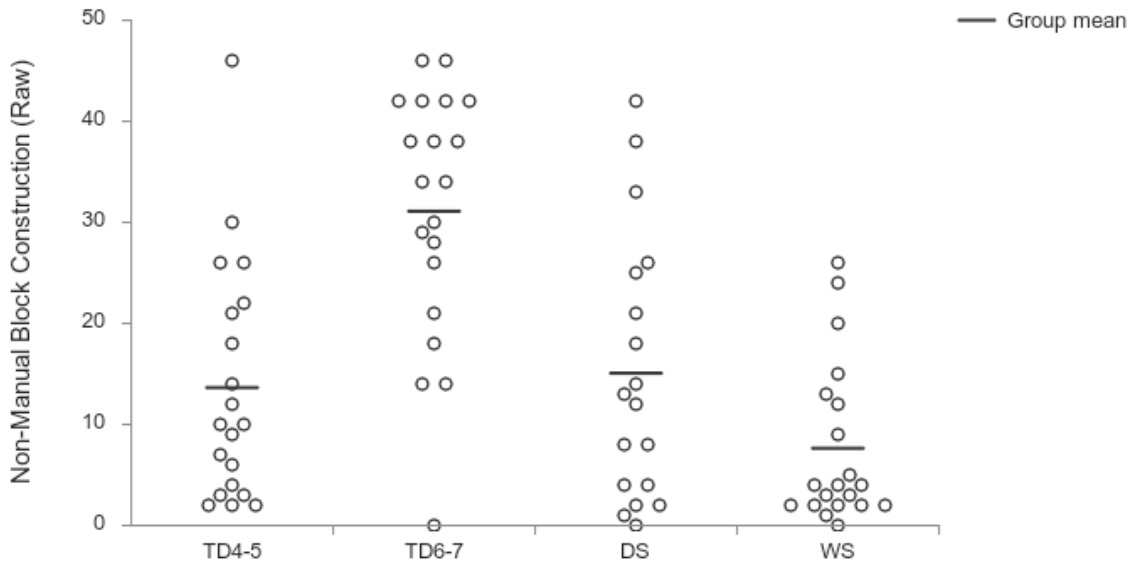

Figure 6. Dot plots to show the mean and spread of scores on the Non-Manual Block Construction task for the TD4-5, TD6-7, DS and WS groups.

3.5.3. Correlations between block construction and motor ability

Correlations were carried out between total score on the two block construction tasks and total raw motor ability for the four groups (WS, DS TD4-5 and TD6-7). As this constitutes two correlations per group, a Bonferroni corrected critical alpha of $p \leq .025$ was used. For transparency, both bivariate correlations and partial correlations are displayed below in Tables 11 and 12. Results from the both the WS and DS groups showed that, after controlling for chronological age, there was a significant positive correlation between motor ability and manual block construction performance only. In typically developing children, there was no significant correlation between motor ability and either manual or non-manual block construction.

Table 12. Correlations between raw total motor and manual and non-manual block construction in the WS, DS and TD groups. Critical alpha: $p \leq .025$

	TD4-5	TD6-7	WS	DS
Manual BC X Motor	r=.482, *p*=.032	r=435, *p*=.055	**r=.555, *p*=.011**	**r=.686, *p*=.002**
Non-Manual BC X Motor	r=.476, *p*=.034	r=.212, *p*=.369	r=.437, *p*=.054	r=.521, *p*=.026

Table 13. Correlations (chronological age partialled out) between raw total motor and manual and non-manual block construction in the WS, DS and TD groups. Critical alpha: $p \leq .025$

	TD4-5	TD6-7	WS	DS
Manual BC X Motor	r=,232., *p*=.339	r=.227, *p*=.250	**r=.539, *p*=.017**	**r=.686, *p*=.002**
Non-Manual BC X Motor	r=.339, *p*=156	r=.078, *p*=.749	r=.448, *p*=.054	r=.523, *p*=.031

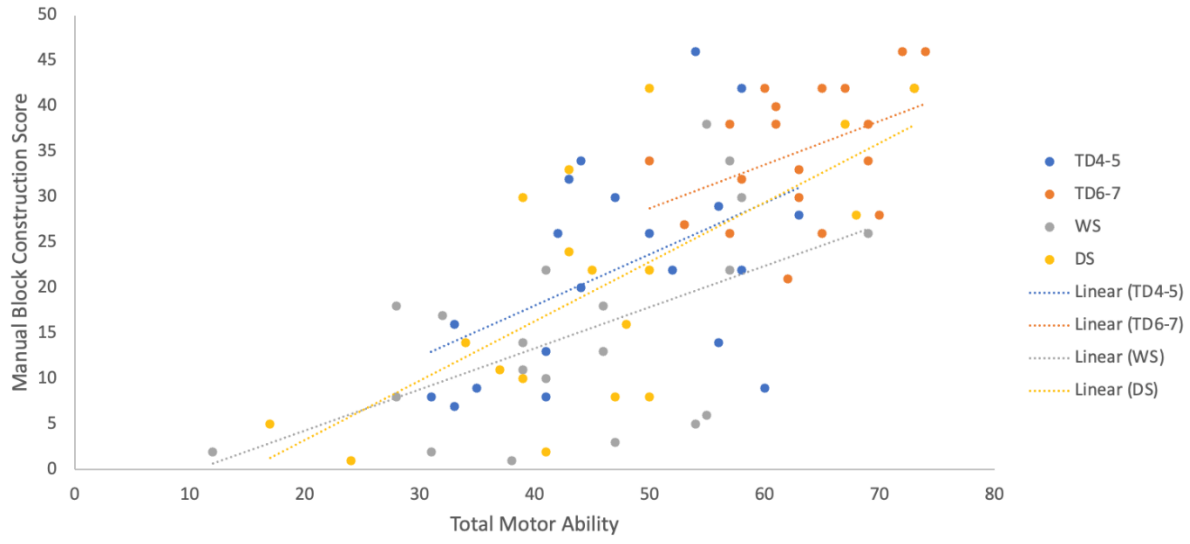

Figure 7. Scatter plot to show the correlations between manual block construction and total motor ability for the TD4-5, TD6-7, WS and DS groups.

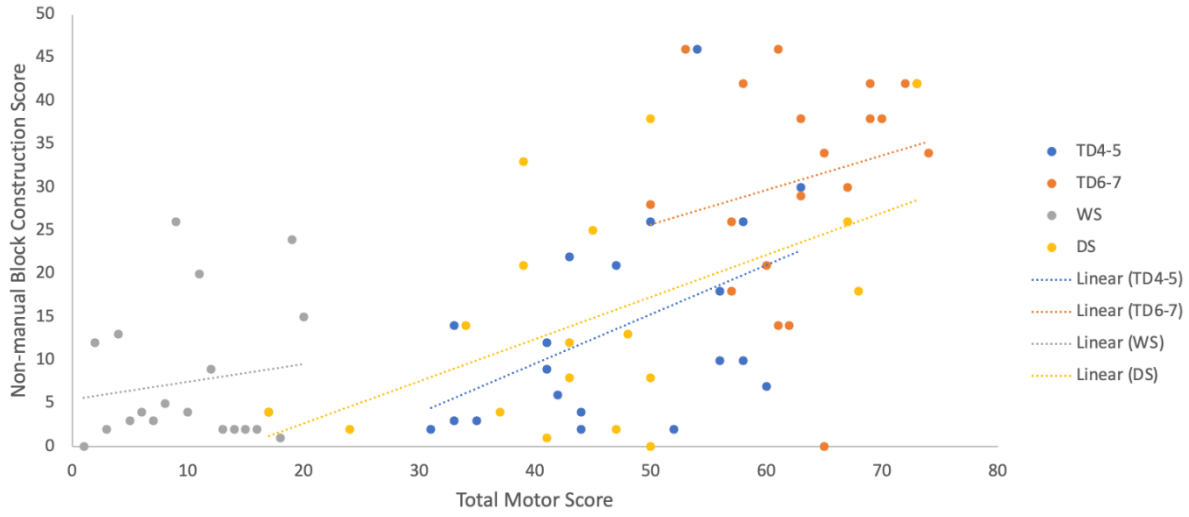

Figure 8. Scatter plot to show the correlations between non-manual block construction and total motor ability for the TD4-5, TD6-7, WS and DS groups.

3.5.4. Tool vs animal mental rotation accuracy

Table 14. The mean (SD) accuracy score of the four groups (WS, DS, TD4-5 and TD6-7) on manual and non-manual mental rotation

	WS	DS	TD4-5	TD6-7
Tool mental rotation	65.62 (15.64)	71.11 (18.91)	84.70 (16.49)	90.80 (13.46)
Animal mental rotation	70.41 (15.58)	83.61 (20.35)	81.60 (17.66)	90.25 (14.24)

Data were collapsed across equivalent anti-clockwise and clockwise trials (e.g. performance accuracy for all 30 and -30-degree rotation trials was summed together). The total number of trials for each degree of rotation was the same (e.g. 4 trials at 0º, 4 trials at 30º, 4 trials at 60º, 4 trials at 90º, and 4 trials at 180º), and the percent correct was calculated. One sample t-tests were also conducted for each degree, for each condition (tool and animal) against chance performance (50% accuracy) and ceiling performance (100% accuracy).

Results showed significant above chance performance for all typically developing participants on all degrees of rotation for the tool condition. However, results indicate that the WS group were performing at chance on the 30º: t(19)=1.000, p=.330, Cohen's d=.224, 90º :

t(19)=1.189, *p*=.250, Cohen's *d*=.255, and 120º: t(19)=-.547, *p*=.591, Cohen's *d*=-.122, trials on the tool condition (and above chance and below ceiling on the 0º and 60º trials; p<.05 for both). Therefore, the WS group have been removed from the analysis of the Tool mental rotation task, as they were scoring at chance on the majority of the degrees of rotation, and therefore, any analysis of their data is meaningless. The DS group performed at chance on the 90º condition, t(17)1.072, *p*=.299, Cohen's *d*=.253, and above chance and below ceiling on all other conditions (p<.05 for all). The TD 6-7 year olds scored at ceiling on the 0º, t(19)=-1.80, *p*=.0.88, Cohen's *d*=-.402, and 30º, t(19)=-1.93, *p*=.069, Cohen's *d*=-.431, rotations and above chance and below ceiling on all other conditions (*p*<.05 for all). The TD 4–5-year-olds scored above chance and below ceiling for all conditions (*p*<.05 for all).

Results indicate that the WS group and the DS group performed above chance and below ceiling on all degrees of rotation on the animal condition (*p*>.05 for all). Again, the typically developing groups both performed above chance on all degrees of rotation (*p*<.05 for all). The TD4-5 group scored at ceiling on the 0º trial, t(19)=-2.01, *p*=.059, Cohen's *d*=-.450, and the TD6-7 group scored at ceiling on the 0º, t(19)=-1.93, *p*=.069, Cohen's *d*=-.431, and 120º, t(19)=-2.04, *p*=.055, Cohen's *d*=,-457 trials.

Three factor mixed ANOVAs were conducted to examine the differences between the tool and animal conditions across groups. There were two within participant factors, which were degrees of rotation (5 levels; 0, 30, 60, 90 and 120 degrees), and condition (2 levels: tool and animal), and one between participant factor, which was group (3 levels: DS, TD4-5 and TD6-7 {as the WS group have been removed from analysis due to scoring at chance on the Tool condition}).

Results indicate that there was no main effect of condition (F(1,55)=3.250, *p*=.077, η^2=.056). There was a significant main effect of degree of rotation, indicating reduced accuracy as rotation increased F(1, 55) = 2.662, *p*=.034, η^2 =.046. There was a main

effect of group (F(2, 55)= 3.532, p=.036, η^2=.114). Post-hoc Tukey tests indicate that the DS group were significantly different from the TD6-7 group (p=.034), but not significantly different from the TD4-5 group (p=.703). There was no significant difference between the two TD groups (p>.05).

There was an interaction between degree of rotation and group (F(1, 55)= 2.171, p=.031, η^2=.073). Observation of Figure 4 dictated that this was best explored further by investigating the effect of group at each of the degrees of rotation (0^o, 30^o, 60^o, 90^o, 120^o). It was found that the DS group were performing to the same level as the TD4-5 group on all degrees of rotation (p>.05). The DS group were performing below the TD6-7 group on the 30^o (p=.030), the 90^o, (p=.043) and 120^0 (p=.030) degree rotations (p<.05 for the 0^o and 60^o). The TD4-5 group were performing to the same level as the TD6-7 group on all degrees of rotation (p>.05) with the exception of 120^0, where they were significantly less accurate (p=.014).

There was also an interaction between degree of rotation and condition (F(1, 55)= 5.015, p<.001, η^2=.084). However, when this was explored further, it was shown that there were no significant difference between conditions (p>.05 for all). There was no interaction between condition and group (F(1, 55)= 2.104, p=.132, η^2=.071) or three-way interaction between condition, degree of rotation and group (F(1, 55) = 1.579, p=.132, η^2=.054).

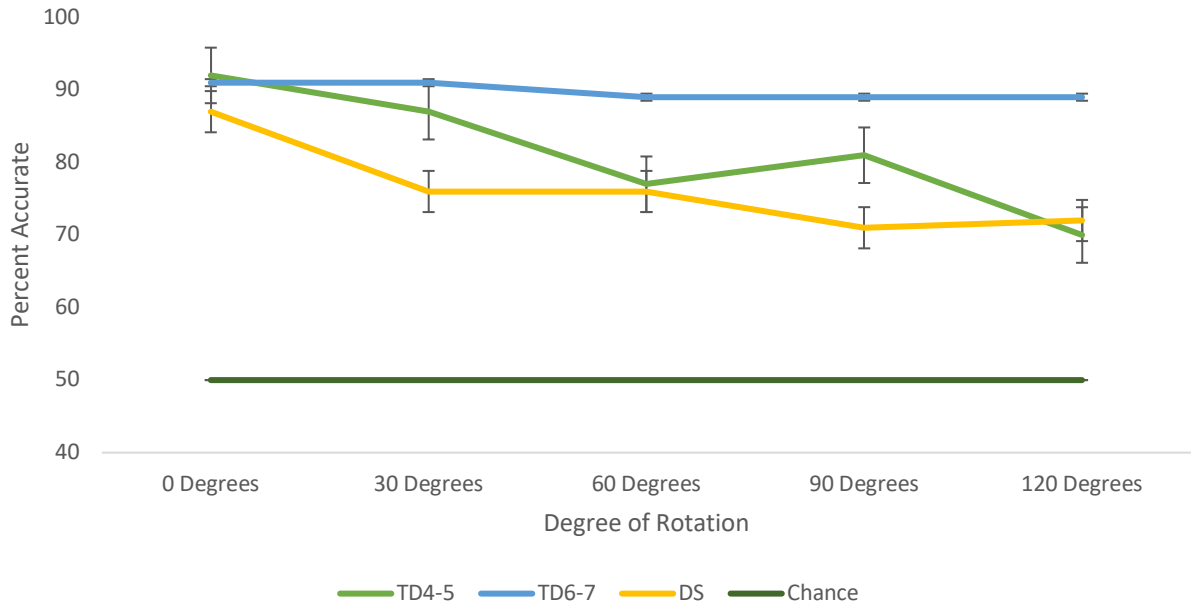

Figure 9. Mean percent accurate on each degree, for both conditions combined, for the TD4-5, TD6-7 and DS groups. Error bars represent standard error.

As the WS group were performing above chance on the animal condition of the mental rotation task, a separate analysis was conducted on the animal condition data only. To do this, a two Factor ANOVA was conducted. The within participant factor was degrees of rotation (5 levels; 0º, 30º, 60º, 90º and 120º degrees), and the between participant factor, which was group (4 levels: WS, DS, TD4-5 and TD6-7).

Results indicate that there was a main effect of group ($F(1, 74)=5.596$, $p=.002$, $\eta^2=.185$), with post-hoc Tukey tests showing that this was due to the WS group performing significantly below the TD4-5 group and TD6-7 group on the 0º, 30º and 60º rotations ($p<.05$ for both), and below the TD6-7 group on the 120º rotation ($p=.006$). However, non-parametric Mann-Whitney U tests indicate that the WS group are also performing significantly below the TD6-7 group on the 90º rotation ($p=.012$). The WS group were not significantly different from the DS group on any degree of rotation ($p>.05$ for all). However, non-parametric Mann-Whitney U tests indicate that the WS group are performing significantly below the DS group on the 0º ($p=.044$) and 60º ($p=.022$) trials. The DS group

were not significantly different from any other group on any degree of rotation (p>.05 for all).

There was also a main effect of degree of rotation (F(1, 74)=8.338, p=.005, η^2=.101), indicating that participants were less accurate with increases in rotation. There was an interaction between degree of rotation and group (F(1, 74)=2.745, p=.049, η^2=.100) (reported as a linear effect), suggesting that the effect of increases in rotation was stronger for some groups than others. When this was investigated further, it was found that this was driven by the WS group, as this association between degree of rotation and group was not present when the WS group were removed from the analysis (p=.079).

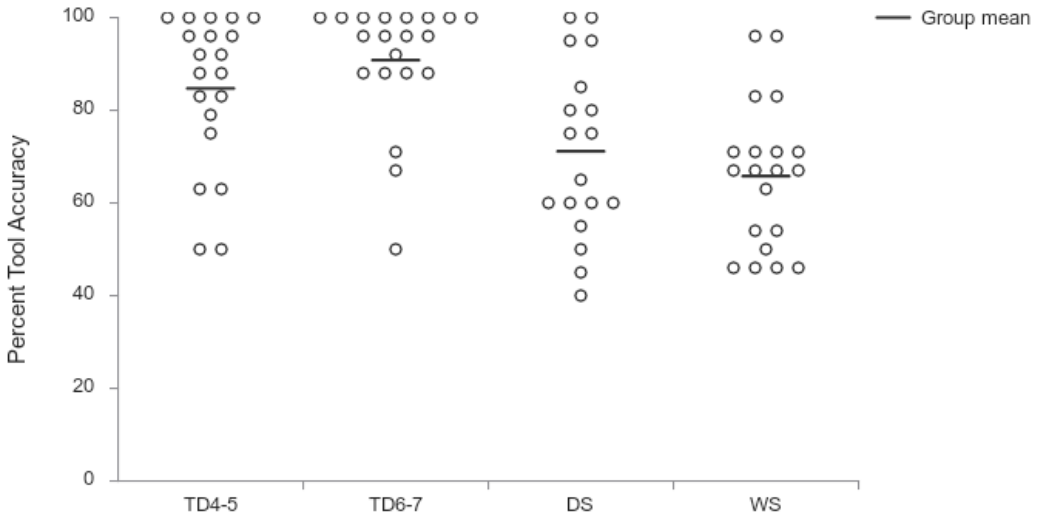

Figure 10. Dot plots to show the spread of scores on the Tool mental rotation task for the TD4-5, TD6-7, DS and WS groups

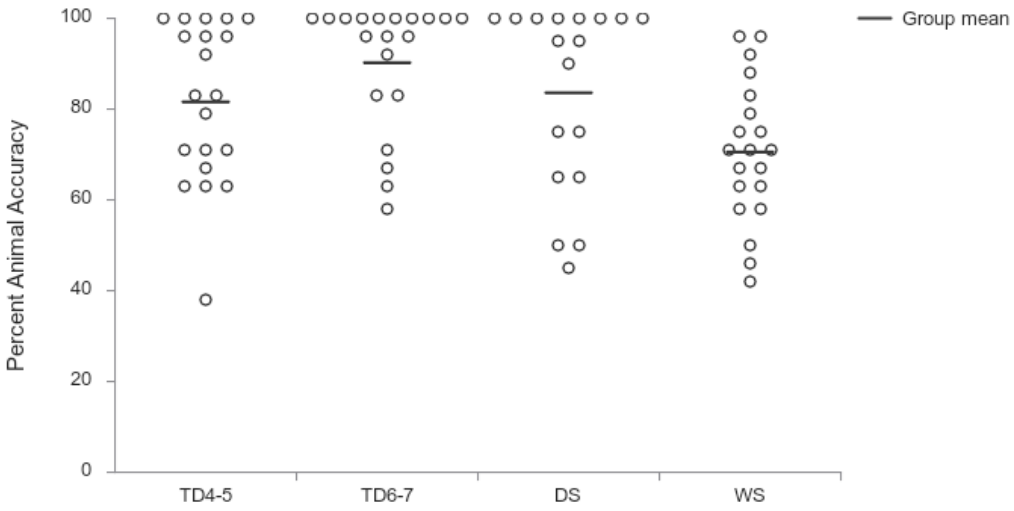

Figure 11. Dot plots to show the spread of scores on the Animal mental rotation task for the TD4-5, TD6-7, DS and WS groups

3.5.5. Tool vs animal mental rotation response times

Response times of correct responses were examined. To examine differences in mean response times for each degree of rotation, for each condition, for each group, a three Factor mixed ANOVA was conducted. There were two within participant factors, which were degrees of rotation (5 levels; 0º, 30º, 60º, 90º and 120º degrees), and condition (2 levels: manual and non-manual), and one between participant factor, which was group (3 levels: DS, TD4-5 and TD6-7 {again the WS group were excluded due to them performing at chance on the Tool condition}).

Results indicate that there was no main effect of condition ($F(1, 55)=.622$, $p=.434$, $\eta^2=.011$). There was a main effect of group ($F(1, 55)= 7.870$ $p<.001$, $\eta^2=.223$). Post-hoc Tukey tests indicate that the DS group were showing similar response times to the TD4-5 group ($p=.60$) and that they were slower than the TD6-7 group ($p<.001$).

As with the accuracy data, there was an effect of degree of rotation, indicating that the groups were slower with increases in rotation ($F(1,55) =3.405$, $p=.010$, $\eta^2=.058$). Again, consistent with the accuracy data, there was an interaction between group and degrees of

rotation ($F(1, 55)=2.800$, $p=.006$, $\eta^2=.092$). When this was investigated further it was found that degree of rotation did not have a significant effect on response time in the TD4-5 group ($p=.087$) or the DS group ($p=.052$). Degree of rotation did, however, have an effect on response time in the TD6-7 group ($p=.002$). However, this was not supported by Friedman tests, which showed that there was an effect of degree for the DS and TD6-7 groups ($p<.05$ for all), though it did support that there was no effect of degree of rotation for the TD4-5 group ($p=.144$). There was no interaction between condition and group ($F(1, 55)=3.021$, $p=.057$, $\eta^2=.099$), and was no three way interaction between group, degree of rotation and condition ($F(1, 55)=1.561$, $p=.138$, $\eta^2=.054$).

As the WS group were above chance on the Animal condition of the mental rotation task, but not the Tool condition (for the majority of degrees of rotation), analyses were also conducted separately for the Animal condition to examine group differences in response time. To do this, a two factor ANOVA was conducted. The within participant factor was degrees of rotation (5 levels; 0^o, 30^o, 60^o, 90^o and 120^o degrees), and the between participant factor, which was group (4 levels: WS, DS, TD4-5 and TD6-7).

The results that there was a main effect of group ($F(1, 74)=5.153$, $p=.003$, $\eta^2=.175$), with post-hoc Tukey tests showing that this was due to the DS group showing longer response times than the TD6-7 group ($p=.002$). There were no other significant differences between the groups ($p>.05$ for all). However, non-parametric Mann-Whitney U tests indicate, that while it is the case that the DS group are showing longer response times than the TD6-7 group, there are also significant differences between the DS and TD4-5 group on the 30^o ($p=.024$) and 90^o ($p=.044$) rotations, with the DS group showing longer response times than the TD4-5 group. There were also differences found on Mann-Whitney U tests between TD4-5 and TD6-7 groups on the 0^o ($p=.011$), 30^o ($p=.026$), 90^o ($p=.033$) and 120^o ($p=.013$) rotations, with the TD4-5 group showing longer response times than the TD6-7 group.

There was also a linier main effect of degree of rotation (F(1, 74)=8.408, p=.005, η^2=.103) (reported as a linier effect), indicating that individuals were showing longer response times with increases in rotation. However, there was no interaction between degree of rotation and group (F(1, 74)=2.062, p=.113, η^2=.078), indicating that this was true for all groups.

3.5.6. Correlations between mental rotation and motor abilities

Non-parametric correlations were carried out to investigate the relationship between motor ability and mental rotation ability in the four groups. Two correlations were carried out per group and thus the critical alpha is p≤.025. For transparency, both bivariate correlations and partial correlations are displayed below in Tables 13 and 14. Spearman's correlations were carried out between mental rotation accuracy and the residual for motor performance with age partialled. As the WS group were performing at chance on the majority of degrees on the Tool condition, correlations between Tool mental rotation and total motor ability for the WS group have not been reported. As demonstrated in Tables 13 and 14, there were no significant associations for the TD4-5 or TD6-7. However, there was a significant correlation between raw total motor score and Animal mental rotation in the WS group, and raw total motor score and Tool mental rotation in the DS group (when chronological age was taken into account).

Table 15. Spearman correlations between raw total motor score and the accuracy score on the tool and animal mental rotation tasks for the WS, DS, TD4-5 and TD6-7 groups. Critical alpha: p≤.025

	TD4-5	TD6-7	WS	DS
Tool X Motor	r=447, p=048	R=-.114, p=546	-	r=468, p=.050
Animal X Motor	r=371, p=107	r=084, p=725	**r=617, *p*=004**	r=193, p=442

Table 16. Spearman partial correlations (chronological age partialled out) between raw total motor score and the accuracy score on the tool and animal mental rotation tasks for the WS, DS, TD4-5 and TD6-7 groups. Critical alpha: $p \leq .025$

	TD4-5	TD6-7	WS	DS
Tool X Motor	R=.145, *p*=.555	r=-.236, *p*=.330	-	**r=.570, *p*=.017**
Animal X Motor	R=.179, *p*=464	R=.008, *p*=975	**r=612, *p*=.005**	r=.101, *p*=.700

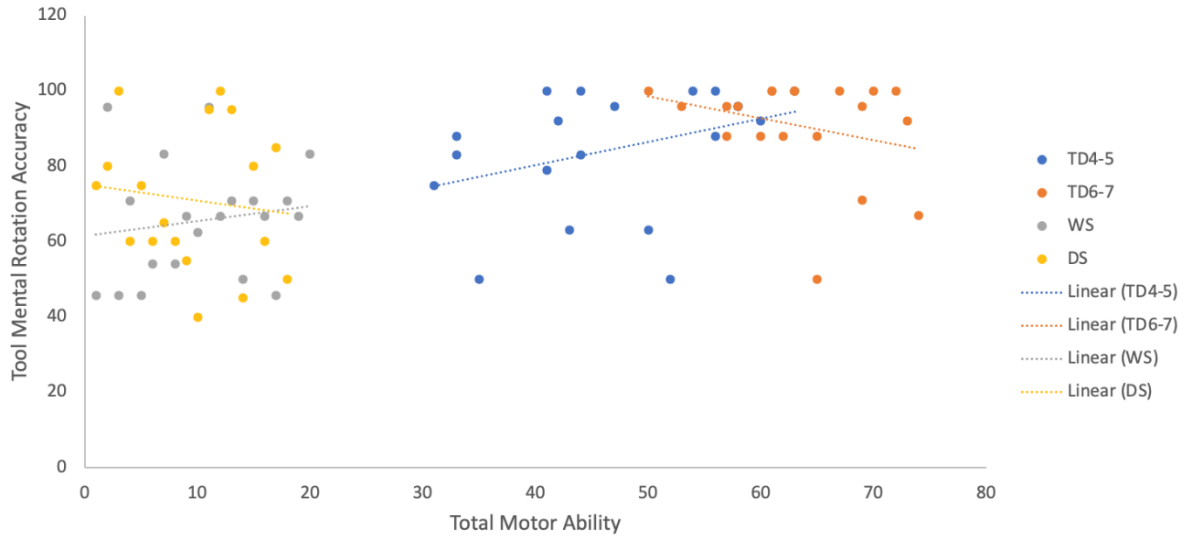

Figure 12. Scatter plot to show the correlations between tool mental rotation accuracy and total motor ability for the TD4-5, TD6-7, WS and DS groups.

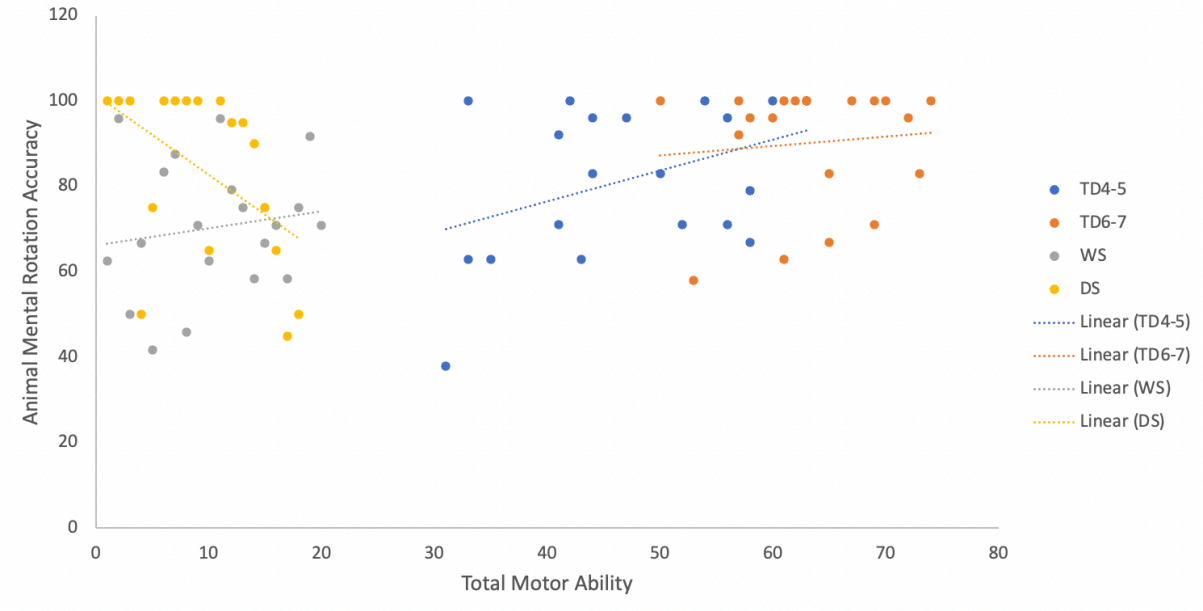

Figure 13. Scatter plot to show the correlations between animal mental rotation accuracy and total motor ability for the TD4-5, TD6-7, WS and DS groups.

3.6. Discussion

The aim of this study was to investigate performance on small scale spatial tasks (block construction and mental rotation), both with and without a motor element, and how this relates to motor ability. All groups found the manual block construction task easier than the non-manual task, which goes against the hypothesis that the WS and DS group would find the non-manual task easier on account of the motor element of the task being minimal. This could be due to participants finding the manual block construction task more fun and engaging, so they were more motivated, which was certainly the case when participants were anecdotally asked which task they preferred. Both the WS and DS group performed at a TD4-5-year-old level, and below the TD6-7 group on block construction. This is an interesting finding, as you would expect the DS group to perform better than the WS group based on previous research showing that individuals with DS tend to perform better than individuals with WS on spatial tasks (Brock & Jarrold, 2005; Cardoso-Martins et al., 2009; Carretti et al., 2013; Edgin et al., 2010; Frenkel & Bourdin, 2009; Jarrold & Baddeley, 1997; Jarrold, Baddeley & Hewes, 1999; Lanfranchi et al., 2009; Lanfranchi et al., 2004; Lanfranchi et al.,

2009; Numminen et al., 2001; Pennington et al., 2003; Rowe et al., 2006; Visu-Petra et al., 2007; Vicari et al., 1995; Vicari et al., 2006). There may be a number of reasons for this lack of group difference, and it is likely that the individual groups' specific cognitive difficulties may be limiting block construction performance in different ways. This will be explored further below.

This chapter also focused on mental rotation abilities. As in the block construction task, there were two versions of the mental rotation task, one reduced-motor task (animal), and one with an added motor element (tool). The WS group were performing at chance level for the majority of the tool condition, which indicates that they were broadly not able to do this task. The DS group performed at a similar level to the TD4-5 group, but below the TD6-7 group. When data from the animal mental rotation condition was examined separately, it was found that the WS group were performing below the TD6-7 group on all degrees of rotation, and below the DS and TD4-5 group on some degrees of rotation, which was to be expected.

3.6.1. Block construction in WS

One possible explanation for the poor performance that was found on the block construction task in the WS group was the number of complex puzzles included in the task. Indeed, it has been found that individuals with WS show a severe deficit in solving complex puzzles (puzzle's that include blocks separated by horizontal or vertical lines) in comparison to simple puzzles (that only contain bocks of a solid colour), even on puzzles involving only four blocks (Hoffman, Landau & Pegani, 2003). It may, therefore, have been the case that, with less complex puzzles (i.e. ones involving more solid coloured blocks rather than those separated by a vertical line), the WS group may have obtained a higher score. However, this was not a focus of the current study, and was therefore, not investigated.

However, it should be noted that, in comparison to the TD groups, the WS group showed a large amount of heterogeneity of their scores. For example, while the group mean for the WS group on their overall manual block construction score was 15, some individuals were achieving scores of up to 38, whereas others were achieving as low as a score of 1. Similarly, in the non-manual block construction task, the mean score was 7.65, however some participants were achieving scores of up to 26 and as low as 0. This indicates that block construction abilities are more of a difficulty for some individuals with WS than others.

Problems seen on the block construction task in the WS group could also be due, in part, to these individuals potentially spending less time looking at the patterns before and during using the blocks. However, Hoffman et al. (2003) found that in a block construction task, although individuals with WS spent significantly less time looking at the picture to be constructed than did the TD control sample, this did not significantly correlate with lower performance, with the exception of the most complex puzzles. However, less time spent looking at the image may also place additional demands on working memory, another area that individuals with WS show poor performance (Jarrold, Baddeley & Hewes, 1998). Additionally, Hudson and Farran (2013) asked 17 adults with WS and a group of non-verbal mental age-matched children to complete a drawing task, where participants were asked to copy models of a houses. They found that the WS group made less frequent looks to the model compared to the TD group. Hudson and Farran (2013) posit that this may be due to individuals with WS having poor switching skills, and so were not able to switch their attention from the model to the copy, or due to participants giving more attention to the copy as opposed to the model. Again, as in Hoffman et al. (2003), this places additional demands on working memory (Menghini et al., 2010). This poor memory of the image in turn may have impacted on the participant's ability to successfully plan which pieces should go where to complete the pattern. Instead of problems with planning impacting performance in the WS

group, Hoffman et al. (2003) suggest instead that the children with WS showed a difficulty with faulty spatial representations; this group were less likely to choose the correct blocks to move, and were less likely to correct errors to the finished design than were typically developing children. For the more complex puzzles in Hoffman et al. (2003) study, the WS group did not differ from chance. This, alongside the observed low fixations to the model, suggest that the WS group were simply moving the pieces randomly, hoping to create the correct design by trial and error. From these findings, the authors conclude that lower fixations are not leading to lower accuracy, but rather that lower accuracy was leading to less fixation to the model; the individuals with WS found the task too difficult and so simply moved the blocks randomly to create a pattern, and so were not using the model as a guide. This may have also been the case in the current study, which is likely to have reduced accuracy in the WS group.

3.6.2. Block construction in DS

It was hypothesised that the DS group would perform better than the WS group on the block construction tasks based on previous research showing that individuals with DS usually perform significantly better than individuals with WS on spatial tasks (Bihrle, 1990; Edgin et al., 2010; Klein & Mervis, 1999; Vicari et al., 2004). However, it was found that the DS group performed to a similar level to the WS group on both the manual and non-manual conditions of the block construction task.

However, it should be noted that, in comparison to the TD groups, as in the WS group, the DS group showed a large amount of heterogeneity of their scores. For example, while the group mean for the DS group on their overall manual block construction score was 19.78, some individuals were achieving scores of up to 42, whereas others were achieving as low as a score of 1. Similarly, in the non-manual block construction task, the mean score was 15.06, however some participants were achieving scores of up to 42 and as low as 0. This

indicates that block construction abilities are more of a difficulty for some individuals with DS than others, and some individuals were scoring as well as the older TD group on block construction.

One possible explanation for the poor performance on the block construction tasks in DS is language ability. As previously mentioned, individuals with DS have poor language abilities (e.g. Rohr & Burr, 1978; Silverstein et al., 1982), and the instructions for the task were given verbally to participants. It may have been that participants with DS did not fully understand what they were being asked to do (despite passing the practice trials), particularly when it came to the more complex patterns. Another aspect of language ability that may have affected performance in the DS group on this task is verbal memory (Carlesimo, Marotta & Vicari, 1997; Jarrold & Baddeley, 1997; Jarrold et al., 2000, 2002; Silverman, 2007; Vicari et al., 2004; Vicari, Bellucci & Carlesimo, 2005). Even if participants with DS were able to understand the instructions initially (as evidenced by them passing the practice trials), if they could not keep that information in mind while continuing the task, they may find the task more difficult and, therefore, make more mistakes. However, this was an observation made by the experimenter and therefore, not recorded for analysis.

While the results show that the WS and DS group performed similarly on the block construction tasks, it is likely that they struggled for different reasons. For individuals with WS, it is likely that they found the task difficult due to their classic deficit in visuospatial ability and faulty spatial representations leading to blocks being chosen and moved at random (Hoffman et al., 2003). In comparison, the DS group may have failed due to their classic difficulties with language ability (e.g. Rohr & Burr, 1978; Silverstein, et al., 1982) and verbal memory (Carlesimo et al., 1997; Jarrold & Baddeley, 1997; Jarrold et al., 2000/2002; Silverman, 2007; Vicari et al., 2004; Vicari et al., 2005). Further research into small-scale spatial skills in DS should focus on the potential role of language ability in understanding the

instructions of spatial tasks with a range of complexities.

3.6.3. Block construction and motor ability

As well as participants with WS and DS showing poor performance on both motor and block construction tasks, this study aimed to investigate whether poor motor ability was impacting small scale spatial ability, or vice-versa in the groups. A correlation was found between motor ability and the manual version of the block construction task in the WS and DS groups. The correlation between motor ability and manual block design is to be expected, as the manual block construction task involves the precise fine motor manipulation of small plastic blocks in order the create the patterns.

These findings do not support previous research from typically developing infants (e.g. Clearfield, 2004; Schwarzer et al., 2013), as there was no association between block construction and motor ability found for either of the TD groups. A relationship between motor ability and block construction was expected, as the block construction task requires small precise movements to complete the task. Therefore, we would expect both the manual and non-manual block construction task to be correlated with fine motor ability, as even when the participants are not moving the blocks themselves, we would expect them to imagine moving the blocks using fine motor movements. Indeed, it was observed (but not recorded) that many participants used their hands to mime moving the blocks in the non-manual condition. However, neither motor nor non-manual block construction showed this relationship with motor ability in the TD groups. Many of the older typically developing children found the tasks too easy, and so adding more complex puzzles for this group may increase variability and produce stronger correlations. While not the focus of this thesis, this suggests that this relationship between motor and spatial ability may not persist into later childhood in typical development, and it is possible that children are now moving towards using other, non-motor, strategies to solve spatial tasks.

3.6.4. Mental rotation in typical development

The typically developing groups were neither less accurate, nor did they show longer response times on either the tool or animal condition. However, the TD6-7-year-olds did reach ceiling accuracy on more degrees on the tool (0^o, 30^o, 90^o and 120^o degrees) condition than the animal condition (0^o and 120^o degrees). On both conditions (tool and animal), for accuracy and response time, there was a significant linear effect of rotation, which suggests that individuals get less accurate, and show longer response times with increases in rotation, which is in line with previous findings from adult (Shepard & Metzler, 1971) and child (Marmor, 1975) data. Mental rotation has been shown to be extremely sensitive to practice (Tarr & Pinker, 1989; Wexler, Kosslyn & Berthoz, 1998), so it is possible that participants could have done better on the second mental rotation task due to practice effects. However, trials were counterbalanced to help to control for this, so it is unlikely that results are due to practice effects.

3.6.5. Mental rotation abilities in WS

The results from the WS group in the current study are also in line with previous findings that show poor mental rotation abilities in this population (Farran & Jarrold, 2004; Farran et al., 2001; Stinton, Farran & Courbois, 2008; Vicari et al., 2006). As a group, the individuals with WS performed below both typically developing groups on the animal mental rotation condition, but were not significantly different from the DS group.

As was the case in the block construction tasks, in comparison to the TD groups, the WS group showed a large amount of heterogeneity of their percentage accurate on both the animal and tool mental rotation tasks. For example, while the group mean for the WS group on their overall tool mental rotation accuracy score was 65.62%, some individuals were achieving scores of up to 96% accurate, whereas others were achieving as low as a score of 46% accurate. Similarly, in the animal mental rotation task, the mean score was 70.41%

accurate, however some participants were achieving scores of up to 96% and as low as 42%. This indicates that block construction abilities are more of a difficulty for some individuals with WS than others, and some individuals were showing very little difficulty on this task with accuracy scores of 96%.

The WS group were at chance on the majority of rotations on the Tool condition, and this suggests that this group could not do this task. As the WS group were broadly at chance on the Tool condition, it was not possible to calculate whether the WS group would show any significant differences in performance between the tool and animal conditions, though this group did show more above chance performance on the animal condition (0^o, 30^o, 90^o and 120^o) than the tool condition (0^o and 60^o). This group showed decreases in accuracy and increases in response times with increases in rotation on the Animal condition (when this was examined separately), as in the typically developing groups, suggesting that participants found the task more challenging with increases in rotation, indicating that they were able to use mental rotation on the Animal condition, even if this was to a lesser extent than the typically developing individuals.

3.6.6. Mental rotation abilities in DS

As previously mentioned, the DS group performed above chance on more trials than the WS group. However, again as was seen in the WS group, in comparison to the TD groups, the DS group showed a large amount of heterogeneity of their percentage accurate on both the animal and tool mental rotation tasks. For example, while the group mean for the DS group on their overall tool mental rotation accuracy score was 71.11%, some individuals were achieving scores of up to 100% accurate, whereas others were achieving as low as a score of 40% accurate. Similarly, in the animal mental rotation task, the mean score was 83.61% accurate, however some participants were achieving scores of up to 100% and as low as 45%. This indicates that block construction abilities are more of a difficulty for some

individuals with DS than others, and some individuals were showing no difficulty on this task with accuracy scores of 100%.

The DS group performed above chance on all trials on the animal condition and all except the 90º trial on the tool condition. This suggests that the DS group are less likely to guess their responses and that they have a better understanding of how to mentally rotate the image than the WS group. The DS group were also as good as (but not better than) the TD4-5 group on both mental rotation conditions, but below the TD6-7 group. This suggests poor performance in mental rotation in the DS group, as these individuals were performing well below what would be expected for someone of the same chronological age. This, along with the poor block construction performance, suggests that while small scale spatial ability in individuals with DS may be a strength *in comparison to verbal abilities*, it remains a difficulty for these individuals none-the-less, and should not necessarily be treated as a strength, and something that does not require support overall.

When response times in this group are examined, it was found that the DS group were showing similar response times to the TD4-5 group, but longer response times than the TD6-7 group. This may suggest that, while the DS group are able to perform the task as well as the younger TD group, they are requiring more time to mentally rotate the image and choose the correct response. This may suggest that the DS group are less efficient than the TD groups, again providing evidence that this group may still require support and practice on small scale spatial tasks.

Overall, these findings suggest that the mental rotation deficit is not specific to WS as the DS group were not performing better than the TD6-7 group, indicating that this group also experience significant deficits in their small scale spatial skills. Again, as in block construction, it is likely that these groups performed poorly for different reasons. Deficits in mental rotation in WS are expected due to differences in the parietal lobe in individuals with

WS, specifically, in the dorsal stream (Gaser et al., 2006; Kippenhan et al., 2005; Meyer-Lindenberg et al., 2004; Schmitt et al., 2002; Van Essen et al., 2006) impacting spatial ability. In DS, it is again possible that poor language ability may have limited performance in understanding the task and following task instructions (e.g. Rohr & Burr, 1978; Silverstein et al., 1982). It may also be that, while the WS and DS groups may have initially found the task difficult for different reasons, both groups may have experienced boredom and low motivation to complete the task. Indeed, anecdotally, participants from both groups reported not enjoying the task, and many frequently asked the experimenter how many trials were left and when they would be finished.

3.6.7. Mental rotation and motor ability

There were no correlations between mental rotation and motor ability in the typically developing participants. One explanation for this may be that there are numerous ways to make same/different judgements of images at different rotations. For example, Wexler et al. (1998) found that, in their mental rotation task, subjects reported shifting their strategy from the mental rotation strategy they were instructed to use to memory based or landmark based strategies, which they found easier to use (see also Hinton & Parsons, 1988). It may be the case that individuals in the current study used another or various strategies to enable them to complete the task, and that these strategies are less correlated with motor mechanisms. In the WS group however, there were observed correlations between motor ability and the animal condition. It is surprising that the correlation is between the animal condition and motor ability and not the tool condition but could be an artefact of the predominantly chance-level performance in the WS group on this condition. The DS group showed a correlation between motor ability and Tool mental rotation, when chronological age was taken into account. This was hypothesized as it is thought that the Tool mental rotation task would have stronger links to motor ability based on previous research (Dekker et al., 2011; Vingerhoets et al., 2002).

The finding that this correlation was only present when chronological age was controlled for should also be noted, as it suggests a role of age in mental rotation and motor ability in the DS group.

Both these groups show the same motor profile and were not significantly different on their overall motor ability. It may be possible that the task instructions contributed to these differences in findings, as participants were told to find the two chickens that were going the same way, so it is possible that the WS group may have imagined the chickens moving to solve this task. As this is the first piece of research to investigate this association between motor ability and spatial ability in individuals with WS and individuals with DS, more research would be needed to further investigate this association using larger groups and different types of spatial tasks.

3.7. Limitations

One limitation of the mental rotation task, on the accuracy measure, is limited sensitivity. As the mental rotation task only gave a score out of four, there was less room for variability between chance performance and ceiling performance. This may have reduced sensitivity with respect to group differences and correlations. A more sensitive version of the task with more trials per degree may have yielded different results, and therefore showed the expected stronger correlations between motor ability and mental rotation.

The poor language abilities of individuals with DS were not considered in the design of this study as this group was not added until the second round of testing (Chapters 4 and 5), and so this data for the DS group was collected after that of the WS and TD groups. For example, some designs required the participant to use the same block twice (e.g. block B), and even when told they could use the same block/letter more than once, it was observed by the experimenter that the Ds group would often choose a different block (e.g. block C), which was clearly incorrect. When asked if there were any blocks that did not look right, they would

indicate the incorrect block, but would still not understand that they could use a block they had already used. However, as this potential problem with language ability was not part of the original research design, no official data was collected for this observation and no analysis could be done.

Another limitation of the mental rotation task is that, in the WS group, the chance performance, particularly on the tool condition, may have masked any effect of mental rotation. As this group were at chance on so many of the trials, it is likely that their scores on the mental task are not a true representation of their abilities. It may be that a different image of a 'tool' could have been used that was more brightly coloured or familiar to participants. While all participants were asked to confirm that they knew what the image of the jug was, and could all demonstrate how to use it, it may have been that a different image with more distinctive elements (such as the head of the chicken) could have made this task easier and reduced this chance performance in the WS group.

One limitation of the block construction task is that the non-manual task may have been too complex in its instructions for participants. While it was checked that all participants understood the instructions before testing began, and that they could name all the blocks, it may be that participants forgot the task instructions, particularly as the task became more complex. Additionally, as the non-manual block construction task was a novel task, it would have been useful to pilot the task and check that the instructions could be understood by both WS and TD participants (the DS group were not considered at the time of this study design). However, this was not done. For both tasks, it is a limitation that the tasks were not designed with the DS group in mind. As previously mentioned, the DS group were not an original group that were going to be included in this thesis, therefore the tasks were only designed for a WS group and a TD group of 4-7-year-olds. If this study was re-designed to be used with participants with DS, poor language ability should be taken into account.

3.8. Conclusions

This study supports previous findings from WS studies showing poor small scale spatial performance on both block construction tasks (e.g. Bellugi et al., 1999; Hoffman et al., 2003; Mervis et al., 1999) and on mental rotation tasks (e.g. Broadbent et al., 2014), as this group performed to a similar level to the TD4-5 group and below the TD6-7 group on both block construction and animal mental rotation. The findings from the DS group are a little more complicated. This group showed poor performance on the mental rotation tasks and block construction task. On the block construction task, they performed at a similar level to the WS and TD4-5 groups, and below the TD6-7 group, and on the mental rotation task, they were below the TD6-7 group. This paints a complex picture for the DS group, and suggests that spatial ability may not be as much of a strength as has been previously suggested in some research (e.g. Chapman & Hesketh, 2000; Davis, 2008; Moldavsky et al., 2001; Silverman, 2007), and is in line with research suggesting that small scale spatial abilities may actually be a deficit for individuals with DS (e.g. Hodapp et al., 1992; Lanfranchi et al., 2004; Pennington et al., 2003).

In typically developing children, there were no correlations between motor ability and manual or non-manual block construction. In WS and DS, there was a correlation between motor ability and manual block construction, but no correlations between motor ability and non-manual block construction. Further, in WS there was a correlation between motor ability and animal mental rotation, and in DS there was a correlation between Tool mental rotation and motor ability, when chronological age was accounted for. These findings of fewer correlations between mental rotation and motor ability may have something to do with the complexity of the mental rotation task itself. These tasks present high cognitive demands on more than just the act of mental rotation itself. For example, Shepard and Metzler (1971) showed participants two rotated pictures which were either the same or mirror images of each

other, and they were asked to indicate if the two pictures were the same or different using a lever. In order to pass this task, children must not only have the capability to use mental rotation, but also understand what constitutes as “same” and “different”, produce a mental image of the object, and remember which lever stands for which response (see also Marmor, 1975). Indeed, Cronin (1967) found that very young children struggle to discriminate between “same” and “different” on a task involving non-rotated mirror images. The block construction task, in comparison, takes out the mental rotation process, as participants can either physically move the blocks themselves to different positions, or they simply must match one picture to the other using the sheet provided.

Chapter 4

Associations between motor ability and anxiety

4.1. Introduction

4.1.1. The relationship between clinical anxiety and motor abilities

There is increasing evidence for an association between emotions and motor behaviour. Indeed, studies have shown that emotions directly impact people's rate of movement (Gross, Crane & Fredrickson, 2012), speed of movement (Chen & Bargh, 1999; Rotteveel & Phaf, 2004), force production during motor tasks (Coombes, Cauraugh & Janelle, 2006; Coombes, Gamble, Cauraugh & Janelle, 2008), and accuracy of movement (Coombes, Janelle & Duley, 2005). There is also evidence that emotional regulation techniques can improve motor behaviour in typical participants without mental health difficulties (Beatty, Fawver, Hancock & Janelle, 2014).

There is little research into the relationship between anxiety and motor abilities in adult populations, so research with both adults and children will be presented here. The theoretical framework for the relationship between anxiety and motor development is outlined below. An association has been reported between emotional difficulties (namely anxiety and depression) and motor ability in children. That is, motor and movement items are listed in the Diagnostic and Statistical Manual of Mental Disorders (American Psychriatric Association, DSM 5, 2013) as clinical features of anxiety in children. For example, when looking at anxiety in children, psychophysiological symptoms, such as muscle tension and shortness of breath are noted, alongside being more restless and fidgety and muscle aches and soreness, all of which may directly affect movement (American Psychriatric Association, DSM 5, 2013). It is also the case that children with high levels of anxiety are less likely to engage in physical activity and show withdrawal and lack of enjoyment during play (Kirkcaldy, Shephard & Siefen, 2002), which could impact the extent to which they are

practicing motor skills. Similarly, in depression, children show symptoms such as psychomotor agitation, abdominal pains, decreased general physical activity, fatigue and a reduced ability to feel pleasure or enjoyment (American Psychriatric Association, DSM 5), all of which would impact their motor ability in general, but also their ability to take part in physical activity to practice their motor skills. There is even research to suggest that early motor difficulties predict anxiety and depression in later childhood (Piek, Barrett, Smith, Rigoli & Gasson, 2010; Sigurdsson, Van Os & Fombonne, 2002).

Studies have been conducted to investigate the role of emotional problems on motor ability. Erez, Gordon, Sever, Sadeh and Mintz (2004) tested 20 children aged 7-14-years with anxiety disorders and 20 typical controls aged 7-13-years on both static and dynamic balance tasks, and found that the children with anxiety performed more slowly and made more mistakes than controls on the more challenging tasks, suggesting that individuals with anxiety exhibit poorer balance in daily life, and are more sensitive to balance challenging situations. Kristensen and Torgersen (2007) assessed overall motor ability using the M-ABC (Henderson & Sugden, 1992) in 50 socially anxious and 50 non-socially anxious children aged 11 and 12-years-old. They found that the socially anxious and avoidant children performed significantly worse on the M-ABC than non-anxious children, and that the avoidant personality traits were particularly associated with more severe impairment on the M-ABC. Dewey, Kaplan, Crawford and Wilson (2002) found that 45 children (mean age=11.8 years) with a diagnosis of DCD and 51 children with suspected DCD (mean age= 11.2) showed more anxious/depressed, withdrawn and somatic complaints, on the internalizing subscales of the Child Behavioural Checklist (Achenbach & Edelbrock, 1991) in comparison to the control sample of 78 typically developing age matched controls, with no motor problems (mean age=11.4). This is in line with previous findings by Ekornas, Lundervold, Tjus and Heimann (2010), who also found that, in a community sample, 44% of

the sample of 329 children aged 9-11 years with anxiety fell below the 5th percentile on the M-ABC. Moreover, Green, Baird & Sugden (2006) found that parents of 47 children aged 5-10 years with low motor performance also reported high levels of emotional problems. Skirbekk, Hasen, Oerbeck, Wentzel-Larsen and Kristensen (2012) investigated motor impairments in 41 children (mean age=10.9 years) with anxiety, 39 children with ADHD (mean age=9.8 years), 25 children with co-morbid anxiety and ADHD (mean age=10.1), and 36 control children (mean age=10.7 years). The main findings from this study were that children with anxiety showed significantly higher motor impairments than typically developing children, with 46% of the sample falling below the 5th percentile on the M-ABC, and therefore meet the criterion for diagnosis for Developmental Co-Ordination Disorder (DCD). The children with anxiety disorders showed a similar level of motor ability to both the ADHD and ADHD-anxiety group. One limitation of this study is that the M-ABC consists of different test items for different ages, and the motor test did not cover the full range of motor abilities. Therefore, the use of the M-ABC alone may not be sufficient to capture the full range of motor strengths and difficulties. Another limitation of Skirbekk et al. (2012) is that ADHD is associated with motor difficulties generally (e.g. Kaiser, Schoemaker, Albaret & Geuze, 2015; Pitcher, Piek & Hay, 2003; Tseng, Henderson, Chow & Yao, 2004), so it is difficult to disentangle the motor difficulties that are accounted for by anxiety, and which are just co-occurring with ADHD generally. Overall, these studies with children show significant evidence for an association between emotional problems and motor impairment/difficulty in childhood.

Research has also investigated the role of depression and anxiety on self-perceptions of motor ability in children. Indeed, it has been found that a child's perception of their level of motor competence will impact their social and emotional functioning, whether this perception is accurate or not (Skinner & Piek, 2001; Perez & Sanz, 2005). Negative self-

perceptions, poor peer relations, depression symptoms and negative social feedback have all been found to associate with motor difficulties in childhood (Gillberg & Kadesjo, 2003; Piek, Bradbury, Elsley & Tate, 2008). Skinner and Piek (2001) found a relationship between anxiety, self-perception and motor performance in 109 children with DCD, and 109 typically developing control children, aged 8-14 years. They found that poorer motor ability was associated with high levels of state and trait anxiety, and with low self-perceived competence in athletic, scholastic, physical appearance and self-worth domains. State anxiety refers to the physiological and psychological anxiety reaction to a particular situation, in that moment. On the other hand, trait anxiety refers to a trait of the individual's personality, showing individual differences to how likely a person is to experience anxiety across many situations in general. Piek, Bayman and Barrett (2006) found that athletic competence was an important determinant of self-reported self-worth in males. Furthermore, Cairney, Hay, Mandigo, Wade, Faught and Flouris (2007), and Wrotniak, Epstein, Dorn, Jones and Kondilis (2006) found that low motor ability was correlated with negative self-perceptions of motor competence, and less enjoyment and participation in physical activity. While there is not a great deal of research in this area, the research to-date suggests that motor impairment, specifically gross motor impairment, is associated with feelings of low self-perceptions and emotional problems.

There has also been some work with adults to investigate the potential association between anxiety and motor behaviour. Weinberg and Hunt (1976) used electromyography to investigate the quality of movement in 10 high and 10 low anxious adults. They found that not only did the high anxious participants perform significantly worse than the low anxious participants, but they also used much more muscle energy than the low anxious group before, during and after the motor act. Coombes, Higgins, Gamble, Cauraugh and Janelle (2009) investigated the role of anxiety in a motor task, where 16 participants with low anxiety and

18 participates with high anxiety (mean age=20.25 years) had to squeeze a force inducer as quickly as possible when a stimulus was presented on a screen at either 10% force or 35% force. They found that motor efficiency was significantly lower in the highly anxious group, with this group showing significantly higher response times than the low anxiety group. However, motor effectiveness was not significantly different, as both groups performed similarly on the motor task.

Overall, the results from studies carried out with both children and adults suggest an association between anxiety and motor ability, with those individuals experiencing higher levels of anxiety also experiencing more motor difficulties. This association is thought to be bi-lateral and may be due to a number of factors. First, children with anxiety may be more avoidant of activities and less likely to take part in physical activities (Kristensen & Torgersen, 2007). This gives them less chances to practice motor skills. Children with anxiety may be overly cautious, and therefore preform motor tasks and assessments more slowly, perhaps due to fear of getting hurt or wanting to perform the task perfectly to avoid any negative consequences (Coombes et al., 2009; Erez et al., 2004).

4.1.2. Anxiety in WS

Research into anxiety has been a strong topic of discussion in the WS literature, with this population showing increased levels of anxiety in comparison to the general population (e.g. Rodgers, Riby, Janes, Connolly & McConachie, 2012), and in comparison to other intellectual disability groups (e.g. Dimitropoulos, Ho, Klaiman, Koenig & Schultz, 2009; Dykens, 2003; Graham, Rosner, Dykens, & Visootsak, 2005). Anxiety is the most significant mental health difficulty for children and adults with WS and is more prevalent than other difficulties such as depression (Porter, Dodd & Cairnes, 2009; Stinton, Elison & Howlin, 2010).

Royston, Howlin, Waite and Oliver (2017) conducted a systematic review and meta-analysis of the literature around anxiety disorders in WS contrasted with those with intellectual disabilities and the general population. 16 papers were reviewed, and the meta-analysis then compared the prevalence rates from these 16 studies to populations with intellectual disability and the general population. The total number of individuals included in the systematic review was 391 (once overlapping participants had been condensed), the mean sample size in the studies was N=66, and the mean age of participants was 16.5 years. It was found that individuals with WS were four times more likely to experience anxiety than individuals with intellectual disability of mixed aetiology. The average anxiety prevalence in the WS population from these 16 studies was 48%, and the estimate for those with intellectual disability of mixed aetiology is 12%, which was not significantly different than the general population. However, the rates of anxiety reported in the general population were found to vary widely from study to study and appears to be dependent on where the sample was recruited from (i.e., was the sample recruited from those who already struggle with anxiety, or are they individuals from the general population, some of whom may have had anxiety and some who did not). In the studies reviewed, specific phobias were found to be the most common anxiety problem for individuals with WS (39%), and these were often related to noise and medical procedures (e.g. injections, blood, hospitals, etc.) (Cherniske et al., 2004; Dodd & Porter, 2009, 2011a, 2011b; Green et al., 2012; Leyfer, John, Woodruff-Borden & Mervis, 2012; Leyfer, Woodruff-Borden & Mervis, 2009; Leyfer, Woodruff-Borden, Klein-Tasman, Fricke & Mervis, 2006; Pegoraro, Steiner, Celeri, Banzato & Dalgalarrondo, 2014; Stinton, Elison & Howlin, 2010; Woodruff-Borden, Kistler, Henderson, Crawford & Mervis, 2010). However, it should be noted that, in Stinton et al. (2010) study, there was a low agreement between reports given by parents and those given by the individuals with WS themselves. Parents reported that they were unable to provide some

information, particularly physical symptoms such as a racing heart and dry mouth in their son or daughter. This low agreement between parents and the individuals may pose a problem when deciding diagnosis or examining treatment options for individuals with WS as clinicians would need to decide whose report to take as fact and whether the parent or the individual is better able to accurately describe their symptoms. This may also be the case in other studies, as most research relies on parent report only of their son or daughters experience of anxiety, and they do not ask the individual themselves. There are also concerns about the use of the PAS-ADD as a tool, as some research has suggested that this questionnaire is not sensitive to the presence of anxiety disorders (Moss et al., 1997). However, other research suggests that the PAS-ADD overdiagnoses anxiety disorders (Gonzalez-Gordon, Salvador-Carulla, Romero, Gonzalez-Saiz & Romero, 2002). Another potential limitation of some studies is that, while 'life events' were recorded, the frequency and severity of these life events was not taken into account. Further, this study labels 'life events' as always being negative, when in fact, a major life event such as a new baby or a change of career could be a very positive event. It was found that 37% of the studies included recruited samples from a clinical setting, which may have inflated the prevalence rates reported. Further, as this was a meta-analysis, it was not possible to match the groups (WS vs. intellectual disability) on factors such as age, cognitive ability, etc. Therefore, other group differences may have accounted for the differing rates of anxiety observed.

Ng, Bellugi and Järvinen (2016) conducted a study with 25 individuals with WS aged 19-57 years and 16 typically developing individuals aged 17-43 years to investigate the potential relationship between anxiety and autonomic responses to social-affective stimuli. Ng et al. (2016) found that the individuals with WS scored higher on overall anxiety than the TD group, which is consistent with the meta-analysis conducted by Royston et al. (2017). One limitation of the Ng et al. (2016) is the choice of control group used. The difficulty with

using typically developing individuals as control subjects is that these individuals are likely to have had different life experiences than individuals with intellectual disabilities and social vulnerabilities, such as individuals with WS. Therefore, using a population with intellectual disabilities who do not have high incidence rates of anxiety may have yielded more reliable results. Therefore, the current study employs a cross syndrome comparison between individuals with WS, and a population who are not known to exhibit high levels of anxiety, i.e. those with DS.

Royston, Oliver, Howlin and White (2021) explored anxiety in WS further by examining the characteristics of anxiety in 13 individuals with WS aged 12-45 years. To achieve this, Royston et al. (2021) conducted semi-structured interviews with parents using the 5-p's formulation framework, which consists of presenting, predisposing, precipitating, perpetuating and protective factors of mental health (Johnstone & Dallos, 2013). From this, a set of interview style questions and a coding scheme was developed, which examined frequency, severity, triggers, behaviours and the onset of anxiety. The SCAS was also used as a second measure of anxiety, and it was found that there were no correlations between SCAS score and the frequency or severity of anxiety symptoms in the parental interviews. All parents reported that anxiety was the main mental health concern for their son or daughter with WS. Eleven of the parents reported that specific events triggered anxiety in their son or daughter, and three reported generalised anxiety. The majority of parents reported that the onset of anxiety was prior to age 12 years, and some anxiety onset triggers were transitions, relationship difficulties, death of a loved one and parental marital difficulties. Maintaining triggers for anxiety were reported to be, specific phobias, new situations, negative emotions of others and sensory sensitivities, which is consistent with the triggers found in the meta-analysis conducted by Royston et al. (2017). Parents also reported the reasons why they believed these situations were difficult for their son or daughter, and some of the reported

reasons were, lack of understanding, rigidity of thought, difficulties with change, health related issues and family-related factors. One of the most common anxiety related behaviours in WS was reported to be communication with others (seeking reassurance) and reporting anxiety feelings to parents or caregivers. Some parents reported other behaviours such as, crying, seeking out parents, pacing and repetitive behaviours. Parents found it difficult to comment on what their son or daughter would be thinking when they feel anxious, which is a common limitation of relying on parents or caregivers to report on anxiety as the whole picture of anxiety of often missed (Hermans et al., 2011). Parents reported that, generally, anxiety was infrequent, mild and had a minimal lasting impact. However, three parents reported anxiety as a significant and severe problem for their son or daughter, and these were the parents who reported generalised anxiety rather than specific phobias. The two most commonly reported coping strategies used by this sample were distractions and escape, although some other strategies such as reassurance seeking and talking through worries with others were also reported. A strength of this research was that the primary purpose of the study was not revealed prior to recruitment, and so the sample was not biased by parents who already had significant concerns about anxiety in their son or daughter as is often the case. This method of recruitment may have led to a more representative sample of participants and may account for why lower levels of anxiety were reported on the SCAS than has been found in previous research. One limitation of this study is that the interviewers were not clinically trained, and therefore may have missed some potential signs or symptoms of anxiety, or the researcher may have missed the opportunity to find out more information from parents. Instead, the 5-p's formulation was used as a framework to design a structured questionnaire and, therefore, some vital information may have been missed if the researcher was only asking a set of pre-prepared questions, rather than allowing for a more natural conversation with parents. However, the coding scheme developed for this study was reviewed by three

clinical psychologists for applicability and relevance, although the clinical psychologists played no role in the administration, scoring or interpretation of the results.

Ng-Cordell, Hanley, Kelly and Riby (2018) examined anxiety in WS and the potential role of social behaviour and executive function on anxiety over time. To do this, the researchers compared parent reports of anxiety in 17 individuals with WS over a 4-year period. The age of participants at time 1 was 5-36 years. Anxiety was measured using the SCAS and social functioning was measured using the Social Responsiveness Scale, second edition (SRS-2; Constantino & Gruber, 2012), and for those under the age of 18, the SRS-2 School Age Form was used. Executive functioning was measured using the Behaviour Rating Inventory of Executive Functioning, second edition (BRIEF-2; Gioia, Isquith, Guy & Kenworthy, 2015). Ng-Cordell et al. (2018) found that, in line with previous findings, over 70% of their sample scored above the clinical cut off for anxiety on the SCAS, which is much higher than the average percentage of clinical anxiety found in the meta-analysis conducted by Royston et al. (2017). Interestingly, it was also found that anxiety in WS increases over time, however, this was not significant, although there was a trend towards significance with a small to medium effect size. The authors also noted that a third of the sample becoming less anxious over time. This highlights the need for authors to examine the potential risks, triggers and protective factors driving these potential changes in anxiety levels. The authors consider the lack of significant relationship between anxiety and time to be due to small sample sizes and the wide age range of participants. This is another example of when the inclusion of both parent and self-reports may have yielded more accurate results, as parents can only guess at the thoughts and emotions of their son or daughter, and how intense these thoughts and emotions are for the individual themselves.

Ng, Ja¨rvinen and Bellugi (2014) investigated the potential associations between social, anxiety and cognitive phenotypes of WS. To do this, parents of individuals with WS

(N=62, mean age = 32.65 years) and typically developing individuals (N=79, Mean age = 27.10) were given the Beck Anxiety Inventory (Beck, Epstein, Brown & Steer, 1988). A second sample of parents of individuals with WS (N=24, mean age = 32.16 years) and typically developing individuals (N=30, mean age = 22.27) were given the Brief Symptom Inventory (Derogatis, 1993). Participants were also given the Weschler Intelligence Test (Weschler, 1991) to assess intellectual functioning. It was found that anxiety was significantly higher in the WS group than the TD and DD groups, but also that IQ was positively associated with anxiety in WS, i.e., those individuals with a higher IQ also had higher levels of anxiety. The opposite pattern was found in the TD group. Interestingly though, the symptoms of anxiety, though more prevalent, were less severe in the WS group in comparison to the TD group. However, it should be noted that this difference may be due to individuals with WS being less able to express their feelings of anxiety than TD individuals, and so it may be that, while parents of individuals with WS are reporting high levels of anxiety, they are not as aware of the severity. It was also found that anxiety symptoms were unrelated to social functioning in both the WS and TD groups. One limitation of Ng et al. (2014) is the lack of a control group with intellectual disabilities. One of the questions that came from this study was whether the WS group were less able to report on their anxiety to their parents, and if this led to the differences in severity of anxiety symptoms reported between the WS and TD groups. Indeed, this would explain why those participants with WS who had a higher verbal IQ also reported higher levels of anxiety. If a control sample of individuals with intellectual disabilities had been used alongside the TD group, it may have highlighted whether the difference in anxiety prevalence was due to how well the group was able to report on their symptoms, or whether the WS group do have less severe symptoms of anxiety than their TD counterparts, despite having higher rates of anxiety.

Braga et al. (2018) investigated the cognitive and behavioral profile of eight toddlers with WS, aged 48-72 months. Braga et al. (2018) used the Denver Developmental Screening Test II (Frankenburg, Dodds, Archer, Shapiro & Bresnick, 1992); the Peabody Picture Vocabulary Test (Campbell, 1998); the Vineland Adaptive Behavior Scale (Sparrow, Balla & Cicchetti, 1984); the Child Behavior Checklist (Achenbach & Edelbrock, 1991); the Columbia Mental Maturity Scale (CMMS) (Davis, 1973), and the Behavior Problems Inventory-01(Rojahn, Matson, Lott, Esbensen & Smalls, 2001). Parents and caregivers reported behavioral and emotional problems associated with anxiety and depression in the toddlers with WS. The toddlers with WS also presented with impairments in fine motor skills, receptive language and communication, and personal care abilities. However, the authors did not run correlation analysis between the anxiety scores and motor scores. There are several limitations to this study. First, there were only eight participants tested, which makes it difficult to draw any reliable conclusions from the results. Secondly, the authors do not report on what 'personal care' abilities that the toddlers should have been able to do that they are not able to do. Thirdly, speculations on anxiety in a population this young are questionable. It is unclear whether the authors considered that the children with WS would likely be behind their typical peers in terms of their physical as well as mental development and how this may have impacted the results. The authors also do not report what anxiety symptoms that they specifically found. When the percentage of toddlers with anxiety was examined, it was found that 50% fell into the typical range. Similarly, for depression, only around 11% fell into the borderline/clinical range. Considering that there are only eight participants in the entire sample, it is, perhaps, not appropriate to examine mental health in populations of this age. While it is important to consider the mental health and wellbeing of individuals of all ages, pathologizing a toddler with anxiety, depression or ADHD cannot be done at these young ages. While it was not the intention of the authors to diagnose these children, but rather to

report on their behaviour, the behaviours chosen seem, to this author, to be more appropriate for an older child or teenager. Perhaps a better way to examine the mental wellbeing and behaviour of the toddlers would be to have them perform an activity meant to challenge them, and to see how they would react (e.g. giving up, 'throwing a tantrum', crying, reaching for caregivers, etc.) and to compare the WS group to a mental age matched TD or intellectual disability group of infants given the same task.

Stinton, Tomlinson and Estes (2012) examined reports of mental health in 19 adults with WS (aged 20-42 years) using a psychiatric interview. Participants were also given a modified Stroop task and parents were also asked to give information on psychiatric symptoms in their son or daughter with WS. It was found that, both the parents and the individuals themselves reported more symptom of anxiety (N=9) than depression (N=2). There was also a correlation between parent report and the responses from the individuals with WS themselves on symptoms of mental health problems. However, it was found that the individuals with WS themselves did report more symptoms of mental health problems overall, and also more symptoms of anxiety specifically. A strength of this study is the use of psychiatric interview with the individuals with WS themselves. Many studies rely on parent report alone. These reports may miss vital information about the specific thoughts and feelings of the individual. This is due to parents only being able to report on the outward behaviour or what their son or daughter has told them, which may not always be the whole picture. Indeed, in this study, while the overall rates of anxiety reported by parents and the individuals with WS themselves were similar, the individuals with WS reported much more severe symptoms of anxiety than their parents. A limitation of this study is the generalisability of the results to individuals with WS as a whole. In this study, psychiatric interview was used to collect data about the experiences of mental health in adults with WS. While this is a strength of the study (as it allows the individuals voice to be heard), it is also,

perhaps, only appropriate for those individuals with good enough cognitive functioning to be able to reliably report on their own mental health and wellbeing.

Pitts, Klein-Tasman, Osborne and Mervis (2016) investigated predictors of specific phobia in 194 6–17-year-old children with WS. To do this, they examined the effects of age, gender, cognitive ability and behaviour regulation difficulties on the probability of being diagnosed with a specific phobia. The authors asked parents to complete the ADIS-P, the BRIEF and asked the participants with WS to complete the Kaufman Brief Intelligence Test, second edition (KBIT-2; Kaufman, 2004). The results showed that there were no differences between males and females. However, as age increased, the probability of receiving a diagnosis of specific phobia also increased. The strongest predictor of specific phobia, however, was behavioural regulation difficulties. As behavioural regulation difficulties increased, the probability of receiving a diagnosis of a specific phobia also increased. A strength of this study is the large sample size (N=194), which is unusual for a study of individuals with WS. Another strength is that the ADIS-P, which was used to diagnose the presence of specific phobia, was administered by either a clinical psychology doctoral student, a clinical psychologist or a developmental pediatrician, and all interviews were reviewed by a clinical psychologist. This will have improved the accuracy of the diagnosis as these professionals have been trained and have experience in working with mental health difficulties and in the diagnosis of such difficulties. It would also be interesting to examine whether the effect of age on specific phobia diagnosis would continue into adulthood or, more likely, if this effect would eventually stabilize or decrease in adulthood.

Overall, these studies are consistent with the meta-analysis conducted by Royston et al. (2017) in that they found much higher rates of anxiety in the WS population in comparison to their control groups. Another common finding is that anxiety appears to get worse with age (e.g. Leyfer et al., 2006; Ng-Cordell et al., 2018; Pitts et al., 2016), which

may be due to increased pressures on the individuals to be more independent, increases in the number of transitions (e.g. through schools, from childhood to adulthood, etc.) and more awareness of their own difficulties with age, alongside many other individual factors (such as bereavement, house moves, relationship breakdowns, trauma, etc.).

4.1.3. Anxiety in DS

While many individuals with DS present with mental health difficulties, namely depression (Collacott et al., 1992; Cooper & Prasher, 1998), this population does not tend to suffer from high levels of anxiety. Compared to other clinical groups, individuals with DS present with lower levels of anxiety and rarely reach the clinical level (Graham et al., 2005; Haveman et al., 1994; Einfeld, Tonge, Turner, Parmenter & Smith, 1999). Määttä, Tervo-Määttä, Taanila, Kaski and Iivanainen (2006) examined the medical records of 129 adults with DS mean age 35-years for the females and 29-years for the males in the sample. They found that 61% of their sample did not report any mood or anxiety problems, 11% had experienced moderate anxiety and only 8% reported severe symptoms of anxiety. Dykens et al. (2015) found similar rates of anxiety in their sample of adolescents and adults, aged 13 to 29-years (mean age: 21.39-years), with DS (N: 49) compared to a group of 70 chronological age matched individuals with intellectual disability (mean age: 22.07-years).

However, there is some evidence of anxiety signs and symptoms in populations with DS. It has been reported that younger individuals with DS show more anxious behaviours than older individuals (Dykens, Shah, Sagun, Beck & King, 2002). Myers and Pueschel (1991) found anxiety disorders, and repetitive and disruptive behaviour in 22% of their sample of individuals with DS (N: 261) under the age of 20-years. Further, in a sample of 206 adults with DS taken from a psychiatric outpatient clinic, anxiety was one of the most commonly reported psychiatric difficulty in all age groups, second only to depression (Patti & Tsiouris, 2006). However, as this sample is taken from individuals who have required

access to psychiatric help for a mental health disorder, they may not be representative of the general population of individuals with DS.

Overall, this research suggests that individuals with DS do not show increased levels of anxiety in comparison to other populations with intellectual disabilities (e.g. Dykens et al., 2015). More research is needed to better investigate anxiety rates in DS, and how anxiety is impacting other areas of life in this group.

4.1.4. Summary

There appear to be differences in the levels of anxiety between individuals with WS and individuals with DS, and some research has shown that individuals with WS show higher levels of anxiety than those with DS (Dykens et al., 2005; Graham et al., 2005). Individuals with WS show high levels of anxiety in comparison to the general population and to other populations with intellectual difficulties (Papaeliou et al., 2012; Royston et al., 2017; Stinton, Elison & Howlin, 2010; Woodruff-Borden, Kistler, Henderson, Crawford & Mervis, 2010). It may be the case that the high levels of anxiety in WS could be contributing to their low levels of participation in physical activity, due to increased anxiety, e.g. of getting hurt, of going to a new place, which may lead to individuals with WS not feeling able to try something new or to persist at a new activity.

In comparison, evidence from DS is mixed, with some studies reporting that individuals with DS show levels of anxiety similar to the general population (Graham et al., 2005; Haveman et al., 1994; Einfeld et al., 1999) and others reporting similar levels to populations with intellectual difficulties (Dykens et al., 2015). There is also some evidence to suggest that younger individuals with DS may experience more problems with anxiety than older individuals (Dykens et al., 2002; Myers and Pueschel, 1991). More research is needed to better understand rates of anxiety in DS.

It has also been found that motor challenges can trigger fear responses in children with motor impairments, and that this can lead to future avoidance of similar situations (Schoemaker & Kalverboer, 1994). If this is also the case in WS or DS, then it may be that individuals with WS and individuals with DS may avoid certain motor activities for fear of criticism or failure, in turn leading to less opportunities to practice motor skills and to engage in rich social interaction, and may also be affecting their self-esteem and self-confidence. It may be the case that there is a bi-directional relationship, with individuals who experience high levels of anxiety being less likely to want to engage with motor acts, but also that having lower motor abilities may lead to individuals experiencing higher anxiety in situations where they are expected to perform a motor behaviour. It is known that both individuals with WS (e.g. Tsai et al., 2008; Wuang & Tsai, 2017) and individuals with DS (Alesi et al., 2018; Spano et al., 1999) experience motor difficulties from an early age (for more details on motor difficulties in these groups, see Chapter 1, sections 1.4.5 and 1.4.8). However, it will not be possible in this study to determine a causal direction, that is, it will not be possible to say whether it is high anxiety that is a causal factor to poor motor difficulties or whether it is motor difficulties that are contributing to higher anxiety during motor activities.

4.2. Aims and Hypotheses

The aim of the study was to examine the potential relationship between anxiety and motor abilities in two groups with motor difficulties, one who is known to exhibit high levels of anxiety (WS), and the other who is thought to show similar levels of anxiety to those found in the general population (DS). This allowed the researcher to investigate whether the relationship between poor motor ability and anxiety, which is found in individuals with anxiety disorders, is also present in a sample of individuals with a neurodevelopmental disorder (WS and DS). It is hypothesised that anxiety will be negatively associated with overall motor ability in the WS group, as this population is known to suffer from anxiety and

have poor motor ability. It is also hypothesised that this relationship between overall motor ability and anxiety will not exist in the DS group. It is further hypothesised that the WS group will have significantly higher anxiety scores than the DS group based on previous research finding that individuals with WS show higher rates of anxiety than those with DS (Dykens et al., 2005; Graham et al., 2005).

4.3. Method

4.3.1. Participants

The sample included 21 participants with a positive clinical diagnosis of WS, 18 of which are confirmed by florescent in situ hybridization (FISH) tests showing partial deletion of elastin on chromosome 7q11.23, aged 8 to 35-years, recruited via the Williams Syndrome Foundation, UK. These participants are a subsample of those included in Chapter 2, which again is due to data being collected at two different time points. A sample of 18 participants with DS, aged 12 to 35-years was also included, who were recruited via social media, the Down Syndrome Foundation, email and phone calls to existing participants and community centres and word of mouth. A cut-off of age 35 was used for the DS group as this is thought to be, on average, before the age of onset of dementia in this population (e.g. Visser, Aldenkamp, van Huffelen & Kuilman, 1997). All participants had normal or corrected to normal vision. It should be noted that, for analyses involving the SCAS, there is missing data from 1 participant with WS and 1 participant with DS. This is due to parents not completing the online questionnaire. For these participants, motor ability and self-rated anxiety only have been recorded.

Participants were assessed on their verbal and non-verbal IQ using the British Picture Vocabulary Scale III (BPVS III) (Dunn, Dunn, Styles & Sewell, 2009) and the Ravens Colour Progressive Matrices (RCPM, Raven, 1998) respectively. All individuals with DS from Chapter 2 are included in the analysis for this chapter, but the sample of WS Individuals

included were recruited for this study. This is due to data being collected at different time points. The participant information for the sample included in this Chapter is shown in Table 15.

Table 17. Participant details.

	WS (N=21)	DS (N=18)
Mean age (years:months) (range age years)	20:9 (9-36)	24;2 (12-35)
Gender F:M	12:9	9:9
BPVS-III[1] raw score (range)	119.24 (62-160)	103.78 (55-135)
RCPM[2] raw score (range)	17.75 (5-30)	17.78 (8-34)
BOT2-SF raw score[3] (range)	43.14 (13-76)	45.28 (17-73)

[1] British Picture Vocabulary Scale, Third Edition
[2]Ravens Colour Progressive Matrices
[3] Bruininks-Oseretsky Test of Motor Proficiency, Second Edition short form

4.3.2. Design and procedure

Ethical approval was obtained from the UCL ethics committee before testing began. WS and DS participants were tested either in a quiet room at the University or in their own home. For the WS and DS individuals, the entire testing session lasted between 1 hour 30 minutes and 2 hours with breaks. All participants were given breaks when needed, and sessions were sometimes split into shorter blocks to reduce fatigue and maximize motivation.

Motor ability

Motor ability was assessed using the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition short form (BOT2-SF; Bruininks & Bruininks, 2005). More details on the method of running the BOT2-SF are shown in Chapter 2 of this thesis.

Anxiety

Anxiety was assessed in two ways. Firstly, parents were asked to complete the Spence Children's Anxiety Scale (SCAS, Spence et al., 2003), where they rated their son or daughter on a scale of 0-3 (never – always), depending on how well different statements applied to their son or daughter. 20/21 of the WS group lived at home and 15/18 of the DS group lived at home. However, most of the DS responses were given by staff at the community centres these participants attended, and these staff spent 1:1 time with these individuals, up to 5 days a week.

The SCAS was chosen because it has successfully been used in previous research to give a parental report of anxiety in both children (Rodgers et al., 2012) and adults (Dodd et al., 2009; Riby et al., 2014) with WS. The SCAS has been found to correlate with other measures, such as the Screen for Child Anxiety Related Emotional Disorders (SCARED; Muris, Merckelbach, Schmidt & Mayer, 1999) and also shows good concurrent validity with the DSM-IV criteria for anxiety disorders (Muris, Schmidt & Merkelbach, 1999). Additionally, Orgiles, Fernandez-Martinez, Guillen-Riquelme, Espada & Essau (2016) conducted a systematic review of the use of the SCAS, and found that the SCAS showed high reliability even across cultural settings. The SCAS is a 38-item questionnaire, and has been found to have high internal consistency (.92, Spence et al., 2003). A score of 24 or above on the SCAS has been suggested as an indicator of clinical anxiety; this cut-off score has been used in previous research as an indication of clinical anxiety in WS (Rodgers et al., 2012; Riby et al., 2014). As well as providing an overall anxiety score, there are six subscales which relate to different areas of anxiety. These are: separation anxiety, social phobia, obsessive compulsive, panic/agoraphobia, physical injury and generalised anxiety. As many of the sample tested were adult participants, some of the questions on the SCAS were amended to reflect the age of the participant. For example, if the parent was asked about

anxiety in school, the question would be phrased to ask about this anxiety in either school, college or work etc.

Secondly, participants were asked at the beginning of testing, before doing the motor tasks, to rate themselves on a visual five-point scale of how nervous or worried they felt about doing different motor tasks (1 being 'great' and 5 being 'really worried or nervous'). Participants were shown the scale and the experimenter pointed to each picture in turn and explained what each meant. For the first picture (great) the participant was told that if they chose this picture then they wouldn't be feeling nervous or worried at all and would be really looking forward to doing the task. If they chose option 2 they would be feeling good about the task and not feeling worried, but might not be looking forward to the task. They were told that they might not know whether they would feel nervous or not about a task if they chose option 3. They were told that if they chose option 4, this would mean they were a little bit nervous about doing the task, and if they chose option 5, they were told that this meant that they would feel really nervous or worried about doing the task. They were also reminded about the options as they went through the questions and what each meant if they weren't sure. The experimenter asked the participants more probing questions if she was unsure whether the participant was not understanding the instructions, such as "would you feel worried if I asked you to do sit-ups? How worried would you feel a little bit worried or a lot worried?". This measure allowed the researcher a second measure of how anxious participants rate themselves to be before performing motor tasks. This was given before the motor tasks were presented to participants to avoid priming the participants to feel like they should be more anxious when doing the tasks.

Biological measures were also considered in the design of this study, though they were, ultimately, found to be impractical. One measure considered was the use of a heart rate watch or other monitor to measure anxiety. However, as participants were being asked to

conduct motor tasks, this would have influenced the heart rate of the individual as some of the motor tasks required more vigorous movement than others. Another measure considered was the use of a skin conductivity monitor, which can be used to measure anxiety. However, these devices need to be placed on the individuals' finger, and as the participants were asked to perform a range of tasks, many of which required the use of their hands, this method was also deemed to be inappropriate.

4.4. Results

4.4.1. Analysis and parametric assumptions

Participants completed the motor assessment outlined in Chapter 2. As mentioned in Chapter 2, the motor data were normally distributed for the majority of variables (Kolomorov-Smirnov, $p \geq .05$), and outliers were not effecting the means of the data when the 5% trimmed mean was looked at. Parents were asked to complete the Spence Children's Anxiety scale (SCAS). Assumptions of normality were investigated using Kolomorov-Smirnov tests. It was also found that for the majority of variables on the SCAS data met assumptions of normality (Kolomorov-Smirnov, $p \geq .05$). Therefore, parametric tests were also conducted on the SCAS data. SCAS data were examined using descriptive statistics to find the percentage of participants who were in the clinical range for anxiety, and t-tests were used to investigate differences between the groups. Correlations were performed between motor ability and SCAS score to investigate the potential impact of anxiety on motor ability, or vice versa.

Participants were also asked to rate their anxiety on a 5-point scale for each of the BOT2-SF tasks. It was found that on this measure, the data were not normally distributed in over half the variables (Kolomorov-Smirnov, $p \leq .05$). As there is no non-parametric alternative to a mixed ANOVA, parametric tests are reported for this measure. All main effects and interactions were then explored non-parametrically using Wilcoxon Signed Ranks

tests, Mann-Whitney tests, Friedman tests and Kruskal-Wallis tests as appropriate, and only reported when results were different from parametric equivalents.

4.4.2. Anxiety

The two groups' total anxiety and group differences in total anxiety score were investigated. Descriptive statistics were used to investigate the percentage of participants in each group who scored above the clinical cut off (24 points, 84th Percentile) on the SCAS. It should be noted here that there is some missing data due to parents not completing the online questionnaires. There is data missing for 1 participant with WS and 1 participant with DS on the SCAS. It was found that 80% of the WS group scored in the clinical range for anxiety (16/20 participants), and 44% of the DS group scored in the clinical range for anxiety (8/17 participants).

The mean raw anxiety score for the WS group was 33.45 (13.85) and was 22.65 (13.02) for the DS group. T-test comparison showed that the groups were significantly different on total anxiety score (t(35)=2.329, p=.020, Cohen's d = 0.803), with the WS group having a higher raw anxiety score than the DS group.

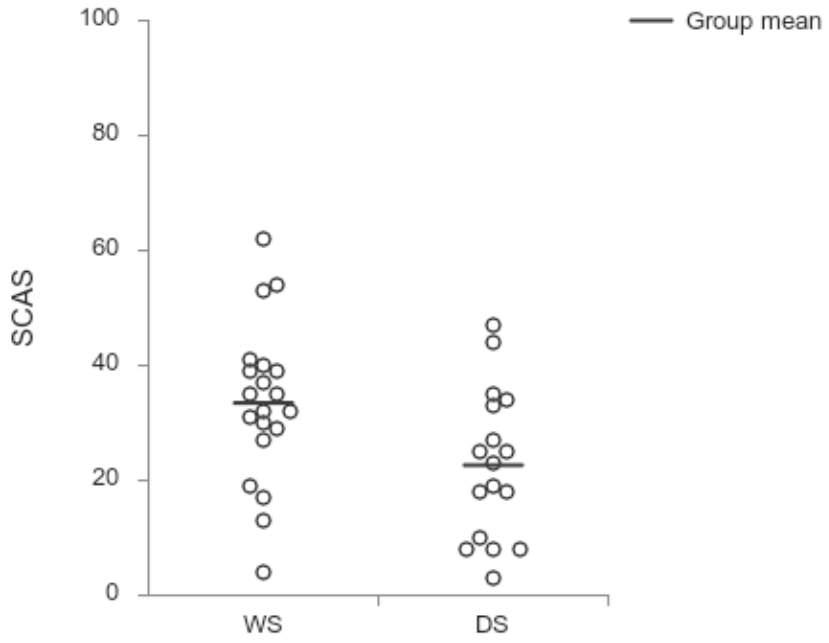

Figure 14. Dot plot to show the spread of raw scores on the SCAS for the WS and DS groups.

4.4.3. Association between anxiety and motor ability

The potential impact of anxiety on motor ability was also explored. To do this, correlations were performed between total raw score on the SCAS and total raw motor ability for each group. It was found that there were no significant correlations between motor ability and total raw score on the SCAS for either group (Table 18).

Table 18. Correlations between motor ability and SCAS raw score for the two groups. Critical alpha value $p<.05$.

	WS (N=20)	DS (N=17)
Total motor X SCAS	r=332., *p*=.165	R=-.028, *p*=.914

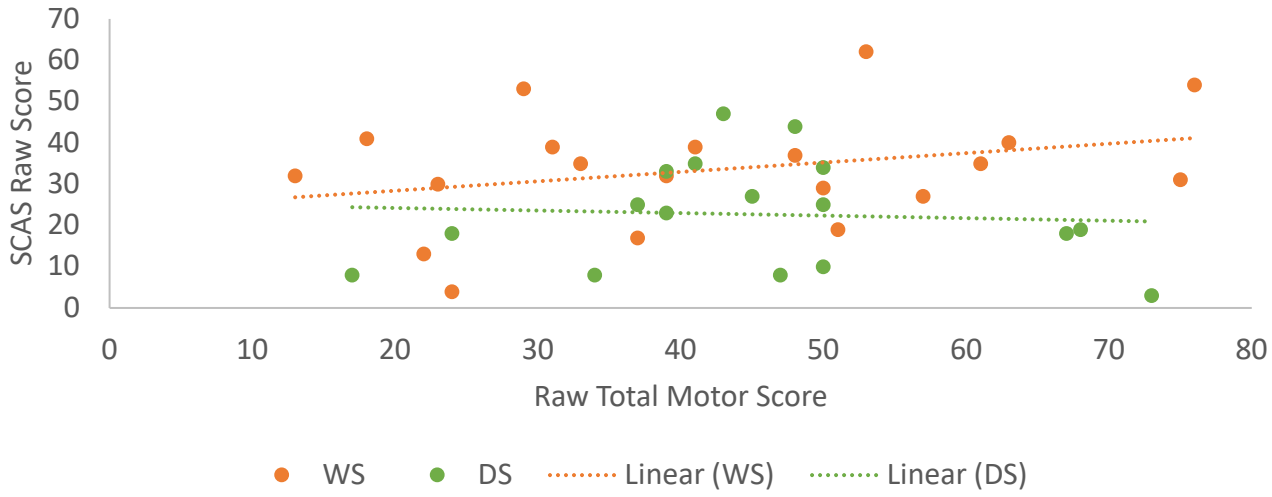

Figure 15. Scatter plots to show correlations between total motor ability and SCAS raw score for the WS and DS groups.

Self-rated anxiety

Descriptive statistics of the self-rated anxiety for each task on the BOT2-SF can be found in Table 19. Repeated measured ANOVA was conducted to investigate whether participants rated themselves as feeling more anxious on some of the 14 different BOT2-SF tasks than others. There was a significant difference between self-rated anxiety on the BOT2-SF tasks ($F(1,38)=5.668$, $p<.001$, $\eta^2=.133$). There was no main effect of group ($F(1, 38)=.220$, $p=.880$, $\eta^2=.001$) or interaction between group and self-rated anxiety ($F(1,38)=.647$, $p=.815$, $\eta^2=.017$) indicating that this was the case for both groups. In the WS group, Sidak pairwise comparisons indicate participants rating themselves as feeling less anxious on the Pennies task than on the Path task, the Star task, the Hopping task and on the Balance task ($p<.05$ for all). There were no other significant differences between self-rated anxiety on the other BOT2-SF tasks. In the DS group, there was a significant difference between self-rated anxiety on the Square and Sit-up's task, with participants rating themselves as more anxious to perform the Sit-up's task ($p=.046$). There were no other differences in self-rated anxiety in the DS group ($p>.05$ for all).

Table 19. Means (SD) of the reported self-rated anxiety for the WS and DS groups (1= not anxious at all, 5= extremely anxious).

Task	WS (N=21)	DS (N=18)
Drawing through a Path	2.70 (1.342)	2.39 (1.461)
Drawing a Square	2.20 (1.508)	1.72 (1.074)
Drawing a Star	2.80 (1.436)	2.89 (1.231)
Folding paper	2.05 (1.234)	1.89 (1.079)
Pennies	1.40 (0.754)	1.89 (1.183)
Tapping	1.60 (0.754)	1.78 (1.114)
Jumping in place	2.00 (1.076)	2.00 (1.328)
Hopping	2.85 (1.631)	2.56 (1.464)
Walking in a straight line	1.85 (1.309)	2.06 (1.474)
Balancing	2.85 (1.565)	2.44 (1.542)
Dropping and catching a tennis ball	1.80 (1.105)	2.11 (1.231)
Dribbling a tennis ball	2.25 (1.209)	2.11 (1.278)
Push-ups	2.80 (1.765)	2.72 (1.526)
Sit-ups	2.45 (1.669)	2.67 (1.237)

4.5. Discussion

The aim of this chapter was to explore the potential impact of anxiety on motor ability in individuals with WS and individuals with DS. In line with previous research, it was found that 80% individuals with WS showed clinical levels of anxiety on the SCAS (e.g. Royston, 2017). While individuals with DS, it should be noted that 44% of the DS group did score in the clinical range for anxiety and showed a similar amount of variability in terms of their anxiety as the WS group (WS: mean anxiety score = 33.45, SD = 13.85; DS: mean anxiety score = 22.65, SD = 13.02). However, this does support the hypothesis that individuals with WS would show higher levels of anxiety than those with DS.

As previously mentioned, the main focus of this chapter was on the potential association between motor ability and anxiety in individuals with WS and individuals with DS. However, no correlations were found between motor ability and anxiety in either the WS or DS groups. There were no significant differences between the WS and DS groups on their self-rated anxiety, and neither of the groups were rating themselves as 4 (very anxious) or 5

(extremely anxious) on any task. Instead the group means show scores ranging from 1.72-2.89 (not anxious at all – a little bit anxious). Individuals with DS reported that they were more anxious to perform the Sit-up's task than the Square task. Individuals with WS did not report that they were most anxious to perform any area of the BOT2-SF, but were least anxious about performing the Pennies task. The lack of group effect goes against the hypothesis that anxiety would affect motor ability in individuals with WS due to their high levels of anxiety generally (e.g. Stinton et al., 2010; Woodruff-Borden et al., 2010). The results from the DS group were expected, as it was not hypothesised that anxiety would affect motor ability in this group due to their reported low levels of anxiety (e.g. Graham et al., 2005; Haveman et al., 1994; Einfeld et al., 1999). This will be explored further below.

4.5.1. Anxiety

As previously mentioned, 80% of the sample of individuals with WS were above the clinical cut off for anxiety on the SCAS. This is in line with previous research, which has consistently found high levels of anxiety in this group in comparison to both the general population (Baxter et al., 2013; Somers, Goldner, Waraich & Hsu, 2006) and to other populations with neurodevelopmental disorders (Dykens et al., 2005; Pegorara, Steiner, Celeri, Banzato & Dalgalarrondo, 2014).

In comparison to individuals with WS, 44% of the DS sample scored above the clinical cut off point. However, it was found that 44% of the DS participants did score in the clinical range for anxiety. According to McManus, Bebbington, Jenkins, Brugha (2016), the prevalence of anxiety in the general population is 5.6%, so there are significantly more individuals in our sample scoring in the clinical range than would be typically seen. This goes against previous research showing similar levels of anxiety in DS to the general population (Graham et al., 2005; Haveman et al., 1994; Einfeld et al., 1999). Therefore, this study replicates previous research that found high rates of anxiety in the WS group (Baxter et al.,

2013; Somers, Goldner, Waraich & Hsu, 2006), but it found higher than expected rates of anxiety in the DS group (Graham et al., 2005; Haveman et al., 1994; Einfeld et al., 1999). This may be because this study was advertised as a study investigating the affects of anxiety, and therefore, parents and carers of individuals with DS who do experience anxiety may have been more motivated to get involved. It may also be due to the fact that many of the DS individuals SCAS questionnaires were completed by the professionals that work with them (in community centres), which also may have affected the scores. For example, it may be that individuals with DS act differently away from home than they would do in their own homes with parents, and so present with more symptoms of anxiety to these professionals. Additionally, it may be that professionals working in these community centres have had some training on recognising mental health difficulties and so are more likely to pick up on the signs of anxiety than parents of individuals with DS. However, this was not data that was gathered, and so these are speculations.

It was also hypothesised that individuals with DS would score significantly lower than individuals with WS on their overall anxiety. This was supported as there was a significant difference between total anxiety in the WS and DS groups, with the WS group experiencing significantly more anxiety than the DS group. Again, this is in line with previous research that has shown that individuals with WS are more likely to experience anxiety than other individuals with neurodevelopmental disorders, including those with DS (Dykens et al., 2005; Pegorara et al., 2014).

However, it should be noted that both the WS and DS groups showed a large amount of heterogeneity of their anxiety scores. For example, while the group mean for the WS group on their overall anxiety score was 33.45, some individuals were getting scores of up to 54, whereas others were getting as low as a score of 4. Similarly, in the DS group, the mean score was 22.65, however some participants were getting scores of up to 47 and as low as 3. This

indicates that anxiety is more of a difficulty for some individuals with WS and DS than others.

4.5.2. The relationship between motor ability and anxiety in WS and DS

As previously discussed, there is a relationship between anxiety and motor ability in the general population (e.g. Dewer et al., 2002; Erez et al., 2004; Green et al., 2006; Kristensen & Torgersen, 2007), with individuals who experience higher anxiety also experiencing more motor difficulties, and vice-versa. It was, therefore, hypothesised that there would be a correlation between anxiety and motor ability in individuals with WS, who experience both significant motor difficulties (Chapter 2) and high anxiety (e.g. Baxter et al., 2013; Dykens et al., 2005; Pegorara et al., 2014; Somers et al., 2006). However, it was found that there was no relationship between motor ability and anxiety in either group. This was hypothesised for the DS group, as this group was not thought to experience high anxiety based on previous research (Graham et al., 2005; Haveman et al., 1994; Einfeld et al., 1999). The finding that there was no association between anxiety and motor ability in WS is surprising, as strong associations were predicted between anxiety and motor behaviour. Further, higher than expected levels of anxiety were found in the DS group, and therefore, the expected correlation in the WS group would also have been expected in the DS group based on these high rates of anxiety. It appears from these findings that, while individuals with WS experience motor difficulties and high anxiety, these two factors are unrelated, and that anxiety cannot be used to help explain the motor difficulties in WS.

4.6. Limitations

The sample size of this chapter was 21 individuals with WS and 18 individuals with DS. The analysis plan (Appendix A) showed that the minimum number of participants needed for reliable results was N=26 participants per group. While every effort was made to reach this number, it was not possible to recruit larger numbers of participants. As previously

mentioned, both the WS and DS participants were opportunity samples, and because only one person (the researcher) was involved in recruitment and testing, larger numbers could not be found. However, this small number of participants means that caution is advised in regards to the interpretation of these results, and if this study was to be replicated, a larger sample of participants should be included.

The anxiety measure used was the Spence Children's Anxiety Scale, which was adapted to be used with the adults in this population where necessary (e.g. if the question was about school, options for college and work were given also, etc.). However, it may have been more appropriate to use an anxiety measure designed for use with both adults and children, or a measure that had a child and adult version. This would have provided the researcher with standard data on the levels of anxiety in individuals with WS and individuals with DS in comparison to chronological age matched population samples. Further, Royston, Oliver, Howlin and White (2021) found that that there were no correlations between SCAS score and the frequency or severity of anxiety symptoms in parental interviews using the 5-p's formulation framework. This suggests that the SCAS may not be an accurate measure of anxiety in WS. In the current study, the clinical cut off of the 84th centile was used as this is the cut off that has been used in previous studies with WS (e.g. Riby et al., 2014). However, this cut-off point is standardised for typically developing children and not adults or individuals with intellectual disabilities. The SCAS was chosen as it has been used successfully with adults with WS previously (e.g. Dodd et al., 2009; Riby et al., 2014; Rodgers et al., 2012). Nevertheless, other anxiety measures should have been considered in the design of this study, and the fact that they were not is a limitation of the current research.

Hermans, van der Pas, and Evenhuis (2011) conducted a systematic review of different methods of assessing anxiety and depression in individuals with intellectual disabilities. In their search of the literature, they found 38 screening instruments for anxiety,

20 for depression and 20 for both anxiety and depression. However, only 22 of these measures had been developed exclusively for individuals with intellectual disabilities. Once measures that were specifically designed for children were excluded, 8 measures remained that measured anxiety. When these measures were evaluated by an expert panel, only three measures of anxiety were thought to be suitable, 2 of which were self-report measures and one an informant report measure. The self-report measures were: the Glasgow Anxiety Scale for people with intellectual disabilities (GAS-ID, Royal College of Psychiatrists, 2001) and the anxiety subscale of the Hospital Anxiety and Depression Scale (HADS-A, Zigmond & Snaith, 1983). The informant report measure that Hermans et al. (2011) recommended was the Anxiety, Depression and Mood Scale (ADAMS, Esbensen, Rojahn, Aman & Ruedrich, 2003). The GAS-ID consists of 27 items which cover 10 of the DSM-5 diagnostic criteria for symptoms of anxiety. The reliability, validity and internal consistency of the GAS-ID are good, and scores range from 0-54, with a clinical cut off of $\leq$17. The HADS-A consists of seven items which cover 4 of the 24 DSM-5 diagnostic criteria for symptoms of anxiety. However, this measure was designed for use in the general population, and therefore there are no norms for populations with intellectual disabilities. The ADAMS was designed for use with adults with intellectual disabilities, and consists of five subscales, exploring different areas of anxiety (e.g. general anxiety). The test-retest reliability, internal consistency and interrater reliability of the ADAMS are 'good'. It is reported by Hermans et al. (2011) that self-report measures are preferable to informant-report measures with individuals with mild-to-moderate intellectual disabilities as they allow for insight into cognition and feelings of the individual, whereas informant-report can only report on observable behaviour. However, self-report can only be used effectively when the questions are phrased at the appropriate level for the level of intellectual functioning of the individual. If the current study was run again, both self-report measures (such as the GAS-ID or the ADAMS), alongside parent report measures.

This would allow the researcher to get both parents and the individual with WS or DS's perspective on their own mental wellbeing. The ideal way to measure anxiety from a parent's perspective would have been to conduct clinical interviews with each family. However, this method would take a long time and may not be reasonable for the purposes of research. The GAS-ID also has a parent version of the questionnaire, which is approved for use by therapists under National Institute for Health and Care Excellence (2019) guidelines (NICE, 2019).

Individuals with WS and individuals with DS may have potentially had some problems with understanding the questions on the self-rated anxiety questionnaire scale. While every effort was made to clearly explain the questions to participants, it was sometimes the case that participants would answer as if they were being asked how easy they thought the task would be, or how able they felt to complete the task, rather than how worried they were about doing the task. Participants were given frequent reminders during questioning, for example, the experimenter would say "how worried or nervous would you feel if I asked you to …" and remind participants that it did not matter whether they thought they would be able to do the task, it was simply asking if it made them feel anxious. It was also sometimes the case that participants, particularly those with WS, would report that they felt "great" about performing all the tasks as they wanted to please the experimenter and say what they assumed the experimenter wanted to hear. This was raised by some of the parents who sat in on the testing sessions, and when it was time for the participants to actually take part in the tasks, they were clearly visibly anxious, though this observation was anecdotally made by the experimenter and was not recorded.

4.7. Conclusions

As expected, the WS group experienced higher anxiety than the DS group. No correlations were found between anxiety and motor ability in either group. This was expected

in the DS group, as this group is not known to experience high anxiety, but was not expected for the WS group. It appears that, while both groups experience low motor ability (Chapter 2), and the WS group experience high anxiety, these two variables are unrelated. When asked to rate how anxious they would feel about performing different motor tasks, the WS group did not report feeling more anxious about any area of motor ability over another. The DS group, were most likely to report high anxiety for the Sit-up's task in comparison to some (but not all) other motor tasks, followed by the Balance and Star tasks.

Chapter 5

Influence of Anxiety and Motor Ability on Daily Living Ability

5.1. Introduction

5.1.1. Daily living skills in WS

One of the main restrictions to quality of life and independence in WS is their reported low levels of daily living skills. Brawn and Porter (2018) conducted a systematic review of the research undertaken investigating adaptive functioning in WS. This review identified 22 published studies and two PhD dissertations that met the criteria for inclusion. Common findings across studies were that, for children and young people with WS, Socialisation and Communication skills were found to be better than Daily Living skills. Further, it was found that, in studies which also included an assessment of motor skills, these were a weakness in comparison to all other skills. However, for adults with WS, a different pattern emerged over studies. In the studies conducted with WS adults, Socialisation skills remained the highest area of ability, followed by Daily Living Skills, with Communication skills being the lowest area of functioning in this group (Cherniske et al., 2004; Davies, Howlin & Udwin, 1997; Howlin, Davies & Udwin, 1998; Howlin, Elison, Udwin & Stinton, 2010). However, this was not always the case. Fu (2015) investigated adaptive behaviour in 100 adolescents and adults with WS aged 12-53 years using the Scales of Independent Behavior-Revised (SIB-R; Bruininks, Woodcock, Weatherman & Hill, 1996), which measures Social Interaction, Communication, Community Daily Living Skills, Personal Daily Living Skills and Motor Skills. The author found that participants scored lowest on their Community Daily Living Skills and Motor Skills, followed by their Personal Daily Living skills. Fu (2015) found no correlation between age and Community or Personal Daily Living Skills or Motor skills. This study did not investigate whether there was an association between motor deficits and daily living skills. Further, while the SIB-R can be split into fine

and gross motor skills, the author only gives details outlining overall motor ability. It would have been helpful to note whether there were any differences between fine and gross motor skills in the WS group using this questionnaire. The difference between this study by Fu (2015) and other studies included in the systematic review may be the use of assessment tool. Fu (2015) measured adaptive skills using the SIB-R, whereas the majority of other studies used the Vineland Adaptive Behavior Scales, Interview Edition (VABS; Sparrow, Balla & Cicchetti, 1984) to assess adaptive functioning. The SIB-R combines the Social Interaction and Communication into one domain, whereas the VABS splits these into their own separate domains.

Many of the above studies included in the systematic review reported group means, which can obscure information about individual variability. However, Howlin et al. (2010) did investigate individual differences in adaptive functioning in their study and found that individual variability was relatively small. Mervis et al. (2001) examined the strengths and weaknesses of domain scores for each child in their study and found that 66% of children showed the same pattern of strengths and difficulties demonstrated at the group level. However, Brawn and Porter (2014) found that individual patterns of scores did not always reflect the group pattern of strengths and weaknesses. For example, while the group profile showed a relative strength in their Socialisation skills, when individual profiles were examined 61% of individuals showed a relative strength in their Daily Living Skills.

In a survey of 119 adults with WS aged 16-38 years, Udwin (1990) identified that most of their sample were unable to live independently and reported needing significant amounts of ongoing support and supervision to complete everyday daily living activities. The majority of the group (74%) were living at home with their parents, and none of the group lived alone or were married. In terms of independence in daily living skills, it was found that the majority of the sample were able to use the toilet (88%) and dress and bathe

independently (66% and 61% respectively). However, only 7% of the sample were able to manage their own money and only 13% of the sample could cook a meal.

Elison, Stinton & Howlin (2010) investigated health and social outcomes using parent interviews in 92 adults with WS aged 19-55 years who participated in a cross-sectional study, and 43 individuals who participated in a longitudinal study (mean age at time of initial testing: 24.9 years; mean age at follow up: 37.3 years). It was found that, in the group as a whole, over 75% of the group were able to perform self-care tasks with minimal or no help, and over 50% of the group were able to make independent decisions regarding their self-care (e.g. knowing when to change into clean clothes). However, a much smaller proportion were able to perform daily chores without difficulty, and only 37% were able to organise all their own routine daily activities. In the longitudinal sample, significant improvements in self-care scores were seen over time, in particular in the numbers of adults requiring no help to complete self-care activities and complete routine household chores. These findings were also reflected in the individuals' VABS scores, which also showed improvements in the Daily Living and Socialisation domains.

Dilts, Morris and Leonard (1990) tested 32 individuals with WS aged 3-30 years and gathered information from a further 37 individuals aged 8 months to 31 years using a parent report, though the authors do not state what measure they used specifically or if they made the interview themselves. They found that, in both adults and children with WS, 36% of the sample were unable to cut food or spread butter with a knife, and a further 29% could only do this poorly. Another finding was that individuals with WS have a low tolerance for frustration, which many authors believe contributes to their unwillingness to attempt daily living tasks, which in turn leads to lower scores on parent questionnaires. If this is the case, it may be that parents will not ask their son or daughter to complete tasks to avoid this anxiety and frustration. This could lead to the individual not having the opportunity to practice the

task and improve. Dilts et al. (1990) hypothesised that the poor daily living skills reported by parents were due to the individuals' poor motor skills. However, while the authors talk about motor skills affecting a variety of activities of daily living skills, they do not provide any specific examples of this beyond using a knife to spread butter. It appears that the authors did ask for details on more activities of daily living and gathered more detailed information on motor abilities, however, they did not provide any details for this in the paper. The authors also did not report what parent questionnaire they used to gather this information.

Hamner, Lee, Hocking and Vivanti (2019) investigated the shared and syndrome specific adaptive difficulties in 18 children with WS (mean age=47 months) and 26 children with ASD (mean age=45 months) using the VABS-II. It was found that, unsurprisingly, the children with WS showed significantly better socialisation skills than children with ASD. However, there were no other differences between the groups. Unlike in previous studies (Dimitropoulos et al., 2009; Greer et al., 1997; Hahn et al., 2014; Mervis & John, 2010; Mervis et al., 2001; Rowe, 2007), the WS sample in this study were not significantly different on their Motor, Daily Living or Communication skills. Further, in this study, the group means for all areas of adaptive functioning in the WS group were $\geq$70, which indicates better functioning than has been found in previous studies. However, this sample consisted of much younger children than have been included in previous research (age 3 years), which may account for the different profile of abilities seen in these children in comparison to the children in other studies. This may also indicate that the development of adaptive functioning may start to show wider gaps between individuals with WS and typically developing children as these individuals get older and are expected to perform more complex tasks.

Overall, these studies suggest that individuals with WS present with difficulties in performing activities of daily living both in childhood (e.g. Dimitropoulos et al., 2009; Greer et al., 1997; Hahn et al., 2014; Mervis & John, 2010; Mervis et al., 2001; Rowe, 2007) and

into adulthood (Cherniske et al., 2004; Davies et al., 1997; Howlin et al., 1998; Howlin et al., 2010).

5.1.2. Daily living skills in DS

As in the WS research, the studies investigating daily living skills in DS have focussed on parent reports of daily living ability, and many combined daily living skills with other functional skills, such as communication and social skills. This may lead to daily living scores appearing lower, particularly in regard to combining the score with communication, as individuals with DS are known to have poor language abilities, which may limit their communication (e.g. Silverstein et al., 1982; Wang, 1996).

Carr and Collins (2018) conducted a longitudinal study over 50 years with individuals with DS investigating various areas of functioning. From the original sample of 54 individuals with DS, 27 individuals were still in the study at age 50 years. The individuals who took part in the study were first seen and tested at 6 weeks old, then at 4-year intervals until 21 years, then at 30 years, thereafter at 5-year intervals to age 45 and then at age 47 years (Carr, 1975, 1995, 2000, 2003, 2012; Carr & Collins, 2014) and finally at age 50 (Carr & Collins, 2018). 18% of the group were found to be in the strongly suspected or confirmed dementia group at age 50. Results indicate that, even when the individuals with confirmed or suspected dementia were discounted, many of the individuals' scores had declined. This included scores of non-verbal IQ, self-care skills and memory. For self-care specifically, scores on feeding, washing and toileting, as well as overall self-care skills had declined significantly over the 50 years for the whole group of individuals. This suggests that the needs of individuals with Down Syndrome may increase over time, putting more of a strain on the healthcare system and families looking after these individuals. One potential limitation of this, and other longitudinal studies involving people who spend some of their life in care,

is the high turnover of healthcare staff. This leads to multiple informants and, therefore, some potential inconsistencies in the information gathered for the study.

It appears from the literature that individuals with DS show impairments in functional skills from a young age. Results from Dolva, Coster and Lilja (2004) report that 5-year-old children with DS (N=43) showed a wide variability in their functional skills when measured using the Paediatric Evaluation of Disability Inventory Functional Skills scales (Nordmark, Orban, Hägglund & Jarnlo, 1999). The weakest area of performance was in self-care activities that required good fine motor skills, such as using a toothbrush (11.6% of the sample able to achieve independently) fastening trousers (4.7%) and zipping zips (7%). However, the authors did not measure motor skills in this study, so there is no information on whether children with better fine motor skills would be able to perform better on these tasks.

In another study investigating daily living in children with DS, Leonard, Msall, Bower, Tremont and Leonard (2002) used the Functional Independence Measure for Children (WeeFIM, Wong, Wong, Chan & Wong, 2002) to measure self-care, communication and social skills in 211 children with DS aged 5 to 17-years. They found that severe functional limitations were rare, with only 5% of children requiring help on tasks, but 25% to 45% of children required supervision to complete self-care tasks. In a similar study using the WeeFIM, Lin et al. (2015) tested 166 children with DS aged 3 to 16-years and found that this group showed deficits in their everyday functional skills, such as eating, dressing and toileting, but that functional skills improved with age. However, while this data showed that 36% of the sample required help or supervision on tasks of self-care, the authors did not split the group into different age groups, so it may be possible that only the younger children required help on self-care tasks, and they brought the group mean down.

Jacola et al. (2014) investigated behaviour and adaptive functioning in 52 adolescents aged 12-18 years with DS using the Behavioral Assessment System for Children, second

edition (Reynolds & Kamphaus, 2004) and the Child Behavioral Checklist (Achenbach & Edelbrock, 1991). It was found that parents and caregivers were most likely to report problems relating to activities of daily living and functional communication. Again, this study did not give any details on what activities of daily living skills specifically were measured, and the authors speak specifically about communication skills and cognitive flexibility under this category rather than more practical activities of daily living (such as getting dressed, cooking, cleaning, personal care, etc.). It is, therefore, unclear from this paper whether the daily living skills (getting dressed, cooking, cleaning, etc.) were measured at all.

Dykens, Hodapp and Evans (1994) examined the profiles and developmental trajectories of adaptive behaviour in 80 children with DS aged 1-11 years. The authors used the VABS and found that the children with DS showed a relative weakness in their Communication skills in comparison to their Daily Living and Socialisation skills. This is unsurprising considering the particular weakness individuals with DS show in regard to their language abilities (e.g. Silverstein et al., 1982; Wang, 1996). However, this is not to say that Daily Living abilities are a strength for children with DS, as it was found that, overall, children with DS in this sample were performing with a mean age of 3.32 years on their Daily Living Skills (mean age of the whole sample=6.08 years). The authors also found that adaptive skills appear to plateau at around age 6 to 7 years in DS and at this point, generally, children do not appear to make any significant improvements in their skills in any domain. It would be interesting to know whether children with DS would begin to make improvements again as they enter the teenage years (and therefore secondary school), as this is the age where, typically, you would expect young people to begin to desire more independence. Indeed, Dressier, Perelli, Feucht and Bargagna (2010) found that, in their study of 75 individuals with DS aged 4 to 52 years individuals continued to make improvements in all three areas of adaptive functioning (as measured by the VABS).

Van Duijn, Dijkxhoorn, Scholte and van Berckelaer-Onnes (2010) also used the VABS to assess adaptive functioning in 984 Dutch children with DS aged 0-12 years. It was found that, in comparison to chronological age norms, children with DS acquire their adaptive skills at a slower pace. As in Dykens et al. (1994), Van Duijn et al. (2010) found that Communication skills were the weakest area of functioning, though Daily Living Skills were still significantly below chronological age expected norms. This study, along with the studies by Dykens et al. (1994) and Dressier et al. (2010), addressed the development of adaptive skills with increases in age. However, none of these studies employed a longitudinal design and instead used a cross-sectional design where they compared the scores of different participants across ages. As the scores of the DS group are much more heterogeneous in terms of their adaptative skill achievement in comparison to typical norms, a longitudinal design would be the more ideal method to test potential improvements or plateaux in performance in this group.

However, there have also been several studies investigating daily living skills and adaptive behaviour in adults and older people with DS. Holland, Hon, Huppert, Stevens and Watson (1998) used the Cambridge Examination for Mental Disorders (CAMDEX; Roth et al., 1986) on a population-based sample of 75 older individuals with DS aged 30-59 years. The authors found that, with increasing age, individuals with DS have declines in memory and other areas such as daily living skills and general functioning. However, the two oldest people who were both over 60 showed no signs of deterioration in any area of functioning. One limitation of this study is that the CAMDEX has not been evaluated as an assessment tool for people with DS or other learning disabilities, although the authors did find total agreement between clinical notes and CAMDEX diagnosis in 21 subjects.

Carfi et al. (2019) collected data on a number of factors, including activities of daily living, in 430 adults with DS (aged 18-75 years) from three countries (Italy, the United States

and Canada). They used the interRAI intellectual disability assessment tool (Martin, Hirdes, Fries & Smith, 2007) to measure adaptive functioning. They found that 28% of the Italian sample, 56% of the US sample and 63% of the Canadian sample required assistance to complete activities of daily living. However, as this study measured a wide range of factors (such as cognitive status, aggressive behaviour, residential status, communication, hearing and toileting problems, physical symptoms, etc.) an in-depth analysis and discussion of daily living skills was not included. Indeed, it is not clear from the paper what specific activates of daily living were included in the questionnaire. There was also a difference between the different counties as to the amount of help that each group needed in order to complete activities of daily living, but the authors do not make any suggestions as to why there are cultural differences or what these may be. For example, it was found that none of the Canadian sample were living at home (44.4% living in group homes and 55.6% living in an 'institution'), and therefore, these individuals may have less opportunities to be independent depending on how these residences are set up compared to the Italian and US samples where more individuals lived in privet residences.

Matthews et al. (2018) conducted an assessment of health, social, communication and daily living skills of 157 adults with DS aged 20 to 69 years. The authors designed their own survey based on work by Bertoli et al. (2011). It was found that, the majority of the DS individuals had no difficulties performing tasks of everyday self-care (e.g., eating meals, dressing self, washing self, etc.). However, parents reported that many individuals were either unable to or had great difficulty performing domestic activities, such as cooking meals (11.8% showed no difficulty), doing laundry (28%) and doing errands (18%). The authors also found that skills started to decrease after the age of 40 years in all domains, which may correspond to the higher rates of early onset Dementia in DS (Wisniewski, 1990). One of the main limitations of this study was that the survey developed by the authors does not appear to

have been piloted or validated, although it was developed based on some previous research Bertoli et al. (2011).

While there is no research that has investigated the association between motor abilities and daily living skills in WS, there has been some investigation into this relationship in DS. Volman, Visser and Lensvelt-Mulders (2007) assessed motor abilities (using the M-ABC, Henderson & Sugden, 1992) and parent rated adaptive behaviour skills, split into self-care skills, such as getting dressed; mobility, such as climbing stairs; as well as social function, such as friendships. They worked with 25 children with DS aged 67 to 94-months and report significant correlations between motor ability and functional skills. Indeed, their study showed that, at 5 to 7-years-old, motor ability was more of a significant predictor of functional skills than cognitive ability. However, the authors do not take into account other potential factors that may influence functional skills, such as motivation. Indeed, Gilmore, Cuskelly and Hayes (2003a) have found that children with DS have deficits in their motivation to master skills and show more task-avoidant behaviour than children with intellectual disabilities without DS (Gilmore, Cuskelly & Hayes, 2003b).

Beqaj, Tërshnjaku, Qorolli and Zivovic (2018) used the GMFM-88 and a balance task to assess gross motor skills and the nine-hole peg test to assess fine motor skills in 44 children and adolescents with DS aged 3 to 18 years. They also assessed functional skills using the PEDI-CAT and found that the nine-hole peg test explained 75.5% of the variance in the Daily Activities section of the PEDI-CAT, which increased to 80.4% when grip strength was added. The PEDI-CAT also showed strong and significant correlations with the GMFM-88 and performance on the balance task. This is further evidence of an association between motor abilities and daily living skills in people with DS.

Overall, these studies suggest that individuals with DS show difficulties in independently performing activities of daily living. There is also some evidence to suggest an

association between motor ability and functional skills (e.g. self-care and mobility) in this group (Dolva et al., 2004; Volman et al., 2007).

5.1.3. Summary

There has been little research investigating daily living skills in WS or DS, and what has been carried out has only employed parent questionnaires to measure daily living skills in this population, for example, the Vineland Adaptive Behavior Scales (VABS, Sparrow, Cicchetti & Saulnier, 1989) (e.g. Davis et al., 1997; Gosch & Pankau, 1994; Mervis, Klein-Tasman & Mastin, 2001) and WeeFIM (Lin et al., 2016; Leonard et al., 2002). This may lead to parents under or overestimating their child's ability. It also does not give any details of why daily living ability may be poor, for example, are skills poor due to high anxiety and intolerance to frustration, or to poor motor abilities or to poor planning ability? Nevertheless, it has been found in these studies that daily living skills are poor in both WS and DS. These difficulties have also been hypothesised to be associated with parent report measures of motor ability in WS (Gosch & Pankau, 1994; Mervis, Klein-Tasman & Mastin, 2001) and with motor assessments in DS (Volman et al., 2007). This suggests that individuals with better motor abilities have better daily living skills, and in turn may have increased independence and a better quality of life.

What has not yet been implemented, however, is an actual practical assessment of daily living skills in WS or in DS, to better investigate whether certain daily living skills are more impaired than others, and if so, whether these are related to specific motor skills. In the design of this study, an occupational therapist was contacted for advice, and they were unable to provide any appropriate tools that could be used to collect practical daily living data that could be used for research purposes. The occupational therapist recommended looking at the Assessment of Motor and Process Skills (AMPS, Fisher and Bray Jones, 2006), which is a tool used by occupational therapists to assess an individual's activities of daily living and/or

independence. The AMPS include' measures such as meal preparation, dressing, household cleaning and shopping. While the AMPS is a comprehensive tool for assessing daily living ability, it was not an appropriate tool to use for this study for several reasons. First, the assessment was developed for use by occupational therapists, and was designed to be used on an individual basis, not to collect data from large numbers to compare. This means that each individual would need to be observed doing each task, detailed qualitative notes would be taken, and each task would be scored on a range of criteria. The AMPS scores the individual on 35 different areas (such as co-ordinating objects, applying knowledge, heeding advice, stabilizing the body and temporal organisation, to name a few) for each individual task, which is above and beyond what is needed for this research. Second, the task assesses many daily living activities, some of which would not be appropriate for this study, due to time constraints e.g. going shopping, or tasks that would be intrusive, such as getting dressed. The AMPS was not developed to be used in its entirety, i.e. occupational therapists use the AMPS to gather information based on each individuals daily living need to inform and design interventions. Since the data has been collected, the researcher has spoken to another two occupational therapists working within the NHS, and they were also unable to think of any measure of daily living that could be used to collect practical data from a large number of people to be used for research purposes.

This study adds to the current research as it is the first study to use a practical daily living assessment with individuals with WS and individuals with DS. This gave the researcher the unique opportunity to film the individuals performing the tasks and the chance to investigate the ways in which these tasks were performed. This was also the first study to directly assess the association between motor ability and daily living ability in individuals with WS and individuals with DS.

This chapter is split into two sections. Section 5A will discuss the initial information gathering about daily living abilities in individuals with WS and with DS. This information from section 5A was used for the design of the practical daily living assessment in section 5B. Section 5B will then outline the procedure of the daily living assessment and daily living ability in individuals with WS and with DS both from a parent perspective (parent questionnaire), using the Vineland Adaptive Behavior Scale, second edition (VABS-II, Sparrow, Cicchetti & Balla, 2005) and from a practical assessment (practical daily living task, P-DLT). It will also investigate potential associations between motor ability, anxiety and daily living ability in these groups.

5A. Designing the P-DLT

5.2. Information gathering about daily living skills in individuals with WS and individuals with DS.

5.2.1. Aims

The aim of this study was to gather more information on the types of daily living skills that individuals with WS and individuals with DS can achieve, and the level at which they can achieve them. This enabled us to better design a practical daily living assessment for these populations.

5.2.2 Hypothesis

There is very little research into daily living skills in older children and adults with either WS or DS, so it is difficult to make any strong predictions. It has been found that children and adults with WS and children with DS show difficulties in their daily living skills (e.g. Davis et al., 1997; Gosch & Pankau, 1994; Leonard et al., 2002; Lin et al., 2015). It is therefore hypothesised that individuals in our study with WS and with DS will also to show difficulties with their daily living ability, particularly on tasks that require a good mastery of motor skills.

It is also difficult to form hypotheses about which kinds of daily living tasks individuals with WS and DS will find most difficult due to the lack of previous research. Some tentative hypotheses can be made, however, based on the motor data from Chapter 2. It is predicted that tasks that require good fine motor precision, an area of motor ability that was found to be impaired in Chapter 2 in individuals with WS and individuals with DS, would be more difficult for these individuals with WS and DS than tasks that do not require such fine motor control. These tasks are: tying shoelaces, using a spoon, knife and fork, and turning on and off a tap.

5.3. Methods

5.3.1. Participants

Parents of 36 individuals with WS, were contacted via email asking them to complete a short online questionnaire on daily living ability. Participants from the WS group were contacted from email addresses provided by the Williams Syndrome Foundation, UK. All WS participants contacted had a positive FISH test, which confirms a deletion of the elastin gene on the long arm of chromosome 7 (Lenhoff, Wang, Greenberg, & Bellugi, 1997). Participant details can be found in Table 20. Parents of individuals with DS were recruited via social media. This yielded a final sample of 12 WS responses, aged 10 to 53-years, and 27 DS responses. Five DS respondents were excluded due to being under 8 years of age, leaving a final sample of N=22 participants with DS aged 9 to 32-years. The age of 8 was chosen as the minimum age, as it was thought, based on previous research from the lab, that participants with WS and DS under this age would have difficulty completing the tasks chosen and struggle to concentrate for the required amount of time.

Table 20. Participant mean (SD) age and gender details from the WS and DS groups.

	WS (N=12)	DS (N=22)
Mean age: years (SD)	20.8 (8.57)	24.2 (7.45)
Gender (M: F)	5:7	9:13

5.3.2. Design of the online pilot Daily Living questionnaire

The pilot Daily Living questionnaire was designed based on some of the daily living items taken from the Vineland Adaptive Behavior Scales, second edition (VABS-II; Sparrow, Cicchetti & Saulnier, 2016). As mentioned above, the VABS-II has been often used with populations with both WS and DS over a variety of ages. As there has been no research thus far that has undertaken a practical assessment of daily living skills in either WS or DS, and because the VABS II questionnaire data on daily living skills does not provide details of specific areas of strengths and weaknesses, this pilot Daily Living questionnaire was used to gather more information on daily living ability. Items from the VABS-II that were chosen were ones that were thought to require motor ability in some way to complete (such as doing up buttons on a shirt or zipping up a bag). The exact wording on the VABS-II was not used, as items were often shortened or adapted to be more concise (e.g. 'buttons small buttons in the correct button holes' from the VABS-II became 'doing up buttons on a shirt' in the pilot Daily Living questionnaire; and 'zips zippers that are fastened at the bottom (e.g. in jeans or trousers, backpacks)' in the VABS-II became 'zipping up a bag' in the pilot Daily Living questionnaire, etc.).

The pilot Daily Living questionnaire was presented using Qualtrics and consisted of 37 daily living questions where parents or carers of individuals with WS or DS were asked to rate on a three-point scale ('can do', 'can do with help' and 'cannot do') regarding how well their son or daughter could complete a variety of daily living tasks. Because we are interested in the potential impact of motor ability on daily living, the specific items that featured in the questionnaire were chosen because they were considered to relate to, or rely on, motor ability. Some example items from the questionnaire, that were sourced and re-worded from the VABS-II are 'putting on shoes with laces', 'using a knife and fork together' and 'using a brush or hoover to clean'. Some example items from the VABS-II which were not included

as they are thought to relate less explicitly to motor ability are ‘tells time in 5-minute increments’ and ‘uses the telephone’.

5.4. Results of the online pilot Daily Living questionnaire

Results from the online pilot Daily Living questionnaire are outlined in Table 21 below and show specific areas of strengths and weaknesses in each group.

To examine specific areas of strengths and weaknesses in each group, the ‘can do with help’ and ‘cannot do’ trials were combined. To organize the tasks with reference to the practical daily living task (P-DLT: see Section 5B), if 75% or above of the group were in the ‘can do’ category, this area was considered a relative strength for this group. If 50% or below of the group were in the combined ‘can do’ category, this area was considered a relative weakness for this group. If 51% to 74% of the group were in the ‘can do’ category, this was considered neither a strength or weakness in the group and was classed as a ‘medium difficulty’ task. These percentages were chosen for practical reasons to split up the tasks. For example, if over 50% of the group could not complete the task then it was felt that the majority of the group would find this task difficult, and if over 75% of the group could complete the task, it was assumed to be a relatively easy task for these populations. The tasks that 51%-74% of the group could complete without help were therefore seen as ‘medium difficulty tasks that showed more variability between participants.

Table 21. Percentage of participants in each group who were able to perform the task independently. Green indicates a strength in the group, red indicates a weakness and orange indicates the task was neither a strength nor weakness in the group.

	WS (N=12)	DS (N=22)
Task	% Can do	
Putting on socks	91.6%	82.6%
Putting on shoes (no laces	91.6%	82.6%
Putting on shoes (with laces)	16.7%	8.7%
Putting on a t-shirt	100%	87%
Putting on a shirt*	66.7%	78.3%
Doing up buttons on shirt	33.3%	39.1%
Zipping up a bag	83.3%	78.3%
Zipping up a coat	66.7%	60.9%
Putting clothes the right way around	50%	47.8%
Folding clothes	8.3%	47.8%
Putting on trousers	83.3%	78.3%
Turning on taps	91.6%	73.9%
Washing hands	83.3%	78.3%
Brushes hair	58.3%	73.9%
Fill a glass with water	83.3%	56.5%
Make a cup of tea	66.7%	39.1%

Butters bread	58.3%	52.2%
Make a sandwich	50%	48.5%
Open a packet	91.6%	65.2%
Uses a spoon	100%	91.3%
Uses a fork	91.6%	91.3%
Uses a knife	50%	65.2%
Uses a knife and fork	66.7%	65.2%
Drink from cup	91.6%	91.3%
Walk with full cup	75%	69.6%
Walk with full plate	58.3%	78.3%
Make a simple hot meal	8.3%	20.1%
Uses a brush or hoover*	33.3%	47.8%
Brushes teeth	75%	73.9%
Uses toilet	91.6%	69.6%
Bathes or showers	41.7%	56.5%
Wash/dry hair	50%	52.2%
Does washing up	25%	30.4%
Clears up after self	41.7%	56.5%
First aid	25%	30.4%
Uses simple appliances	50%	47.8%
Uses a sharp knife	16.7%	34.8%

* Indicate missing data in the WS group.

5.5. Discussion

The aim of the pilot Daily Living questionnaire was to gain a better picture of the daily living abilities of older children and adults with WS and with DS in the UK. As so little research existed, particularly for older individuals with either WS or DS, the pilot Daily Living questionnaire was necessary to, firstly understand whether or not older children and adults with WS or DS *have* difficulties with their daily living skills at all, and secondly, to find out what kinds of daily living skills they may or may not struggle to perform.

Overall, the data from the daily living questionnaire suggests that, both children and adults with WS and with DS require at least some help on many activities of daily living. Common weaknesses over both WS and DS were putting on shoes with laces, doing up the buttons on a shirt, making a simple hot meal, doing the washing up, performing simple first aid, and using a sharp knife when cooking. For the first two tasks, doing up shoe laces and doing up buttons, it is likely that problems with fine motor skills may be limiting performance in successfully completing these tasks without help. It was shown in Chapter 2, and in previous research (WS: Tsai et al., 2008; Wuang & Tsai, 2017; DS: Capio et al., 2018; Jobling, 1998; Rigoldi et al., 2011; Wang et al., 2012) that both individuals with WS and individuals with DS showed difficulty in their fine motor skills. This relationship will be explored further in section 5B.

For the tasks of making a simple hot meal, doing the washing up and performing simple first aid, there may be difficulties around planning the task alongside motor difficulties. For example, to make a hot meal, you would need to make sure you have all the ingredients needed, measure out quantities, cook different things for a certain amount of time, add ingredients in a certain order, etc. Deficits in planning have been found in both WS (e.g. Costanzo, Varuzza, Menghini, Addona, Gianesini & Vicari, 2013; Menghini, Addona, Costanzo & Vicari, 2010; Rhodes, Riby, Park & Campbell, 2010) and DS (e.g. Lanfranchi,

Jerman, Dal Pont, Alberti & Vianello, 2010; Rowe, Lavender & Turk, 2006), and these, alongside their poor motor ability, may lead to these individuals feeling less confident performing these tasks alone.

Interestingly, common strengths were also identified in WS and in DS. These were putting on socks, putting on shoes with no laces, putting on a t-shirt, doing up the zip on a bag, putting on trousers, turning on/off taps, washing hands with soap and water, using a spoon, using a fork, drinking from a glass cup and walking with a full plate without spilling. These strengths are perhaps expected however, as these are all items that individuals would be required to practice every day from a young age, and may be items that parents would be more likely to encourage their son or daughter to practice and to perform these tasks independently. Indeed, the individuals themselves may be more motivated to perform these simpler everyday tasks to boost their own independence, particularly as they get older, where they may be less likely to want parents or carers to help dress them etc. More complex tasks that require more planning, such as washing up or clearing up, may be more difficult for parents to motivate their son or daughter to engage with for various reasons, such as parents losing patience, or the individual with WS or DS showing anxiety or frustration during the task. Similarly, tasks that require fine motor skills, such as doing up buttons or tying shoelaces, may be avoided, e.g. by not wearing clothes with buttons or buying shoes with Velcro, as these tasks may prove too difficult and cause unnecessary distress to the individual.

Overall, the results from this pilot Daily Living questionnaire show that older children and adults with both WS and with DS are showing difficulties with a range of daily living tasks, particularly on more complex tasks that may require good mastery of fine motor skills, such as tying shoelaces. These individuals also show some strengths in their daily living skills, such as putting on socks and using a spoon, but these tasks are ones that you would

expect a child to be able to achieve on their own during the primary school years. It is therefore unsurprising that these more well practiced daily living skills are being performed better by these older children and adults. It is likely that these poor daily living skills are having a real impact on independence and quality of life in individuals with WS and individuals with DS, and may even be contributing to the poor mental health that is often noted in populations with WS and DS (e.g. WS: Papaeliou et al., 2012; Stinton et al., 2010; Woodruff-Borden et al., 2010; DS: Collacott et al., 1992; Cooper & Prasher, 1998). Given the range of scores, the Practical Daily Living Task (P-DLT) presented below was designed to include the full range of difficulty levels, coupled with logistical choices of which tasks were suitable to be part of a practical daily living task.

5.5.1. Limitations

There are some limitations to the initial fact-finding questionnaire. One limitation is the small number of respondents to the questionnaire. Only 36 individuals with WS were contacted to take part. This is due to the researcher trying to limit responses to being only from individuals over the age of 8 years, having a positive FISH test and having an email address to contact. If social media had been used, as it was in the DS participants, it may have yielded a larger sample of individuals with WS. However, if this method was used for the WS participants, responses could have been given by those without a positive FISH test. One way to combat this would be to have a check box at the start of the questionnaire for those parents of children with WS to tick if their son or daughter had a positive FISH test.

Another limitation is the choice of items included in the initial fact-finding questionnaire. Some of the items, such as making a simple hot meal, would not be appropriate for the younger participants included in the sample. This should have been considered better when deciding which items to include in the questionnaire. The items were chosen to include a range of tasks with varying difficulties to try to tease apart the kinds of

tasks that individuals with WS and individuals with DS find more easy/difficult. For example, a difficult task that you would expect a child to perhaps be starting to complete at age 8 years is tying shoe laces, and so more items like this should have been included, rather than items like using a sharp knife and preparing a meal, which you would not expect even a typically developing child to be able to perform.

The initial fact-finding questionnaire was also not piloted. However, as this questionnaire was used only to help inform the design of the practical daily living task outlined below, it was not used to directly answer any of the thesis research questions. The advantage of piloting the fact-finding questionnaire, perhaps with typically developing individuals as well as with parents of individuals with WS or DS, would have been that it could have informed the ages that would be appropriate to include in the study. Parents also would have had the opportunity to provide feedback on the kinds of questions that should have been included.

Another limitation of this initial fact-finding questionnaire was that there were no 'non-motor' items included (such as telling the time, planning for the weather, etc.). It may have been interesting to have these non-motor items to see if there were any initial differences in task difficulty between 'motor' and 'non-motor' items. If it was the case, for example, that parents were reporting that the 'motor' items were more difficult than the 'non-motor' items, this may have provided further evidence for the effect of poor motor ability in daily living ability. However, it is unlikely that these 'non-motor' items would have scored as easier than the 'motor' items, as these tasks would likely involve areas of cognition that individuals with WS and individuals with DS show deficits in, such as difficulties in planning (WS: Costanzo, Varuzza, Menghini, Addona, Gianesini & Vicari, 2013; Menghini, Addona, Costanzo & Vicari, 2010; Rhodes, Riby, Park & Campbell, 2010; DS: Lanfranchi, Jerman, Dal Pont, Alberti & Vianello, 2010; Rowe, Lavender & Turk, 2006).

5B. Implementing the P-DLT

5.6. Aims

The aim of the current study was to investigate performance on activities of daily living in WS and in DS using the Vineland Adaptive Behavior Scale, second edition (VABS-II, Sparrow, Cicchetti & Balla, 2005) and a novel Practical Daily Living Task (P-DLT). The second aim of this study was to examine the impact of poor motor ability and high anxiety on activities of daily living in WS and in DS.

A number of measures were employed. There were two measures of daily living. First, the Vineland Adaptive Behavior Scale, second edition (VABS-II: Sparrow, Cicchetti & Balla, 2005). This is a parent questionnaire, used to assess daily living ability. Second, the Practical Daily Living Task (P-DLT). This is a novel, practical daily living assessment designed for use with individuals with WS and DS.

To measure anxiety, three measures were used. First, The Anx-DLQ, a novel parent questionnaire, where parents are asked to state whether each item on the VABS-II would make their son/daughter feel anxious. Second, the Spence Children's Anxiety Scale (SCAS: Spence et al., 2003) as discussed in Chapter 4. Third, the SR-Anx (self-rated anxiety), a novel scale verbally given to participants which asks how nervous they would feel about performing the various tasks on the P-DLT. Finally, our motor measure was the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition short form (BOT2-SF; Bruininks & Bruininks, 2005), as discussed in earlier chapters. For more details on these tasks, see Section 5.10.2.

5.7. Hypothesis

It was hypothesised that individuals with WS and individuals with DS would show deficits in their daily living skills as measured by the VABS-II. It was predicted that individuals with WS and DS would show poor performance on the P-DLT. This was

predicted because of previous findings of low daily living ability in children and adults with WS (e.g. Howlin, Davis & Udwin, 1998; Mervis & Klein-Tasman, 2000) and DS (Dykens et al., 1994; Leonard et al., 2002; Lin et al., 2015), particularly in tasks of self-care, which were the types of tasks that were tested in the daily living assessment.

It was also hypothesised that there would be correlations between motor ability and daily living, both using the VABS-II and the P-DLT. It was hypothesised that high anxiety would be associated with poor daily living skills in the WS and DS groups, as these groups both presented with high anxiety in the previous chapter of this thesis (Chapter 4), and individuals with WS are known to show high levels of anxiety (Papaeliou et al., 2012; Stinton et al., 2010; Woodruff-Borden et al., 2010). However, anxiety was not expected to be as associated with poor daily living skills as motor ability was.

5.8. Methods

5.8.1. Participants

The participants used in this study were the same as the participants in Chapter 4. Participant details can be found in Table 22. Again, as in Chapter 4, there were some instances where parents did not fill in all online questionnaires, so there is some missing data. These include 1 participant in the WS group and 1 participant in the DS group who do not have SCAS information, 2 participants in the WS group and 2 participants in the DS group who do not have VABS-II data. These participants were, therefore, excluded from analysis where SCAS and VABS-II data were used.

Table 22. Participant details.

	WS (N=21)	DS (N=18)
Mean age (years:months) (range age years)	20:9 (8-36)	24:2 (12-35)
Gender F:M	12:9	9:9
BPVS-III[1] raw score	119.24 (62-160)	103.78 (55-135)
RCPM[2] raw score	17.75 (5-30)	17.78 (8-34)

[1] British Picture Vocabulary Scale, Third Edition
[2] Ravens Colour Progressive Matrices

5.8.2. Design

Motor ability

Motor ability was assessed using the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition short form (BOT2-SF; Bruininks & Bruininks, 2005). More details on the method of running the BOT2-SF are shown in Chapter 2 of this thesis.

Anxiety

Anxiety was assessed first using the Spence Children's Anxiety Scale (SCAS: Spence et al., 2003), where parents were asked to rate their child on a scale of 0-3 (never – always), depending on how well different statements applied to their son or daughter. Second, participants were asked before doing the daily living tasks to rate themselves on a visual scale of how nervous or worried they felt about doing different motor tasks. This task will be here-on referred to as SR-Anx. For more details on the anxiety measures, please see Chapter 4 of this thesis.

Daily living

Daily living ability was assessed in two ways. Firstly, as discussed above, parents were asked to complete the VABS-II daily living questionnaire. The daily living section of the VABS-II has excellent internal reliability (range of .84-.90) good split-half reliability (range of .84-.92) and good inter-rater reliability (range .89-.97) (Sparrow, Cicchetti & Balla, 2005). This questionnaire asked parents to rate their child on a 0-2 scale (0 = usually, 1 = sometimes, 2 = never) on a range of daily living tasks. This allowed the researcher to obtain a standard score based on chronological age for the WS and DS groups.

As previously mentioned, relying on parent questionnaires alone comes with issues (see section 5.1.2 and 5.1.4) and so a novel practical assessment of daily living ability was designed, here-on referred to as P-DLT. The practical daily living task was also used in addition to the parent questionnaire as the researcher wanted to investigate how the participants were performing the task, and not just whether or not they could complete the task itself. Participants were asked to complete a practical daily living assessment (P-DLT), designed based on the pilot Daily Living parent questionnaire in section 5A. Of the items from the pilot Daily Living questionnaire, some would not be appropriate for experimental purposes, either because they would intrude on the individual's dignity (e.g. getting dressed), would be unsafe (e.g. using a sharp knife, making a cup of tea), or would not be practical during the time constraints of testing (e.g. making a simple hot meal). For these reasons, some items were not considered for inclusion in the P-DLT.

For the design of this study, a mixture of tasks were used. Four tasks that participants have been rated as being able to do on their own are included and were dispersed through the task. These tasks served four purposes: the first is that they would provide encouragement and a sense of achievement for participants and thereby make it more likely that they will engage with the task. The second is that it would then be possible to see how these tasks are

correlated with motor abilities. The third is that, while participants may have been able to achieve the task, they may have done so using alternative strategies to typically developing individuals. Finally, it was also used to validate the full range of abilities and make sure that parent reports were accurate in terms of what the participant can and cannot do on their own.

A further four tasks were included that seem likely to be 'middle difficulty' tasks, since only around half the sample were able to complete these tasks without help on the initial questionnaire, and so it is likely that these tasks were still causing significant difficulties for the groups as a whole. It is also possible that, as in the 'can do' tasks, alternative strategies were being used to achieve the tasks.

Lastly five of the lowest rated tasks that are common to both WS and DS were included to see if these tasks are particularly related to poorer motor abilities. These five tasks were also chosen as, of the set of low rated tasks, these were the tasks that could be completed practically in the testing environment. The tasks were washing up and drying items, clearing up, tying shoelaces, and doing up buttons (see table 22). There are five tasks in this section rather than four as, originally, the washing up and drying task were one task, but as testing began, it became apparent that these tasks should be split into two separate tasks. Initially, when this task was designed, the washing-up task consisted of both 'Washing-up and drying items'. However, once testing began, it became clear that these tasks should be split into two separate tasks. Therefore, there is an extra task in the 'difficult' tasks than in the 'easy' and 'medium' difficulty tasks.

In total, the daily living task consisted of 13 tasks (four easy, four middle difficulty, and five difficult). These were given in a fixed random order to avoid participants losing motivation. They were also ordered so that some tasks will flow naturally into others (e.g. putting on a shirt and then doing up the buttons). Participants were given as much time as

they needed to complete each task, and the whole P-DLT took, on average, around 20 minutes to complete.

Participants were tested in a quiet room either in their own home or in the university in one session, lasting between 1 hour 30 minutes and 2 hours. Participants were shown a video of what they should do and were given the same items as in the video to complete the task (with the exception of the turning on and off taps task, where they used a tap in their home or in the university, and the putting on shoes (no laces) task, where they put on their own shoes). They were then asked to complete the task as quickly as possible without making mistakes, and to let the experimenter know when they had finished. It was not observed (or recorded) that any of the individuals found any of the tasks to be more tiring or difficult to understand. As the tasks were designed with individuals with learning difficulties in mind, the instructions were designed to be easy to understand and presented both verbally and visually. No participants expressed confusion or that they did not understand what they were being asked to do. The participants were video recorded performing the task, and the data was coded by both the experimenter and a second coder to ensure inter-rater reliability. The value for Cronbach's Alpha for the P-DLT was $\alpha = .85$. Floor and ceiling effects were also examined, and it was found that both the WS and DS groups were performing above chance and below ceiling on the P-DLT ($p<.001$ for all).

The following table (Table 23) gives a description of each daily living task, along with how each task was coded and scored.

Table 23. A description and explanation of the items and scoring used for the P-DLT.

Task	Time score (secs)	Description	Performance score (out of 7)
Putting on shoes no laces	Start timing when the individual touches the shoe. Stop timing when the shoe is on, or the individual has given up.	Shoes will be put in front of them. Shoes will be facing the right way, and in front of the correct foot. Will be asked to put on the shoes as quickly as possible.	Action: the shoe is held in place (1), making sure the heel of the shoe stays in place (doesn't get tucked in) (1), and put the foot inside the shoe until it is in fully (1). Tool: multiple, appropriate for the shoe (1) ESC: the shoe is held in a way that would allow end-state comfort i.e. the hand holding the shoe is not bent at a strange angle (1). Orientation: The shoe is kept in the correct orientation (the toe of the shoe facing away from the participant) (1).
Tying the laces on shoes	Start timing when the individual touches the shoe. Stop timing when the shoe is tied, or the individual has given up.	A shoe with laces will be placed next to their foot and held in place for them to tie the laces. They will be asked to tie the laces as quickly as possible without making mistakes.	Action: The laces are tied in a knot (1), the bow shape is made (1) and then into a bow (1). Tool: each lace is held in the correct/prototypical way (1) ESC: laces held for end-state comfort (1) Orientation: the laces meet one another (touch) (1)
Putting on a shirt (not doing up buttons)	Start timing when the individual touches the shirt. Stop timing when the shirt is on both arms, or the individual has given up.	Will be given a long-sleeved shirt and be asked to put it on.	Action: the participant puts their arms through the correct sleeves (1 point each sleeve) and pulls the shirt straight (1). Tool: the shirt is held in the correct/prototypical way (1) ESC: held for end state comfort when putting it on (1). Orientation: The shirt is held in the correct orientation (i.e. not back to front, upside-down, etc.) (1).
Doing up buttons on a shirt	Start timing when the individual	Will be given a shirt of the right size. They will be asked to put it on, and to do up all the buttons,	Action: The sides of the shirt are brought together and lined up (1). The participant selects a button and puts it

	touches the first button. Stop timing when the buttons are done up, or the individual has given up.	except the top button. The shirt will be put on over the participant's clothes.	through the correct hole (1) without dropping the button (1). Tool: the button is held in the correct way using a pincer grip (thumb and 1 finger or thumb and two finger). ESC: action affords end-state comfort (1) (e.g. button not held with the hand in an uncomfortable way). Orientation: The participant attempts to button through the back of the hole to the front (1).
Putting clothes the right way around	Start timing when the individual touches the trousers. Stop timing when the trousers are the right way around, or the individual has given up.	Will be given a pair of trousers that are inside-out and be asked to put them the right way.	Action: the participant puts one arm through the trouser leg and grips the end (1), and then pulls it through (1). They then repeat this action on the other leg (1). Tool: various - the trousers are held in the correct/prototypical way (1) usually palmer grasp ESC: held for end state comfort (1). Orientation: The trousers are held the correct way up, so that the top corners can be grasped for putting the arms through the leg holes. (1).
Folding a pair of trousers	Start timing when the individual touches the trousers. Stop timing when the trousers are neatly folded, or the individual has given up.	Will be given a pair of trousers and asked to fold them as demonstrated.	Action: The trousers are folded in half, so the legs come together (1), and then folded again so that the top of the trousers meet the bottom (1), and then folded once more (1). Tool: various correct grips prototypical way, mainly pincer ESC: hold the trousers in a way that would afford them easy folding (1). Orientation: The trousers are held the correct way up, so that the top corners can be grasped for folding. (1).

Fill a glass cup with water from a jug.	Start timing when the individual touches the cup. Stop timing when the cup is full to the line, or the individual has given up.	Will be given a glass cup and asked to fill it to a marked line.	Action: The participant holds the handle (1) and tips the jug to pour water (1) without spilling any (1). Tool: radial palmer grip used. ESC: the handle is grasped the right way around Orientation: The participant pours water from the spout on the jug and not from the sides (1).
Use a spoon to pick up raisins and pour into a bowl e.g. as if weighing ingredients (using correct grip)	Start timing when the individual touches the spoon. Stop timing when the raisins tip into the other bowl without any raisins spilling, or the individual has given up.	Will be given a bowl half full of dried raisins and a spoon. Will be asked to put a spoon-full of raisins on the spoon and move them into another bowl 3 times.	Action: Spoon used to scoop up raisins (1) and move them (1) without spilling any (1) Tool: correct/prototypical grip used on spoon (1). Digital pronate grasp ESC: prototypical Orientation: spoon is held in the correct orientation to pick up the raisins and put them in the bowl (1).
Use a fork to hold soft food and a knife to cut it (using correct grip)	Start timing when the individual picks up the knife and fork. Stop timing when the food has been cut in four pieces, or the individual has given up.	Will be given a knife and fork and a banana. Will be asked to cut the banana into 4 quarters. Picture will be given to model.	Action: Fork used to hold food (1) and knife to cut (1). Both knife and fork used (1). Tool: Knife and fork – correct grips (.5 point for each ESC: prototypical (.5 point for each) Orientation: knife/fork are held the correct way up to allow cutting (.5 point for each).
Turns on and off tap	Start timing when the individual touches the tap. Stop timing when the tap has been switched on and off, or the individual has given up.	Will go to a sink in the kitchen or bathroom and be asked to turn on and off the hot and cold taps.	Action: the tap is turned on (1), without spraying everywhere (1) and off (1). Tool: usually using a palmer grasp (1) (dependent on tap type). ESC: the tap is gripped in a way that affords end-state comfort (1). Orientation: the tap is directly in front of the person (1)
Washing up	Start timing when the	Will be asked to wash up the plate, spoon,	Action: the participant fully cleans all areas of the objects

	individual touches the first item. Stop timing when all items are clean, or the individual has given up.	bowl, fork and knife that were used to move the raisins and cut up the banana.	(1) using the sponge (1) and washing up liquid (1). Tool: multiple, appropriate grip (1). ESC: objects are held in a way that allows end-state comfort e.g. washing up liquid, glass, etc. (1) if 4 or more (of 7) are held correctly then they get the score. Orientation: the majority of the objects (4/7) are held in the correct orientation for washing up (1).
Dry items	Start timing when the individual touches the first item. Stop timing when all items dry, or the individual has given up.	They will also be asked to fully dry the items that they have washed.	Action: the participant fully dries all areas of the objects (1) using the tea towel (1). They put the objects on a dry surface (1). Tool: various, appropriate for drying ESC: objects are held in a way that allows end-state comfort e.g. washing up liquid, glass, etc. (1). Majority (4/7) held with end-state comfort in mind to get point Orientation: majority (4/7) held prototypical for the point (1).
Clears up after themselves	Start timing when the individual touches the first item. Stop timing when all the items are put away, or the individual has given up.	Once the task has finished, the participant will be asked to put the testing materials away into their proper place.	Action: items are put away (1), neatly (1), in the correct way as shown in the video and on the help sheet (1). Tool: various, appropriate grips to securely hold the object put them away without dropping them. ESC: majority of the objects are held with end-state comfort in mind when putting them away to get the point (6/10 items (1)). Orientation: majority of the items are held in the prototypical orientation to get the point (6/10 items (1))

* green= easy task

*orange= medium difficulty task
*red= difficult task

5.9. Results

5.9.1. Analysis and parametric assumptions

Parents were asked to complete the Vineland Adaptive Behaviour Scale, daily living questionnaire (VABS-II), and t-tests were used to investigate differences between the groups on daily living ability. Assumptions of normality were investigated using Kolomorov-Smirnov tests. It was found that data met assumptions of normality on the VABS-II (Kolomorov-Smirnov, $p \geq .05$). Therefore, parametric tests were conducted on the VABS-II data. Participants completed a practical daily living assessment (P-DLT), and this was analysed using mixed ANOVA. It was found that on this measure, the data were not normally distributed in over half the cases (Kolomorov-Smirnov, $p \leq .05$). However, as there is no non-parametric alternative to a mixed ANOVA, parametric tests are reported. However, all main effects and interactions were explored non-parametrically using Wilcoxon Signed Ranks tests, Mann-Whitney tests, Friedman tests and Kruskal-Wallis tests as appropriate, and only reported when results were different from parametric equivalents.

As outlined in Chapter 4, parents completed the Spence Children's Anxiety Scale (SCAS), and it was also found that data met assumptions of normality on the SCAS (Kolomorov-Smirnov, $p \geq .05$). Therefore, parametric tests were conducted on the SCAS data. For the SR-Anx measure, participants were also asked to rate their anxiety on a 5-point scale for each of the P-DLT items. On the SR-Anx measure, the data were not normally distributed in over half the cases (Kolomorov-Smirnov, $p \leq .05$). The SR-Anx was analysed using a mixed ANOVA, and again, as there is no non-parametric alternative to a mixed ANOVA, parametric tests are reported, and all main effects and interactions were explored non-parametrically and only reported when results were different from parametric equivalents. Correlations were carried out to investigate the relationship between total VABS-II score and

score on the SCAS. Correlations were also carried out to investigate the relationship between performance on the P-DLT and score on the SCAS. For correlational analyses, Spearman correlations were used to investigate bivariate correlations as the P-DLT data was not normally distributed.

Participants completed the motor assessment outlined in Chapter 2. As mentioned in Chapter 2, the motor data were normally distributed for the majority of variables (Kolomorov-Smirnov, $p \geq .05$). Therefore, parametric tests were conducted. Correlations were carried out to investigate the relationship between total VABS-II score and motor ability. Correlations were also carried out to investigate the relationship between performance on the P-DLT and motor ability. For correlational analyses, Spearman correlations were used to investigate bivariate correlations as the P-DLT data was not normally distributed.

5.9.2. Daily living ability

First, daily living ability in individuals with WS and individuals with DS was explored. To do this the group's score on the VABS-II parent questionnaire, and the participant's performance on the P-DLT was examined.

5.9.3. Potential effects of age and IQ on daily living ability

Correlations were conducted to consider the potential effect of age on daily living ability in the WS and in the DS groups. This is due to the wide age range of the WS and DS groups, and so it is helpful to know whether age is influencing daily living ability as measured by the VABS-II or the P-DLT. It was found that there was no correlation between age and raw total score on the VABS-II daily living subscale in either the WS or the DS group. There was also no correlation between age and total score on the P-DLT in the DS group. However, there was a significant correlation between age and total P-DLT score in the WS group (Table 23).

Correlations were also conducted to consider the potential effect of verbal and non-verbal IQ on daily living ability in WS and in DS. Again, this was due to the wide age range of participants taking part in the study. It was found that language ability (as measured by the BPVS III) was correlated with performance on the P-DLT in the WS group, but not in the DS group. This was also the case when correlations between the BPVS III and the VABS-II was studied. In the case of non-verbal ability however, there was no correlation for either group between RCPM score and total score on the P-DLT. There were also no correlations between RCPM score and score on the VABS-II for the WS group or for the DS group (Table 24).

Table 24. Correlations between daily living performance (as measured by the VABS-II and the P-DLT) and age, verbal IQ (BPVS) and non-verbal IQ (RCPM) in WS and in DS.

	WS	**DS**
Age X VABS-II	r=.341, p=.167	r=.287, p=.280
Age X P-DLT	**r=.760, p<.001**	r=.310, p=.211
BPVS III X VABS-II	**r=.671, p=.002**	r=1.092, p=.735
BPVS III X P-DLT	**r=.718, p<.001**	r=.111, p=.660
RCPM X VABS-II	r=.475, p=.046	r=.470, p=.066
RCPM X P-DLT	r=.269, p=.251	r=.005, p=.984

*Statistical significance $p<.008$

Parent questionnaire (VABS-II – daily living subscale)

Differences between the three daily living areas measured by the VABS-II (Community, Cares for Home and Cares for Self) were investigated. A mixed ANOVA was conducted, and the within participant factor was VABS-II subdomain (3 levels: Community, Cares for Home and Cares for Self), and the between participant factor was group (2 levels: WS and DS). It was found that there was no main effect of type of daily living ($F(1, 38)=3.818$, $p=.059$, $\eta^2=.104$). There was, however, a main effect of group ($F(1, 38)=4.563$, $p=.040$, $\eta^2=.121$), with the WS group performing below the DS group. There was no significant interaction between group and VABS-II daily living area ($F(1, 38)=3.071$, $p=.053$, $\eta^2=.085$) (Figure 16).

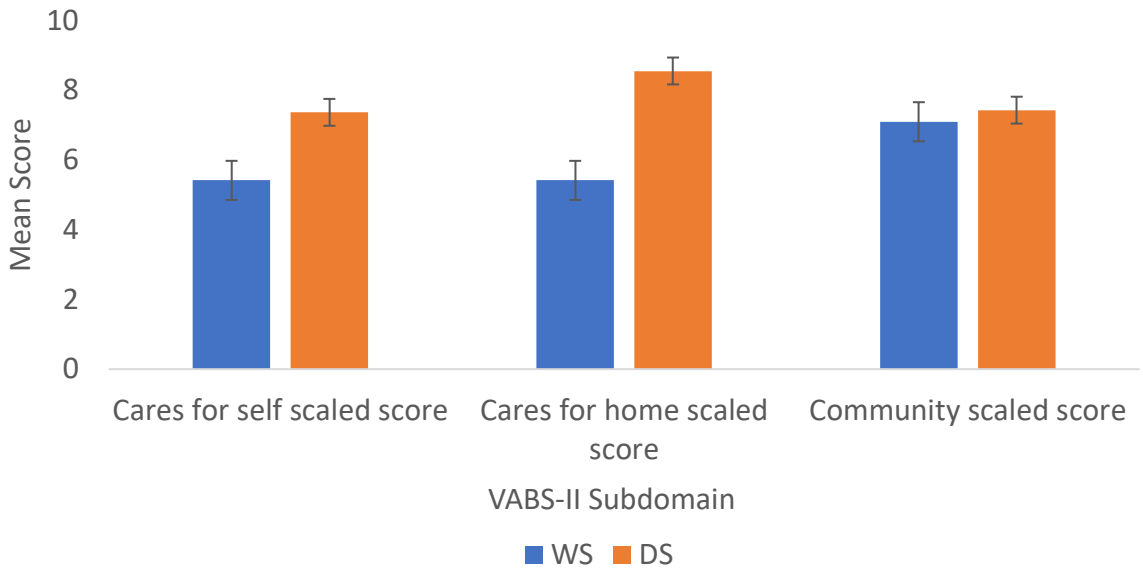

Figure 16. Mean scores for the WS and DS groups on the three subscales of the VABS-II daily living subdomain.

P-DLT

To validate the P-DLT, a correlation was carried out between the total P-DLT score total VABS-II score for both groups. This showed a significant correlation between total score on the P-DLT and total VABS-II score in the DS group, but not in the WS group, when non-parametric Spearman's Rho correlations were conducted (Table 25).

Table 25. Correlations between total score on the P-DLT and total score on the VABS-II.

	WS (N=19)	DS (N=16)
P-DLT X VABS-II	r=.343, *p*=.143	**r=.630, *p*=.009**

As previously mentioned, the total score on the P-DLT was made up of participants scores on four elements (action, tool grip, end-state comfort, orientation) along with whether they got the task correct. Information on total score and scores on each element for each group can be found in Table 26 and Table 27.

Table 26. Mean (SD) total scores of the WS and DS groups on the P-DLT

	WS	DS
P-DTL score	67.52 (13.46)	77.03 (10.12)

Table 27. Mean (SD) scores of the WS and DS groups on each element (action, tool grip, end-state comfort, orientation) of the P-DLT

	WS	DS
Action (max score 39)	28.40 (5.92)	32.11 (5.26)
Tool grip (max score 13)	8.93 (2.53)	10.50 (1.95)
End-state comfort (max score 13)	10.33 (2.06)	11.83 (1.19)
Orientation (max score 13)	11.03 (1.54)	12.19 (10.12)

Dot plots are used to explore individual differences between participants on total P-DLT score (Figure 17).

Participants scores ranged from 38 to 88 in the WS group (mean score=67.52) and from 56 to 90 in the DS group (mean score=77.03) on overall P-DLT performance, indicating that some individuals found the task more difficult than others. There was also a wide range of scores in both the WS and DS groups on the success on strategies used to complete the P-DLT. For Motor Action, scores in the WS group ranged from 16-38 and in the DS group, they ranged from 20-39. For Tool Grip, scores in the WS group ranged from 4-12.5 and in the DS group, they ranged from 5.5-13. For End-State Comfort, scores in the WS group ranged from 6-13 and in the DS group, they ranged from 8.5-13. Finally, for Orientation, scores in the WS group ranged from 7.7-13 and in the DS group, they ranged from 8.5-13.

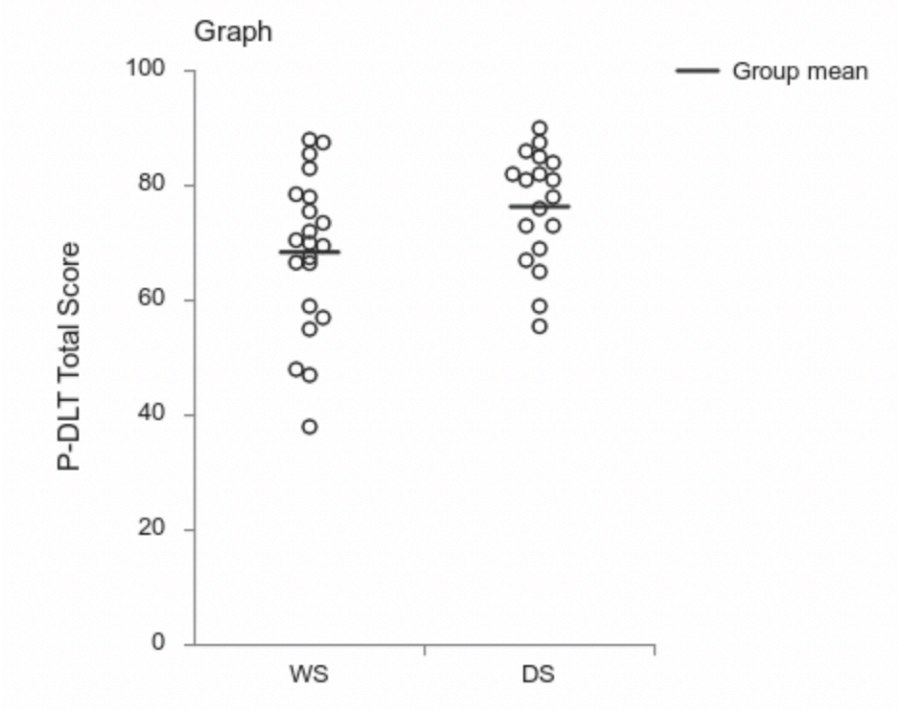

Figure 17. Dot plot to show the range of individual scores on the P-DLT in the WS and DS groups

To explore differences between groups on the various daily living tasks included in the P-DLT, a mixed ANOVA was conducted. The within participant factor was P-DLT task (13 levels), and the between participant factor was group (2 levels: WS and DS). There was a main effect of group, with the WS group performing below the DS group (p=.048). However, non-parametric Mann-Whitney tests did not support this (p=.073). There was a main effect of task on the P-DLT (F(1, 33)=20.551, p<.001, η^2 =.357), indicating that participants found some tasks more difficult than others.

This is best explored within the context of the interaction between group and task (F(1, 33)=2.061, p=.018, η^2 =.053), This was explored further using t-tests to look for differences between groups on each task. T-tests showed that the only significant difference between the groups was on the Folding Clothes task (t(33)=-3.575, p<.001), which the WS group found more difficult than the DS group did. There were no other differences between groups on any other task. Non-parametric Mann-Whitney tests confirm this for the Folding Clothes task (p<.001), but also show that the WS group performed significantly lower than

the DS group on the Knife and Fork task (p=.006). There were no other differences found between the groups (p>.05 for all) (Figure 18).

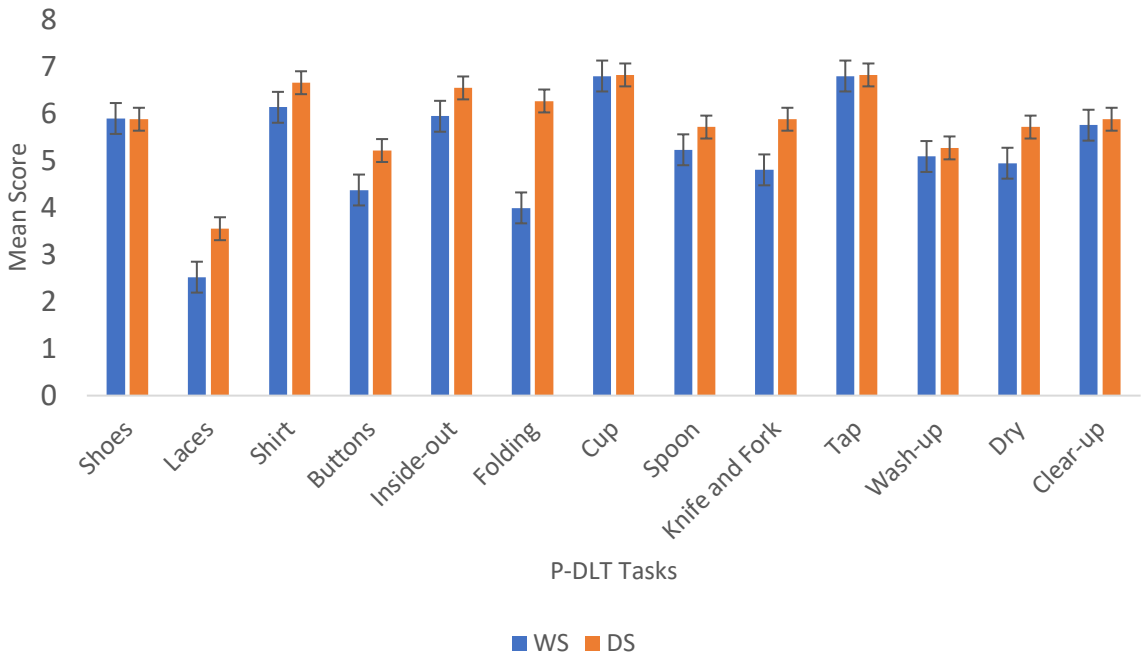

Figure 18. Mean scores for the WS and DS groups on each task on the P-DLT.

5.9.4. Daily living and anxiety

SR-Anx

Repeated measured ANOVA was conducted to explore whether participants rated themselves as feeling more anxious on some of the 12 different P-DLT tasks than others. There was a significant difference between SR-Anx ($F(1,33)=10.643$, $p<.001$, $\eta^2=.223$). There was no main effect of group ($F(1,33)=.136$, $p=.715$, $\eta^2=.004$), and no interaction between SR-Anx and group (($F(1,38)=1.139$, $p=.329$, $\eta^2=.030$), indicating that this was true for both groups. Sidak pairwise comparisons indicate that participants with DS rated themselves as feeling most anxious on the Laces task, which they rated themselves as being most anxious to perform in comparison to the Shoes, Shirt, Folding, Spoon, Knife and Fork, and Tap tasks (p<.05 for all). There were no other significant differences between SR-Anx on the other P-DLT tasks in the DS group (p>.05 for all). Sidak pairwise comparisons indicate

that participants with WS rated themselves as feeling least anxious on the Putting on Shoes task, on which they rated their anxiety lower than on the Laces task, the Folding task, and the Washing-up task (p<.05 for all). Participants with WS rated themselves as feeling most anxious about performing the Washing-up task, on which they rated themselves as higher than the Shoes, Using a Spoon and Tap task (p<.05 for all). There were no other significant differences between SR-Anx on the other P-DLT tasks in WS (p>.05 for all).

Correlations between anxiety and daily living ability

To further explore the relationships between daily living ability and anxiety, total VABS-II daily living score and total SCAS score were analysed using correlational analysis. This showed that there was no relationship between anxiety and daily living ability as measured by the VABS-II for either group (Table 28 and Figure 19).

Table 28. Correlations to explore the relationship between total raw score on the VABS-II and the raw score on the SCAS for the WS and DS groups.

	WS (N=19)	DS (N=16)
VABS-II[1] X SCAS[2]	r=-.287, p=.234	r=-.409, p=.115

[1] Vineland Adaptive Behaviour Scale, third edition

[2] Spence Children's Anxiety scale

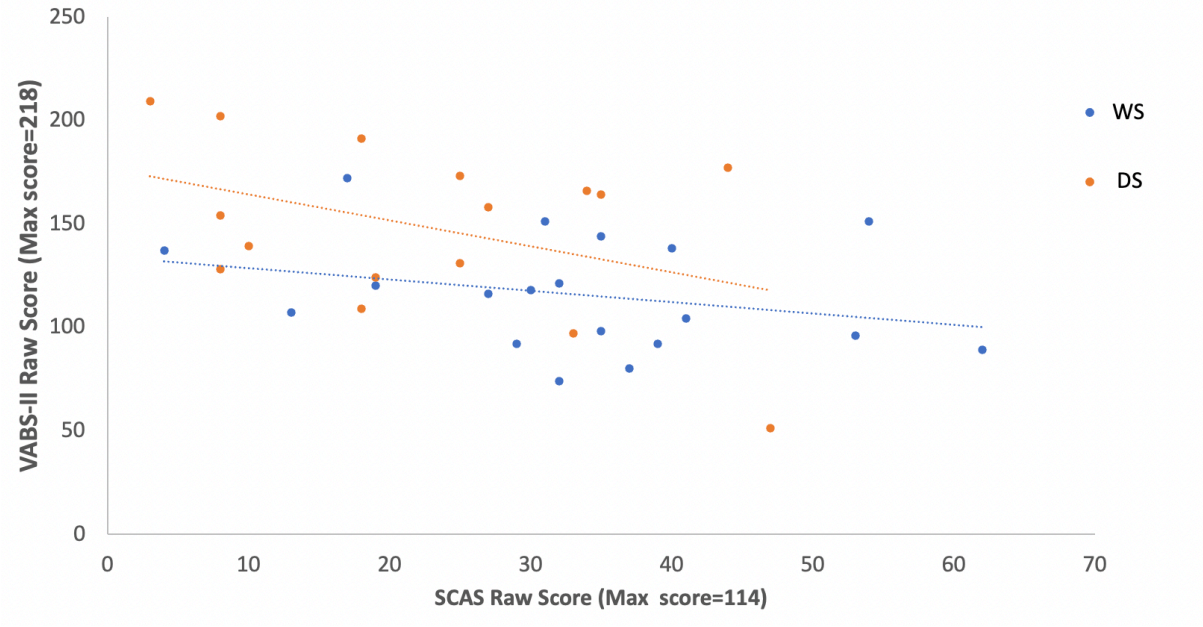

Figure 19. Distribution of scores in the correlations between SCAS and the VABS-II.

We were also interested in whether there was an association between anxiety and performance on the P-DLT. Again, it was found that there was no significant correlation between anxiety and daily living ability for either group (Table 29 and Figure 20).

Table 29. Correlations to explore the relationship between total score on the P-DLT and the raw score on the SCAS for the WS and DS groups.

	WS (N=19)	DS (N=16)
P-DLT X SCAS	r=-.093, *p*=.696	r=.128, *p*=.624

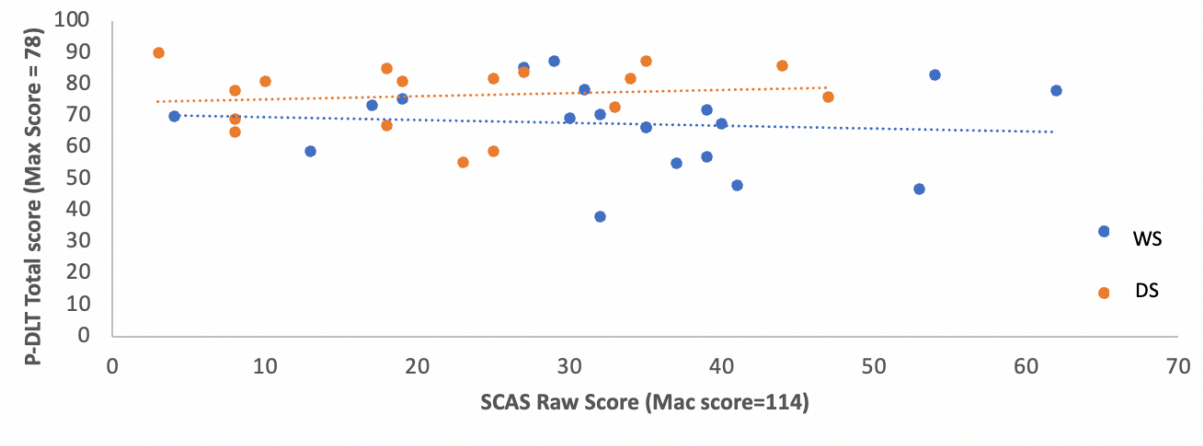

Figure 20. distribution of scores in the correlations between SCAS and the P-DLT.

5.9.5. Daily living and motor

The association between motor ability and daily living ability was investigated. This was achieved by first exploring the relationship between total motor ability and score on the VABS-II. Correlation analysis shows that there was no relationship between daily living ability on the VABS-II and total motor ability for either group (Table 30).

Table 30. Correlations to explore the relationship between total score on the VABS-II and the fine and gross motor scores on the BOT2-SF for the WS and DS groups. Critical alpha value $p<.025$.

	WS (N=19)	DS (N=16)
VABS-II X BOT2-SF fine motor	**r=.555, *p*=.014**	r=.172, *p*=.524
VABS-II X BOT2-SF gross motor	r=.224, *p*=.162	r=.475, *p*=.063

We were also interested in whether there was a relationship between the P-DLT and total motor ability. A strong positive correlation was found for both the WS and DS groups between daily living ability as measured by the P-DLT and both fine and gross motor ability (Table 31).

Table 31. Correlations to explore the relationship between total score on the P-DLT and the fine and gross motor score on the BOT2-SF for the WS and DS groups. Critical alpha value $p<.025$.

	WS (N=19)	DS (N=16)
P-DLT X BOT2-SF fine motor	**r=.720, *p*<.001**	**r=.591, *p*=.010**
P-DLT X BOT2-SF gross motor	**r=.590, *p*=.005**	**r=.592, *p*=.010**

5.10. Discussion

This chapter aimed to practically assess the daily living abilities of individuals with WS and individuals with DS. It also explored the relationship between anxiety and daily living ability and motor skills and daily living ability in individuals with WS and individuals with DS. It was found that, when the VABS-II was split into its three subdomains, there was a significant difference between score on the Cares for Home subdomain, with the WS group performing significantly below the DS group, but there were no significant differences in the Cares for Self or Community subdomains. On the P-DLT, there were no significant differences between groups on overall score when results were analysed using non-parametric tests. When the P-DLT was examined further, it was found that both groups scored lowest on the Tying Laces task, and highest on the Pouring Water from a Jug task in comparison to most (though not all) other tasks. On the Tying Laces task, most participants were not able to tie the laces into a knot (WS: 6/21; DS:8/18 able to tie a knot), and very few were able to make the shape of a bow (WS: 5/21; DS:4/18 able to make a bow shape). The WS group scored lower than the DS group on the Folding and the Knife and Fork tasks. When this was examined further, it was found that the WS group lost more points on all aspects of the Knife and Fork task than the DS group (Motor action: WS=6 instances of lost points, DS=3 instances; Tool grip: WS=17 instances, DS=5 instances; End-state comfort: WS=14 instances, DS=4 instances; Orientation: WS=10 instances, DS=3 instances). Overall, it appears that the WS group are experiencing more difficulties than individuals with DS in regards to their daily living ability.

The potential relationship between anxiety and daily living ability in these groups was also explored. As in the case for motor ability (Chapter 4), it was found that anxiety was not correlated with daily living ability in either group. This was expected for the DS group, as this group is not known to experience high anxiety (Graham et al., 2005; Haveman et al.,

1994; Einfeld et al.,1999). However, this was not expected for the WS group who are known to experience high anxiety (Graham et al., 2005; Haveman et al., 1994; Einfeld, Tonge, Turner, Parmenter & Smith, 1999). When participants were asked about how nervous they would feel about performing the various P-DLT tasks (SR-Anx), participants with DS reported that Tying Laces would make them most anxious. Participants with WS stated that they would feel most worried about doing the Washing-up task, and least anxious about performing the Putting on Shoes task. This shows that, while performance on the P-DLT was not significantly different for the two groups, they anticipated experiencing difficulty on very different tasks. This is explored further below.

Finally, the association between motor ability and daily living ability in WS and in DS was examined. This provided mixed results. It was found that there was no correlation between gross motor ability and VABS-II score for either group, and a correlation between fine motor ability and VABS-II score in the WS group only.

There was also a correlation between motor ability and performance on the P-DLT in both groups. There may be a number of reasons for this, such as parents over or underestimating their son or daughter's ability on the VABS-II, or the fact that all items on the P-DLT required the use of motor abilities to perform the tasks. This will be explored further below.

5.10.1. Daily living abilities in individuals with WS and DS

Daily living abilities in individuals with WS and individuals with DS will first be discussed. As previously mentioned, the WS group scored below the DS group on the Cares for Home subscale VABS-II, but were not lower on the Cares for Self or Community subdomains. One possible reason for this difference may be access to support. Many of the DS group who were included in the sample attended day groups, where they spent much of the day involved in daily living activities (such as washing up, cooking, cleaning, etc.), with

support from staff. These individuals, therefore, take part in, and are encouraged to perform daily living tasks on a day to day basis. In comparison, many of the WS group were not expected to take part in these kinds of activities at home or in the community. Though some of the WS group did report attending college or part-time work, where they would be required to perform tasks such as washing-up and cleaning, this was true for far less of the WS group than the DS group. Therefore, it is possible that the group differences were due to recruitment differences, i.e. the WS group were recruited from contacting families directly and tested at home, whereas the DS group were, mostly, recruited from community centres. It may be that if the DS sample had been recruited in a similar way to the WS group, there may have been less individuals who attended these centres and the results may have been more similar to the WS group, however, this was not possible due to difficulties in recruiting the DS group.

However, the WS and DS group were not significantly different on the P-DLT, and showed similar strengths and difficulties. Both groups scored lowest on the Laces task, and scored highest on the Pouring Water from a Jug task. This may suggest that parents in the DS group may be assuming their son or daughter can perform a task well because they do the task frequently with staff at their day centres (e.g. washing-up), without seeing them perform the task. Indeed, when asked, many parents anecdotally reported that 'they do that at work' or 'they do that with their carer', but do not perform the task at home. Alternatively, parents of individuals with WS may be underestimating their ability to perform activities of daily living. During the WS testing, many parents remarked 'I didn't know they could do that' or 'we always do it for them, so I didn't think they could', though this information was not recorded. It may be that individuals with WS are more capable than parents believe them to be, and that they do not perform certain tasks because they are not motivated to do them and parents do

not ask them to perform tasks. Again, it may be that the differences between groups was due to where they were recruited from (home vs community groups).

However, there were individual differences in the scores of the P-DLT. Participants scores ranged from 38 to 88 in the WS group (mean score=67.52) and from 56 to 90 in the DS group (mean score=77.03) on overall P-DLT performance, indicating that some individuals found the task more difficult than others.

When group differences on each P-DLT were investigated, it was found that the WS group scored lower than the DS group on the Folding task and the Knife and Fork task. Again, this may be due to the differences between where the samples were recruited from (home vs. community groups). The individuals in the DS group who attended day groups or who lived in supported living were expected to learn to do their own washing of clothes and put them away neatly and, also, to eat together as a group. This may have, not only provided more opportunity for learning and practice, but also motivated the DS group to learn these skills like their peers. The WS group were less likely to have these same opportunities as it was anecdotally reported that most of this group did not attend any groups in the community and only one individual lived away from parents in supported living. However, this does not explain why only these two tasks, and no other tasks such as washing-up and clearing things away, were different in the groups, as you would expect the DS group to score higher in other tasks that they had more practice in than the WS group.

5.10.2. The association between daily living ability and anxiety in individuals with WS and DS.

The association between anxiety and daily living ability in the individuals with WS and individuals with DS will now be discussed. It was hypothesised that anxiety would impact daily living ability (or vice versa) in WS as this is a population that is known to experience high anxiety (e.g. Stinton et al., 2010; Woodruff-Borden et al., 2010) and have

poor daily living skills (e.g. Howlin, Davis & Udwin, 1998; Mervis & Klein-Tasman, 2000). However, no significant correlation was found between anxiety and score on the VABS-II or on the P-DLT. This was predicted in the DS group as, even though they have been known to display poor daily living ability (Dykens et al., 1994; Leonard et al., 2002; Lin et al., 2015), this group is not thought to experience high anxiety (Chapter 4). These findings suggest that anxiety cannot be used to explain poor daily living ability in populations with WS or DS. This was the first study to investigate the association between anxiety and daily living ability in these populations. The finding that anxiety is not related to daily living ability in individuals in WS is surprising as an association between anxiety and daily living ability has been found in other populations who experience high anxiety, such as individuals with Autism Spectrum Disorder (e.g. Drahota, Wood, Sze & Van Dyke, 2011). It may be that if this study was replicated with a larger sample, an association would be found. It may also be the case that there is something different about the WS group that is leading to their high anxiety not impacting their ability to carry out daily living tasks. For example, it was previously mentioned that parents anecdotally reported that their son or daughter with WS often was not required to perform many daily living activities, so this group may not feel worried about performing these activities, because they know they usually would not have to.

Finally, we asked individuals to rate how worried they would feel about performing the P-DLT tasks before testing began, using the SR-Anx questionnaire. It was found that the DS group reported that they were most worried about performing the Tying Laces task. This was the task that both groups scored lowest in, and so this may indicate that the DS group were good at predicting that they would find this task difficult. The WS group on the other hand reported that they were most nervous about the Washing-up task, and least nervous about the Putting on Shoes task. All participants tested were expected to put on their own shoes at home (though not to tie the laces if their shoe had laces), so it is unsurprising that

this was a 'low anxiety' task. The Washing-up task may have been worrisome to the WS group for a number of reasons. The first possible reason was mentioned earlier, and this is lack of practice and motivation. If you do not perform the task regularly, or in some cases at all, it is to be expected that there would be some nervousness around performing the task. It may also be that individuals with WS did not enjoy this task due to sensory difficulties (not wanting to touch the water). There have been a number of studies that have investigated sensory difficulties in individuals with WS, though many of them have focused on hypersensitivity to sound (e.g. Dilts et al., 1990; Einfeld, Tonge & Florio, 1997; Klein et al., 1990; Levitin, Cole, Lincoln & Bellugi, 2005; Leyfer et al., 2006; Pober & Dykens, 1996; Udwin & Yule, 1990). There are other studies though that have found that individuals with WS show a range of sensory difficulties, including over or under sensitivity to touch. For example, John and Mervis (2010) found that over 40% of their sample of 78 children with WS showed either over or under tactile sensory sensitivity. When the videos from the P-DLT were examined, some individuals with WS appeared to not want to touch the dirty or wet objects or to put their hands too far in the water. It may be that they were feeling worried not only about performing an unfamiliar task, but also due to the anticipation of having to touch the dirty or wet objects they were washing up. However, we have little evidence from this study to support this, and future research should conduct more of an interview style investigation to find out what particularly about these tasks' individuals are anxious about.

5.10.3. The association between daily living ability and motor ability in individuals with WS and DS

Finally, the association between motor abilities and daily living ability in individuals with WS and individuals with DS will be discussed. The data used to answer this question provided mixed results. It was hypothesied that for both groups there would be significant correlations between motor ability and daily living ability, as both groups have poor motor

ability (Chapter 2) and are thought to have poor daily living skills (WS: e.g. Howlin, Davis & Udwin, 1998; Mervis & Klein-Tasman, 2000; DS: Dykens et al., 1994; Leonard et al., 2002; Lin et al., 2015). When the results from the BOT2-SF motor assessment were correlated with score on the VABS-II, no correlation was found, except in the case of fine motor ability and VABS-II score in the WS group, suggesting that motor ability is not impacting daily living ability, or vice versa. As discussed in the limitations section, this may be due to the VABS-II containing both 'motor' and 'non-motor' items, and it may be that any impact of motor abilities is being diluted by the inclusion of these non-motor items on the VABS-II.

However, strong correlations were found between motor ability and the P-DLT in both groups. To investigate this question further, the P-DLT could be expanded to include an equal number of both 'high-motor' and 'low-motor' items, and see if the 'low-motor' items were less/not correlated with motor ability. Another reason that there was a correlation between the P-DLT and motor ability, and not between VABS-II and motor ability could be that parents may be over or underestimating their son or daughter's ability on the VABS-II. As previously mentioned, parents of individuals with DS included in this study may have over-estimated their son or daughter's ability on some of the daily living tasks, due to the individuals performing certain tasks at their day centres or in supported living. However, in these cases, it is possible that the individual is not performing the tasks independently, but instead with the help of staff or carers. Therefore, when they are tested on the practical task, and they must perform the daily living tasks alone with no help, they struggle more than parents may think. It is also possible that parents of individuals with WS tested in this study were under-estimating their son or daughter's ability, due to parents performing many daily living tasks for their son or daughter, and not giving them the opportunity to do the task themselves. This led some parents to believe that their son or daughter was not capable of performing a task, when in fact they were when tested on the P-DLT.

5.11. Implications and Limitations

The author is cautious about implying any clinical implications of this study due to the fact that this is the first study of its kind, not only with individuals with WS and DS, but also, as far as I am aware, in any population. However, one potential implication is that the P-DLT could be further developed and used with populations with intellectual disabilities to assess their daily living skills quickly without an occupational therapist having to go through the entire assessment of the AMPS. Further, this task does not require any specific training or qualifications to use, and so it could be used by teachers in schools or other researchers. As the scoring method follows a clear pattern for all items (i.e. motor action, tool grip, end-state comfort, orientation and correct), it would be relatively easy for a future researcher to expand on this system and add new items to fit their specific purpose. If this study was focused only on the P-DLT (and not its association with motor ability and anxiety), then this task could have been made longer and a more in depth investigation into daily living skills and the strategies that individuals with WS and DS use to complete them could have been conducted.

One limitation of the current research is the wide age range of the participants. Some of the participants included were children with WS or with DS, and so these younger participants would not have had as much experience as the older participants in performing activities of daily living. Also, these children potentially would have not yet been expected to perform all the tasks given (for example, the washing up task). When age was examined, it was found that, while age did not affect performance on the P-DLT in the DS group, it did affect performance in the WS group. This supports the above suggestion of an impact of experience on performance in the WS group. The youngest participant in the DS group was 12-years-old, whereas in the WS group, they were 8-years-old. This may account for why there was no correlation between age and P-DLT ability in the DS group.

Another limitation of this research is that no information was collected about why individuals did worse on some tasks than others. For example, no data was collected about the individuals home life and living conditions. For example, the majority of individuals with WS lived at home with their parents, however, the researcher did not collect data regarding how much independence the individual was expected to have. Some parents may have spent time out at work whereas others may have stayed at home with the individual with WS. This would be likely to affect how many activities of daily living the individual would engage in if they did not have a parent home to do things for them. The impact of other individual factors was also not assessed, for example, the individual's health status and other mental health difficulties. It was assumed that all individuals tested were of good physical health as parents/carers were asked prior to testing if their son or daughter would be able to perform motor tasks. However, this did not account for if the individual was unwell on that day or if they had had any other recent physical injuries (e.g., bumps, falls, etc.). This study measured the effect of anxiety on daily living ability; however, it did not account for other mental health conditions (such as sensory processing disorder, OCD, depression, etc.) which may have also affected the results. For example, the DSM-5 core symptoms of depression include: "markedly diminished interest or pleasure in all, or almost all, activities most of the day, nearly every day", "a slowing down of thought and a reduction of physical movement (observable by others, not merely subjective feelings of restlessness or being slowed down)" and "fatigue or loss of energy nearly every day". All these core symptoms would likely have a significant effect on an individual's ability to carry out activities of daily living, as well as engage in the assessment process and perform motor tasks to the best of their ability. While depression is not a common difficulty observed in WS (e.g. Porter, Dodd & Cairnes, 2009; Stinton, Elison & Howlin, 2010), it is the most common mental health difficulty experienced in individuals with DS (e.g. Collacott et al., 1992; Cooper & Prasher, 1998).

This study did not measure any non-motor activities of daily living. This makes it difficult to make conclusions about the impact of motor abilities on daily living, as the researcher did not compare the performance of motor daily living activities (outlined in this study) with non-motor activities (such as telling the time, road safety, answering the phone, etc). It is therefore not possible to say from these results whether motor ability would affect all activities of daily living skills or only those which require the use of motor skills. Indeed, when correlations between motor ability and daily living were examined, there were strong corrections between motor abilities and the P-DLT, but less so between motor skills and the VABS-II. This may be because the VABS-II includes a wider range of activities of daily living, some of which do not require the use of motor skills.

As with previous studies throughout this thesis, this study was not piloted. The initial fact finding questionnaire was given to families before the design of the P-DLT to help to give the researcher some examples of appropriate tasks to include in the P-DLT. However, the P-DLT itself was not piloted. This was due to two unavoidable factors. The first was that recruitment of both these populations (WS and DS) was very difficult. As previously mentioned, recruitment took place over a 12-month period, and participants were recruited using a number of methods (such as telephone calls, email, social media, etc.), and still only small numbers could be obtained. Therefore, if this study had been piloted, there would have been fewer participants actually tested, if these numbers could have been found at all. There is also the obvious factor of time. As this study was conducted as part of a PhD thesis, the researcher was under a certain time constraint to collect data to ensure that the thesis was completed on time. This meant that the researcher did not have the luxury of having the time to piolet the study.

5.12. General discussion and conclusions

In this chapter, a P-DLT to be used with individuals with WS and individuals with DS was designed and implemented. In section 5A, an online 'fact finding' questionnaire to gather more information about daily living ability in individuals with WS and individuals with DS was distributed. Common difficulties were identified from this questionnaire. These were: tying shoe laces, doing up buttons, making a simple hot meal, doing the washing up, performing simple first aid and using a sharp knife to prepare food. These common difficulties are thought to be at least partly due to fine motor difficulties that both groups experience (Chapter 2), and also due to difficulties in planning (WS: Costanzo, Varuzza, Menghini, Addona, Gianesini & Vicari, 2013; Menghini, Addona, Costanzo & Vicari, 2010; Rhodes, Riby, Park & Campbell, 2010; DS: Lanfranchi, Jerman, Dal Pont, Alberti & Vianello, 2010; Rowe, Lavender & Turk, 2006). There were also some common strengths identified in the two groups. These were: putting on socks, putting on shoes (no laces), zipping up a zip on a bag, putting on trousers, washing hands, using a spoon and fork, drinking from a full cup of water and walking with a full plate without spilling. These strengths are thought to be due to both practice and motivation to complete these tasks independently, particularly in regards to personal care items, which older children and adults are likely to feel motivated to complete alone. Overall, the online questionnaire found various strengths and difficulties in both groups, and these were used to design the P-DLT.

Section 5B used the data from section 5A to design the P-DLT. In Section 5B, we also examined the results from an established measure of daily living ability (VABS-II). We found that, on the VABS-II, the WS group were performing significantly below the DS group on the Cares for Home subdomain. This may be due to differences in where the samples were recruited from (home vs community) many individuals with DS tested attending community

day groups, whose main aim to teach and improve daily living skills such as cooking, cleaning, etc.

This was then taken further and the impact of anxiety on daily living ability was investigated. It was found that there was no correlation between anxiety and daily living ability in either group. This was predicted in DS, as this group is thought to have low levels of anxiety generally (Graham et al., 2005; Haveman et al., 1994; Einfeld, Tonge, Turner, Parmenter & Smith, 1999), and were not above the clinical cut-off for anxiety as a group when measured by the SCAS (Chapter 4). However, a relationship between anxiety and daily living ability in the WS group was expected, as this group is known to experience high anxiety generally (e.g. Stinton et al., 2010; Woodruff-Borden et al., 2010), and was shown to be above the clinical cut-off for anxiety as a group in Chapter 4. Overall, these findings suggest that while individuals with WS have poor daily living skills and high anxiety, these two variables are unrelated.

Finally, the relationship between motor ability and daily living ability was examined. It was found that there was no correlation between motor ability and score on the VABS-II, however, there was a strong correlation between motor ability and score on the P-DLT. The final chapter of this thesis will bring together the overall message of the research carried out, and discuss how this research might impact individuals with WS and individuals with DS.

Chapter 6

General Discussion

6.1. Thesis aims

The overall aim of this thesis was to investigate motor abilities in individuals with WS and individuals with DS and the broader impact of impaired motor abilities in these groups. To investigate these aims, a cross-syndrome design was used, comparing the performance of individuals with WS and individuals with DS. Using a cross-syndrome comparison allowed the researcher to investigate whether the difficulties that individuals with WS and individuals with DS experience in regards to their motor, spatial, anxiety and daily living ability are characteristic of each disorder, or whether certain difficulties are common to both groups, and may therefore reflect their learning difficulties generally. WS and DS were the two disorder groups chosen because they are both genetic neurodevelopmental disorder groups, both have been found to have a similar average IQ (WS: average 55 (Morris & Mervis, 1999); DS: average 50 (Mégarbané et al., 2013)), both groups have been reported to show motor difficulties in childhood (WS: Tsai et al., 2008; Wuang & Tsai, 2017; DS: Alesi et al., 2018; Jobling, 1998; Malak et al., 2015; Spano et al., 1999) and both have been reported to have difficulties in activities of daily living (WS: Howlin, Davis & Udwin, 1998; Mervis & Klein-Tasman, 2000; DS: Dykens et al., 1994; Leonard et al., 2002; Lin et al., 2015). There are, however, some differences between the groups, such as their reported levels of anxiety. Individuals with WS reportedly experience high levels of anxiety (e.g. Papaeliou et al., 2012; Stinton, Elison & Howlin, 2010; Woodruff-Borden, Kistler, Henderson, Crawford & Mervis, 2010), whereas the DS group have been reported to have low levels of anxiety (e.g. Graham et al., 2005; Haveman et al., 1994; Einfeld et al., 1999). The groups have been reported to present with different cognitive profiles to each other, with the WS group reportedly showing particular difficulties with their spatial abilities within their cognitive profile (e.g. Bellugi et

al., 1994/1999; Broadbent et al., 2014; Hudson & Farran, 2011; Pani et al., 1999; Wang et al., 1995). In contrast, it is thought that individuals with DS show better visuospatial abilities than individuals with WS (Brock & Jarrold, 2005; Cardoso-Martins et al., 2009; Carretti et al., 2013; Edgin et al., 2010; Frenkel & Bourdin, 2009; Jarrold & Baddeley, 1997; Jarrold et al., 1999, 2002; Lanfranchi et al., 2004; Lanfranchi et al., 2009; Numminen et al., 2001; Pennington et al., 2003; Rowe et al., 2006; Visu-Petra et al., 2007; Vicari et al., 1995; Vicari et al., 2006). Further, while both groups have been found to have atypicallities in the structure and function of motor brain areas, such as the cerebellum, these atypicallities are thought to be different for each group. In WS, a slight increase in the relative volume of the cerebellum has been observed in comparison to overall brain volume (Jernigan et al., 1993; Osorio et al., 2014; Reiss et al., 2000; Wang, Hesselink & Jernigan, 1992), whereas in DS, a reduced density in both white and grey matter of the cerebellum has been reported (Baxter et al., 2000; Pinter et al., 2001; Roubertoux et al., 2005; Sveljo et al., 2014). It was therefore interesting to investigate whether these differences in mental health, cognition and brain structure would affect motor ability in these groups differently.

One aim of this thesis was to investigate motor abilities in individuals with WS and DS, and to investigate any specific strengths and difficulties in these groups by examining their motor profiles. This was the aim of Chapter 2, where the aim was to obtain a full motor profile for individuals with WS and individuals with DS, and to investigate how this differed from a sample of typically developing children. The second aim of Chapter 2 was to investigate whether there is an association between motor ability and physical activity for each of these groups, as a relationship between motor ability and physical activity has been found in typical development (e.g. Barnet et al., 2008; Fisher et al., 2005; Oja & Jorimae, 2002; Stodden et al., 2008; Wrotniak et al., 2006).

Once the motor profile for individuals with WS and individuals with DS had been obtained, the researcher was interested in how these poor motor skills were impacting other areas of cognition. It was decided to investigate this question using small scale spatial skills. This was done for several reasons. First, it is known that spatial ability is the weakest area of performance in individuals with WS (e.g. Bellugi et al., 1994/1999; Broadbent et al., 2014; Hudson & Farran, 2011; Pani et al., 1999; Wang et al., 1995), and some evidence to suggest that individuals with DS also show difficulties in their spatial abilities (e.g. Hodapp et al., 1992; Lanfranchi et al., 2004; Pennington et al., 2003), despite some research citing spatial skills as a strength in this group (e.g. Chapman & Hesketh, 2000; Davis, 2008; Moldavsky et al., 2001; Silverman, 2007). There has also been research to show an association between spatial ability and motor ability in typically developing infants (e.g. Clearfield, 2004; Oudgenoeg-Paz, Leseman and Volman, 2015; Schwarzer et al., 2013). Therefore, this potential relationship was investigated in individuals with WS and individuals with DS. This was the aim of Chapter 3, which investigated whether individuals with WS, individuals with DS and typically developing participants would perform differently on two small scale spatial tasks, one with and one without a motor element. Correlations between small scale spatial abilities and motor abilities were also investigated. This allowed us to investigate whether there are associations between motor deficits and spatial abilities in these populations.

During the original motor testing in Chapter 2, it was anecdotally observed that many individuals with WS appeared anxious about performing some motor tasks, particularly the balance task, and often expressed fears of falling and getting hurt or feelings of embarrassment. There is a high incidence of anxiety in individuals with WS (Papaeliou et al., 2012; Stinton, Elison & Howlin, 2010; Woodruff-Borden, Kistler, Henderson, Crawford & Mervis, 2010), and there has been some research to suggest an association between anxiety and motor difficulties (particularly balance) in the general population (e.g. Dewer et al.,

2002; Erez et al., 2004; Green et al., 2006; Kristensen & Torgersen, 2007). The aim of Chapter 4, therefore, was to examine the potential relationship between anxiety and motor abilities in two groups with motor difficulties, one group thought to experience high anxiety (WS), and the other thought to not struggle with anxiety (DS: e.g. Graham et al., 2005; Haveman et al., 1994; Einfeld et al., 1999). The second aim was to investigate whether some motor acts are more anxiety provoking than others in the two disorder groups.

Finally, we wanted to investigate the impact of poor motor ability on everyday life. As previously mentioned, the successful development of motor skills in humans is essential to everything that we do; from feeding ourselves, dressing ourselves and being able to move ourselves independently around our environments. Without adequate acquisition of motor skills, independent living becomes difficult, if not impossible. Both individuals with WS (e.g. Howlin, Davis & Udwin, 1998; Mervis & Klein-Tasman, 2000) and individuals with DS (Dykens et al., 1994; Leonard et al., 2002; Lin et al., 2015) experience difficulties in their daily living ability, and, as discussed above, both groups have poor motor ability (WS: Tsai et al., 2008; Wuang & Tsai, 2017; DS: Alesi et al., 2018; Jobling,1998; Malak et al., 2015; Spano et al., 1999). The aim of Chapter 5, therefore, was to investigate potential associations between motor abilities and daily living abilities in individuals with WS and individuals with DS. Chapter 5A was focussed on gathering more information on the types of daily living skills that individuals with WS and individuals with DS can achieve, and the level at which they can achieve them. This information was then used to design a practical daily living task (P-DLT) to be used for these groups. The aim of Chapter 5B was to then investigate performance of activities of daily living in WS and in DS using the Vineland Adaptive Behaviour Scale, second edition (VABS-II, Sparrow, Cicchetti & Balla, 2005) and our novel Practical Daily Living Task (P-DLT). The second aim of this chapter was to examine how

these activities of daily living were impacted by poor motor ability and anxiety in WS and in DS.

Overall, therefore, this thesis was the first to investigate motor abilities and the motor profile of older children and adults with WS and DS. It is also the first investigation that has looked at the associations between poor motor abilities and other areas of difficulties in these populations. The next section will discuss the findings of this thesis, chapter by chapter.

6.2. Discussion of findings by chapter and ideas for future research

In Chapter 2, it was found that the hypothesised motor deficits were present in both individuals with WS and individuals with DS. Both groups performed at a similar level to the TD4-5 group, and below the TD6-7 group. Further, 34/36 participants in the WS group and all participants in the DS group were in the 'below average' or 'well-below average' zone of the BOT2-SF, which further highlights their motor difficulties.

However, it should be noted that both the WS and DS groups showed a large amount of heterogeneity of their scores in comparison to the older (6-7 years) TD group (range 50-74). For example, while the group mean for the WS group on their overall motor score was 44.86, some individuals were achieving scores of up to 76 (a higher score indicates better performance), whereas others were achieving as low as a score of 12. Similarly, in the DS group, the mean score was 45.28, however some participants were achieving scores of up to 67 and as low as 17. This indicates that motor tasks are more of a difficulty for some individuals with WS and DS than others.

Interestingly, both individuals with WS and individuals with DS showed a relative weakness in Fine Motor Integration, and the WS group presented with a relative strength in Upper Limb Control. However, it should be noted that the WS group's performance in the Upper Limb Control subdomain was still only at the level of a typically developing 6 to 7-year-old. One possible explanation for the similarities in these two populations in their motor

profile may be the presence of learning difficulties. An association has been found between cognitive ability and motor ability in populations with learning difficulties. Smits-Engelsman and Hill (2012) found that IQ explained 19% of the variance in motor ability in groups with and without motor difficulties. However, we cannot rule out other similarities that individuals with WS and individuals with DS share. As has been noted both individuals with WS and individuals with DS have been found to have atypicallities of the cerebellum, which are hypothesised to affect balance (WS: Jernigan et al., 1993; Osorio et al., 2014; Reiss et al., 2000; Wang et al., 1992; DS: Baxter et al., 2000; Pinter et al., 2001; Roubertoux, Bichler & Pinoteau, 2005; Sveljo et al., 2014). However, as previously discussed, the atypicallities of the cerebellum are different for each group (WS: a slight increase in the relative volume of the cerebellum [Jernigan et al., 1993; Osorio et al., 2014; Reiss et al., 2000; Wang et al., 1992]; DS: reduced density in both white and grey matter of the cerebellum [Baxter et al., 2000; Pinter et al., 2001; Roubertoux, Bichler & Pinoteau, 2005; Sveljo et al., 2014]). Another similarity in both individuals with WS and individuals with DS is the high incidence of hypotonia (WS; Chapman, du Plessis & Pober, 1996; Morris, 2005; DS: Almeida et al., 2000; Frith & Frith, 1974; Latash, Wood & Ulrich, 2008; Rarick & McQuillan, 1977; Shumway-Cook & Woollacott, 1985). Some research has suggested that an explanation for poor motor ability in both individuals with WS and individuals with DS is the presence of hypotonia (e.g. Morris, 2005; Latash et al., 2008). These reasons, in conjunction with others, may be the reason that this motor profile is not syndrome specific.

This study also did not investigate *how* the motor abilities of individuals with WS and individuals with DS were impaired, i.e., it does not investigate the nature of the impairment in terms of delay vs. atypical strategy use. We have seen from the data that individuals with WS and individuals with DS were performing broadly at the level of the TD4-5-year-old group. Although, we do not know why motor abilities were poor and whether these

individuals used different strategies to complete tasks. Future research should consider this to get a better picture of how individuals with WS and individuals with DS are completing motor tasks and what new, more effective strategies could be taught to these individuals to enable them to complete motor tasks more effectively. One way to do this would be to examine error types in more detail, for example by looking more closely at the types of tool grip used on each task and comparing it to a typically developing, chronological age matched sample of participants. This future study could also include typically developing, mental age matched children, as this would allow the researcher to investigate whether the strategies that individuals with WS and DS use are more like those more immature strategies of younger children in comparison to typical adults.

This chapter also investigated associations between motor ability and physical activity. However, the hypothesis that individuals with better motor abilities would also be involved in more physical activity (or vice versa) was not supported in the WS or DS groups, as neither fine nor gross motor ability correlated with participation in physical activity in these groups. This is hypothesised to be because most individuals with WS and individuals with DS lacked opportunity to take part in physical activity, such as joining sports groups as they may not have lived in an area that provides suitable sports groups for their age and level of ability. This lack of opportunity may have weakened correlations.

In Chapter 3, it was found that there was no difference on the block construction task between the WS and DS groups, as both groups performed at a TD4 to 5-year-old level, and below the TD6-7 group. This was an unexpected finding, as it was hypothesised that the DS group would perform better than the WS group based on previous research showing that individuals with DS tend to perform better than individuals with WS on spatial tasks (Brock & Jarrold, 2005; Cardoso-Martins et al., 2009; Carretti et al., 2013; Edgin et al., 2010; Frenkel & Bourdin, 2009; Jarrold & Baddeley, 1997; Jarrold, Baddeley & Hewes, 1999,

2002; Lanfranchi et al., 2009; Lanfranchi et al., 2004; Lanfranchi et al., 2009; Numminen et al., 2001; Pennington et al., 2003; Rowe et al., 2006; Visu-Petra et al., 2007; Vicari et al., 1995; Vicari et al., 2006). All groups scored higher on the manual block construction task compared to the non-manual task, which was again unexpected in the WS and DS groups, as we expected that these groups would find the non-manual task easier because the motor element of the task being minimal. This was thought to be due to participants finding the manual block construction task more fun and engaging.

However, it should be noted that the WS group showed a large amount of heterogeneity of their scores in comparison to the older TD group (range manual block construction = 21-46, range non-manual block construction =26-42). For example, while the group mean for the WS group on their overall manual block construction score was 15, some individuals were achieving scores of up to 38 (a higher score indicates better performance), whereas others were achieving as low as a score of 1. Similarly, in the non-manual block construction task, the mean score was 7.65, however some participants were achieving scores of up to 26 and as low as 0. This indicates that block construction abilities are more of a difficulty for some individuals with WS than others. Similarly, the DS group showed a large amount of heterogeneity of their scores. For example, while the group mean for the DS group on their overall manual block construction score was 19.78, some individuals were achieving scores of up to 42, whereas others were achieving as low as a score of 1. Similarly, in the non-manual block construction task, the mean score was 15.06, however some participants were achieving scores of up to 42 and as low as 0. This indicates that block construction abilities are more of a difficulty for some individuals with DS than others, and some individuals were scoring as well as the older TD group on block construction.

The findings from the mental rotation tasks showed that, as was expected, the WS group performed below both typically developing groups. However, again, the WS and DS

group were not significantly different from one another. In the WS group, the chance performance, particularly on the tool condition, may have masked any effect of mental rotation. As this group were at chance on so many of the trials, it is likely that their scores on the mental task are not a true representation of their abilities. It should be noted that the DS group performed at a similar level to the TD4-5 group as well as the WS group, but they were still performing below the TD6-7 group. Again, it is interesting that the DS group were not performing better than the WS group on these tasks.

As was the case in the block construction tasks the WS group showed a large amount of heterogeneity of their percentage accurate on both the animal and tool mental rotation tasks in comparison to the older TD group (range tool accuracy = 50%-100%, range animal accuracy =58%-100). For example, while the group mean for the WS group on their overall tool mental rotation accuracy score was 65.62%, some individuals were achieving scores of up to 96% accurate, whereas others were achieving as low as a score of 46% accurate. Similarly, in the animal mental rotation task, the mean score was 70.41% accurate, however some participants were achieving scores of up to 96% and as low as 42%. This indicates that block construction abilities are more of a difficulty for some individuals with WS than others, and some individuals were showing very little difficulty on this task with accuracy scores of 96%. Similarly, while the group mean for the DS group on their overall tool mental rotation accuracy score was 71.11%, some individuals were achieving scores of up to 100% accurate, whereas others were achieving as low as a score of 40% accurate. Similarly, in the animal mental rotation task, the mean score was 83.61% accurate, however some participants were achieving scores of up to 100% and as low as 45%. This indicates that block construction abilities are more of a difficulty for some individuals with DS than others, and some individuals were showing no difficulty on this task with accuracy scores of 100%. while the group mean for the DS group on their overall tool mental rotation accuracy score was

71.11%, some individuals were achieving scores of up to 100% accurate, whereas others were achieving as low as a score of 40% accurate. Similarly, in the animal mental rotation task, the mean score was 83.61% accurate, however some participants were achieving scores of up to 100% and as low as 45%. This indicates that block construction abilities are more of a difficulty for some individuals with DS than others, and some individuals were showing no difficulty on this task with accuracy scores of 100%.

In WS and DS, there was a correlation between motor ability and manual block construction. There was also a correlation between motor ability and animal mental rotation in the WS group, and the DS group showed a correlation between motor ability and Tool mental rotation, when chronological age was taken into account. The correlation between motor ability and animal mental rotation also became more significant when age was taken into account in the WS group. The finding that these correlations become stronger when chronological age was controlled for should also be noted, as it suggests a role of age in mental rotation and motor ability in the DS and WS groups.

Future research should employ a more sensitive version of the mental rotation task with more trials per degree, as this may have yielded different results, and therefore showed the expected stronger correlations between motor ability and mental rotation. Additionally, the poor language abilities of individuals with DS were not considered in the design of this study as this group was not added until the second round of testing (Chapters 4 and 5). The non-manual version of the block construction task required a good understanding of verbal instructions, which may have limited the performance of the DS group. This should be considered in future research, and perhaps the use of more visual aids or examples would be helpful for this group.

In Chapter 4 it was found that 80% of individuals with WS, were above the clinical cut-off for anxiety on the Spence Children's Anxiety Scale (SCAS), which is in line with

previous research (e.g. Royston, 2017). In comparison, 44% of individuals with DS, were above the clinical cut-off for anxiety on the SCAS (Graham et al., 2005; Haveman et al., 1994; Einfeld et al., 1999). The DS group showed a similar amount of variability in terms of their anxiety as the WS group (WS: mean anxiety score = 33.45, SD = 13.85; DS: mean anxiety score = 22.65, SD = 13.02). However, it was still the case that individuals with WS showed higher levels of anxiety than those with DS, which was expected. However, it should be noted that both the WS and DS groups showed a large amount of heterogeneity of their anxiety scores. For example, while the group mean for the WS group on their overall anxiety score was 33.45, some individuals were getting scores of up to 54, whereas others were getting as low as a score of 4. Similarly, in the DS group, the mean score was 22.65, however some participants were getting scores of up to 47 and as low as 3. This indicates that anxiety is more of a difficulty for some individuals with WS and DS than others.

Motor ability and anxiety were not associated in either the WS or DS groups, which was expected in the DS group, but not in the WS group. It appears from these findings that, while individuals with WS experience motor difficulties and high anxiety, these two factors are unrelated, and that anxiety cannot be used to help explain the motor difficulties in WS. When self-rated anxiety was examined, it was found that there were no significant differences between groups. If the current study was run again, both self-report measures (such as the GAS-ID or the ADAMS), alongside parent report measures could be included. This would allow the researcher to get both parents and the individual with WS or DS's perspective on their own mental wellbeing. The ideal way to measure anxiety from a parent's perspective would have been to conduct clinical interviews with each family. However, this method would take a long time and may not be reasonable for the purposes of research within the context of a large testing battery due to fatigue and the potential loss of motivation. The GAS-ID also has a parent version of the questionnaire, which is approved for use by

therapists under NICE guidelines (NICE, 2016). Individuals with DS reported that they were most anxious to perform the Sit-up's task in comparison to the Square task, but individuals with WS did not report high anxiety to perform any area of the BOT2-SF. Overall, these findings do not support the hypothesis that anxiety affects motor ability in individuals with WS due to their high levels of anxiety generally (e.g. Stinton et al., 2010; Woodruff-Borden et al., 2010). The results from the DS group were expected, as it was not hypothesised that anxiety would affect motor ability in this group due to their reported low levels of anxiety (e.g. Graham et al., 2005; Haveman et al., 1994; Einfeld et al., 1999).

In Chapter 5A, we designed and distributed an online 'fact finding' questionnaire to gather more information about daily living ability in individuals with WS and individuals with DS. From this questionnaire, common difficulties (e.g. tying shoe laces, doing up buttons, doing the washing up, etc.) and common strengths (e.g. putting on shoes [no laces]), washing hands, using a spoon and fork, drinking from a full cup of water, etc. were identified in the two groups. The results of the online questionnaire were then used to design the P-DLT. If this questionnaire was used in future research, the researcher should add a wider range of daily living tasks that would be appropriate for a wider range of ages. This would allow the researcher to see whether certain daily living skills develop over time, or whether they are stable (plateau in performance) at a certain age.

In Chapter 5B, it was found that the WS group were performing significantly below the DS group on the Cares for Home subdomain of the VABS-II, which measures activities of daily living that would take place in the home but are not self-care activities, such as cooking, cleaning, using house-hold appliances, etc. It was further found that there was no correlation between anxiety and daily living ability in either group, which again was predicted in the DS group, but not in the WS group, as this group is known to experience high anxiety generally (e.g. Stinton et al., 2010; Woodruff-Borden et al., 2010). Overall, these

findings suggest that while individuals with WS have poor daily living skills and high anxiety, these two variables are unrelated. However, there were individual differences in the scores of the P-DLT. Participants scores ranged from 38 to 88 in the WS group (mean score=67.52) and from 56 to 90 in the DS group (mean score=77.03) on overall P-DLT performance, indicating that some individuals found the task more difficult than others. There was also a wide range of scores in both the WS and DS groups on the success on strategies used to complete the P-DLT. For Motor Action, scores in the WS group ranged from 16-38 and in the DS group, they ranged from 20-39. For Tool Grip, scores in the WS group ranged from 4-12.5 and in the DS group, they ranged from 5.5-13. For End-State Comfort, scores in the WS group ranged from 6-13 and in the DS group, they ranged from 8.5-13. Finally, for Orientation, scores in the WS group ranged from 7.7-13 and in the DS group, they ranged from 8.5-13.

Finally, we found that there was no correlation between motor ability and score on the VABS-II, however, there was a strong correlation between motor ability and score on the P-DLT in both the WS and DS groups. This may suggest that there is an association between daily living ability and motor ability in these groups. As the scoring method of the P-DLT follows a clear pattern for all items (i.e. motor action, tool grip, end-state comfort, orientation and correct), it would be relatively easy for a future researcher to expand on this system and add new items to fit their specific purpose. Therefore, if this study was replicated, then this task could be made longer and a more in-depth investigation into daily living skills and the strategies that individuals with WS and DS use to complete them could be conducted.

6.3. Clinical and practical implications

As previously discussed throughout this thesis, research investigating motor abilities in WS limited, and this research adds to the current database that has investigated these skills in WS. While more research has been conducted in DS, few studies have examined the motor

profile in this group either. As previously mentioned, it is thought that there is an association between motor skills and everyday functioning (e.g. Dunford et al., 2005; Magalhaes et al., 2011; Summers et al., 2008). In support of this, we found that motor ability was associated with a novel practical daily living task, providing evidence that improving motor ability may have a significant impact on independence and daily life of individuals with WS and individuals with DS.

Further to this, this research provides an in-depth investigation into the motor profile in these populations. Again, this has implications for future intervention studies to improve motor abilities by providing professionals with information about which areas that individuals with WS and DS are likely to have most/least difficulty with. It also provides information to new parents of children with WS or DS about the specific areas of motor ability that their son or daughter may struggle with, and they can then seek specific help and put things in place for the future.

One potential implication is that the P-DLT could be further developed and used with populations with intellectual disabilities to assess their daily living skills quickly without an occupational therapist having to go through the entire assessment of the AMPS, as the P-DLT can be completed in under 30 minutes with participants, whereas the AMPS would take an hour or more for each participant depending on how many areas of daily living the individual wanted to examine. Further, this task does not require any specific training or qualifications to use, and so it could be used by teachers in schools or other researchers. As the scoring method follows a clear pattern for all items (i.e. motor action, tool grip, end-state comfort, orientation and correct), it would be relatively easy for a future researcher to expand on this system and add new items to fit their specific purpose. If this study was focused only on the P-DLT (and not its association with motor ability and anxiety), then this task could have been

made longer and a more in-depth investigation into daily living skills and the strategies that individuals with WS and DS use to complete them could have been conducted.

6.4. Limitations

6.4.1. Power

The first limitation to the current research is that the data is underpowered. This is often the case in studies involving neurodevelopmental disorder groups, particularly rarer groups such as WS. The sample size required for the WS and DS groups was 16 to 84 participants per group, which was determined by the range of sample sizes suggested for the range of analyses required, with power at 0.8 (appendix A and B). However, due to both time constraints in completing the thesis and difficulties in recruiting rare groups, these larger sample sizes were not possible. This weakened any conclusions that we made about the data. For example, we expected a correlation in the WS group between anxiety and daily living ability, as this association has been found in Autism (another neurodevelopmental disorder group who experience high anxiety) (e.g., Drahota, Wood, Sze & Van Dyke, 2011).

6.4.2. Choice of participants

Chapters 2 and 3 included a control group of typically developing children aged 4-7-years. This age range was chosen to span the expected motor ability of the WS and DS groups, but it should be noted that there is no 'ideal' control group for this study (Jarrold & Brock, 2004). For example, if a chronologically age-matched control group had been used, this group would have, mostly, consisted of adults. As previously noted, some of the older TD children were scoring at ceiling on some of the BOT-2 tasks, and therefore, typically developing adults would have likely scored at ceiling on the majority, if not all, of the BOT-2 tasks. However, a strength of using a chronologically age-matched control group would be that the physical activity questionnaire information may have been more valuable as it would be comparing, in most cases, adults to other adults. This is because it is likely that typically

developing adults would not take part in the same amount or types of physical activity as typically developing children (for example because TD children are more likely to be involved in sports groups, after school clubs, playing out with friends, etc). Therefore, it may have been helpful to compare the physical activity scores of the WS and DS participants to an age-matched control group.

This thesis also did not collect any data on how representative these samples of participants might be, for example socio-economic status, family size, education level, etc, which may have influenced the results.

6.4.3. Motor tasks

The short form of the BOT-2 was used to collect motor data due to time constraints, as the whole BOT-2 assessment is estimated to take an hour to complete per person. However, more information about specific strengths and weaknesses of the motor profile in WS and in DS could have been collected from using the full version of the BOT-2, and it may have been the case that a different profile of strengths and difficulties would have been obtained if more data had been collected. Using the whole version of the BOT-2 would have also allowed the researcher to use the standard scores for each subdomain of the BOT-2 to investigate these strengths and weaknesses in motor ability, instead of having to rely on using z-scored based on a TD sample.

Additionally, it was found that the TD6-7 group scored at ceiling on the Bilateral Co-ordination task, which indicates that this task was too easy for this group. As the BOT-2 is designed for individuals up to 21 years, the fact that this task was too easy for the 6–7-year-olds in the current study may indicate that there is a problem with the task itself, in that the task is not an accurate measure of Bilateral Co-ordination. This may have, in turn, influenced the motor profile for all groups, in that, any strength in the Bilateral Co-ordination may have been affected by the ease of the task itself rather than showing actual ability.

6.4.4. Physical activity questionnaire

The physical activity questionnaire was not piloted, which was mostly due to time limits and difficulties recruiting participants. As only one individual (the experimenter) was recruiting and collecting data at this time, it was not feasible to conduct a pilot study for the physical activity questionnaire. Further, it may also be the case that the young age of the typically developing children (4 to 7-years) may have reduced the variability in physical activity scores, particularly in the younger participants, as they may be less likely to take part in sports clubs and other independent physical activities due to their young age. This, in turn, would weaken any correlations.

6.4.5. Small scale spatial tasks

One limitation of the accuracy measure of the mental rotation task is its limited sensitivity. That is, as the mental rotation task gave a score out of four per degree of rotation, there was less room for variability between chance performance and ceiling performance. In turn, this may have reduced sensitivity with respect to group differences and correlations. A more sensitive version of the task with more trials per degree may have yielded different results, and therefore showed the expected stronger correlations between motor ability and mental rotation.

Another limitation is that the poor language abilities of individuals with DS were not considered in the design of this study as this group was not added until the second round of testing (Chapters 4 and 5), and so the small scale spatial skills data for the DS group was collected after that of the WS and TD groups. An example of when poor language ability may have limited performance was that, on some designs required the participant to use the same block twice (e.g. block B), and even when told they could use the same block/letter more than once, it was observed by the experimenter that the DS group would often choose a different block (e.g. block C), which was clearly incorrect. When asked if there were any blocks that

did not look right, they would indicate the incorrect block, but would still not understand that they could use a block they had already used. However, as this potential problem with language ability was not part of the original research design, no official data was collected for this observation and no analysis could be done.

The WS group were at chance performance on many of the tool mental rotation task, which may have masked any effect of mental rotation. As this group were at chance on so many of the trials, it is likely that their scores on the mental task are not a true representation of their abilities. A potential for future research would be to use a different image of a 'tool', which could be more brightly coloured or familiar to participants, as the image used of the jug was white and blue in colour, in comparison to the chicken image, which was orange, brown and red. While all participants were asked to confirm that they knew what the image of the jug was, and could all demonstrate how to use it, it may have been that a different image with more distinctive elements (such as the head of the chicken) could have made this task easier and reduced this chance performance in the WS group.

The non-manual version of the block construction task may have been too complex in its instructions for participants. While it was checked that all participants understood the instructions before testing began, and that they could name all the blocks, it may be that participants forgot the task instructions, particularly as the task became more complex. The participants were reminded of instructions if they appeared unsure, but this relied on the experimenter noting that the participants had forgotten instructions. Additionally, as the non-manual block construction task was a novel task, it would have been useful to pilot the task and check that the instructions could be understood by both WS and TD participants (the DS group were not considered at the time of this study design). However, this was not done. For both tasks, it is a limitation that the tasks were not designed with the DS group in mind, and if

this study was re-designed to be used with participants with DS, poor language ability should be taken into account.

6.4.6. Choice of anxiety measure

The anxiety measure used was the Spence Children's Anxiety Scale, which was adapted to be used with the adults in this population where necessary (e.g. if the question was about school, options for college and work were given also, etc.). However, it may have been more appropriate to use an anxiety measure designed for use with both adults and children, or a measure that had a child and adult version. This would have provided the researcher with standard data on the levels of anxiety in individuals with WS and individuals with DS in comparison to chronological age matched population samples. Research by Royston et al, (2021) found that that there was no correlations between SCAS score and the frequency or severity of anxiety symptoms in parental interviews using the 5-p's formulation framework. This suggests that the SCAS may not be an accurate measure of anxiety in WS. In the current study, the clinical cut off of the 84th centile was used as this is the cut off that has been used in previous studies with WS (e.g. Riby et al., 2014). However, this cut-off point is standardised for typically developing children and not adults or individuals with intellectual disabilities. The SCAS was chosen as it has been used successfully with adults with WS previously (e.g. Dodd et al., 2009; Riby et al., 2014; Rodgers et al., 2012). Nevertheless, other anxiety measures should have been considered in the design of this study, and the fact that they were not is a limitation of the current research.

It is possible that some individuals with WS and DS may have had some problems with understanding the questions on the self-rated anxiety questionnaire scale. While the researcher made every effort to explain the questions and options to participants, it was sometimes the case that participants would answer as if they were being asked how easy they thought the task would be, or how able they felt to complete the task, rather than how worried

they were about doing the task. It was also sometimes the case that participants, particularly those with WS, would report that they felt "great" about performing all the tasks as they wanted to please the experimenter and say what they assumed the experimenter wanted to hear, even after being given frequent reminders of the instructions. This was raised by some of the parents who sat in on the testing sessions, and when it was time for the participants to actually take part in the tasks, they were clearly visibly anxious, though this observation was anecdotally made by the experimenter and was not recorded.

6.4.7. The design of the daily living fact-finding questionnaire

There are some limitations to the initial fact-finding questionnaire, such as the choice of items included in the questionnaire. Some of the items, such as making a simple hot meal, would not be appropriate for the younger participants included in the sample. The items were chosen to include a range of tasks with varying difficulties to try to tease apart the kinds of tasks that individuals with WS and individuals with DS find more easy/difficult. However, the age appropriateness of the tasks should have been considered, and only tasks that all age ranges could, theoretically, complete should have been included. For example, a difficult task that you would expect a child to perhaps be starting to complete at age 8 years is tying shoelaces, and so more items like this should have been included, rather than items like using a sharp knife and preparing a meal, which you would not expect even a typically developing child to be able to perform.

The initial fact-finding questionnaire was also not piloted. This questionnaire was used to help inform the design of the practical daily living task outlined below, and therefore it was not used to directly answer any of the thesis research questions. The advantage of piloting the fact-finding questionnaire, perhaps with typically developing individuals as well as with parents of individuals with WS or DS, would have been that it could have informed the ages that would be appropriate to include in the study. It may have also been a good

opportunity for parents to provide feedback on the kinds of questions that should have been included.

Another limitation of this initial fact-finding questionnaire was that there were no 'non-motor' items included (such as telling the time, planning for the weather, etc.). It may have been interesting to have these non-motor items to see if there were any initial differences in task difficulty between 'motor' and 'non-motor' items. If non-motor items were included, it may have been that parents were reporting that the 'motor' items were more difficult than the 'non-motor' items, this may have provided further evidence for the effect of poor motor ability in daily living ability. However, it is unlikely that these 'non-motor' items would have scored as easier than the 'motor' items, as these tasks would likely involve areas of cognition that individuals with WS and individuals with DS show deficits in, such as difficulties in planning (WS: Costanzo, Varuzza, Menghini, Addona, Gianesini & Vicari, 2013; Menghini, Addona, Costanzo & Vicari, 2010; Rhodes, Riby, Park & Campbell, 2010; DS: Lanfranchi, Jerman, Dal Pont, Alberti & Vianello, 2010; Rowe, Lavender & Turk, 2006).

6.4.8. Daily living assessment (P-DLT)

The wide age range of the participants in the WS and DS groups may be another limitation of the daily living study. Some of the participants included were children with WS or with DS, and so these younger participants would not have had as much experience as the older participants in performing activities of daily living, and the younger children may not yet been expected to perform all the tasks given (for example, the washing up task). When age was examined, it was found that, while age did not affect performance on the P-DLT in the DS group, it did affect performance in the WS group. The youngest participant in the DS group was 12-years-old, whereas in the WS group, they were 8-years-old. In typical development, you would perhaps expect more from a 12-year-old in comparison to an 8-year-old, as these individuals have transitioned into secondary school, and so would be expected to

be more independent. This may account for why there was no correlation between age and P-DLT ability in the DS group.

Another limitation of this research is that no information was collected about why individuals did worse on some tasks than others. For example, no data was collected about the individuals home life and living conditions. The majority of individuals with WS lived at home with their parents, however, the researcher did not collect data regarding how much independence the individual was expected to have, i.e., some parents may have spent time out at work whereas others may have stayed at home with the individual with WS. This would be likely to affect how many activities of daily living the individual would engage in if they did not have a parent home to do things for them. The impact of other individual factors was also not assessed, for example, the individual's health status and other mental health difficulties, although it was assumed that all individuals tested were of good physical health as parents/carers were asked prior to testing if their son or daughter would be able to perform motor tasks. However, this did not account for if the individual was unwell on that day or if they had had any other recent physical injuries (e.g., bumps, falls, etc.). This study measured the effect of anxiety on daily living ability; however, it did not account for other mental health conditions (such as sensory processing disorder, OCD, depression, etc.) which may have also affected the results. For example, the DSM-5 core symptoms of depression include: "markedly diminished interest or pleasure in all, or almost all, activities most of the day, nearly every day", "a slowing down of thought and a reduction of physical movement (observable by others, not merely subjective feelings of restlessness or being slowed down)" and "fatigue or loss of energy nearly every day". These core symptoms may have a significant effect on an individual's ability to carry out activities of daily living, as well as engage in the assessment process and perform motor tasks to the best of their ability. While depression is not a common difficulty observed in WS (e.g. Porter, Dodd & Cairnes, 2009;

Stinton, Elison & Howlin, 2010), it is the most common mental health difficulty experienced in individuals with DS (e.g. Collacott et al., 1992; Cooper & Prasher, 1999).

This study also did not measure any non-motor activities of daily living which makes it difficult to form conclusions about the impact of motor abilities on daily living, as the researcher did not compare the performance of motor daily living activities (outlined in this study) with non-motor activities (such as telling the time, road safety, answering the phone, etc). It is therefore not possible to say from these results whether motor ability would affect all activities of daily living skills or only those which require the use of motor skills. Indeed, when correlations between motor ability and daily living were examined, there were strong corrections between motor abilities and the P-DLT, but less so between motor skills and the VABS-II. This may be because the VABS-II includes a wider range of activities of daily living, some of which do not require the use of motor skills. It may be that, if these 'non-motor' items were removed, there would be stronger correlations between VABS-II daily living score and motor ability.

As with previous studies throughout this thesis, this study was not piloted. This was due to two unavoidable factors: difficulties with recruitment and time constraints. Recruitment took place over a 12-month period, and participants were recruited using a number of methods (such as telephone calls, email, social media, etc.), and still only small numbers could be obtained. Therefore, if this study had been piloted, there would have been fewer participants tested. Additionally, as this study was conducted as part of a PhD thesis, the researcher was under a certain time constraint to collect data to ensure that the thesis was completed on time. This meant that the researcher did not have the luxury of having the time to piolet the study.

6.5. Summary and concluding remarks

This research showed that both individuals with WS and individuals with DS show motor deficits, performing broadly at the TD4-5 level and below the TD6-7 level on their overall motor ability. We also found that both individuals with WS and individuals with DS show a relative strength in Upper Limb Control, and a weakness in Balance, when assessed using the BOT2-SF.

Similarly, on small-scale spatial tasks, both the WS and DS groups presented with difficulties on both block construction and mental rotation, performing at a similar level to the TD4-5 groups. All groups showed better performance on the manual block construction task in comparison to the non-manual task, and the WS group showed a correlation between motor ability and performance on the manual block construction task. The WS group showed a correlation between motor ability and animal mental rotation and, when chronological age was controlled for, the DS group showed a correlation between tool mental rotation and motor ability.

Correlations between anxiety and motor ability did not reveal any significant associations in either group, which was expected in the DS group, but not in the WS group. However, we did find associations between motor ability and daily living ability in both groups, suggesting that individuals with poor motor ability would experience difficulties with activities of daily living, and may struggle to live independently. As this research is still in its infancy, future research should focus on investigating a wider range of motor abilities in individuals with WS and individuals with DS to better explore the motor profile.

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Appendix A

Analysis Plan – Study 1 and 2

The motor profile in individuals with WS, DS and typically developing children and the impact of motor ability on small scale spatial skills

Measures	Responses recorded	Dependent variables	Participants
1.British Picture Vocabulary Scale, third edition (BPVS III)	Number of correct responses.	Verbal IQ score (raw)	All
2.Ravens Coloured Progressive Matrices (RCPM)	Number of correct responses.	Non-verbal IQ score (raw)	All DS and 20 WS
3. British Abilities Scale (BAS-III)	Number of correct responses.	Non-verbal IQ score (ability score based on raw score)	All TD participants and 21 WS
3.Bruininks-Oseretsky Test of Motor Proficiency, Second Edition, short form (*BOT*2-SF)	Total, fine and gross motor ability.	Total motor standard score. Fine motor raw score. Gross motor raw score. Percentile rank (BOT-2 zone).	All
4. Physical Activity Questionnaire	Total score	Total score	All TD participants, all DS and 20 WS
5. Block Construction task	Number of correct responses.	Total number of correct responses on the manual and non-manual task.	All TD participants, all DS and 20 WS
6. Mental Rotation task	Number of correct responses.	Percentage of correct responses and reaction times (seconds).	All TD participants, all DS and 20 WS

	Williams Syndrome	Down Syndrome	Typically Developing
Age range	**8+ years**	**8-35 years**	**4-7 years**
Number of participants	**20-26**	**18-26**	**40**

- **Motor profile**

  Question 1

  - What is the motor profile for individuals with WS and DS?

  Predictions

  - Based on previous research, an uneven motor profile is predicted in the WS group, with a particular weakness in the Balance subdomain predicted. This is based on research that suggests that individuals with WS show specific weaknesses in balance (e.g. Jernigan et al., 1993; Osorio et al., 2014; Reiss et al., 2000; Wang et al., 1992).
  - Based on previous research, an uneven motor profile is predicted in DS, with a particular weakness in the Balance subdomain predicted. This is based on research that suggests that individuals with DS show specific weaknesses in balance (Galli, Rigoldi, Mainardi, Tenore, Onorati & Albertini, 2008; Lai & Fu, 2009; Webber, Virji-Babul, Edwards & Lesperance, 2004). Children with DS have also been shown to have overall motor difficulties, in both fine and gross motor skills (e.g. Alesi, Battaglia, Pepi, Bianco & Palma, 2018; Spano et al., 1999), and so it is likely that these difficulties will persist into adulthood.

  Analysis

  - Use the raw score to get a standard score for the WS and DS group to find their motor 'zone' using percentiles from the BOT-2.
  - Use ANOVA to compare the performance on overall raw score motor ability of the WS and DS groups to the groups of TD children (TD4-5, TD6-7) to see which group they are most like. Then look at post hoc tests to determine which TD group(s) are a motor-matched group to the WS and DS groups. DV = overall motor performance.
  - **Power analysis**: Input: G*Power– F tests, ANOVA one-way. Tails: two, effect size f=0.25 (medium), input for effect size: alpha error probability p=.05, power=0.8, number of groups=4 Outcome: N=180 (45 each group).
  - Use the raw score to get a standard score for the WS and DS group to find their motor 'zone' using percentiles from the BOT-2.
  - Create Z-scores for individual subdomain performance of the WS group based on the mean and SD of each subdomain performance of all groups. Create Z-scores for individual subdomain performance of the DS group based on the mean and SD of each subdomain performance of all groups. Use z-scores to find strengths and weaknesses in the motor profile of the WS and DS groups. DV = subdomain motor Z-score, 8 levels. Post-hoc Sidak tests will be used to examine differences across

subdomains to look at relative strengths and weakness in the DS and WS motor profiles.

- **Power analysis:** Input: G*Power– F tests, repeated measures, within factors. Effect size f= 0.25 (medium), partial eta squared = 0.06, p=.05, power=0.8, number of groups: 4, number of measurements=8. Outcome: N=16 total sample size.

- **Physical Activity**

Question 1

- Do individuals with WS and/or DS show lower levels of physical activity than typically developing children?

Predictions

- It was predicted that individuals with WS and individuals with DS would show low levels of physical activity.

Analysis

- A one-way ANOVA to compare the performance of physical activities in the WS and DS groups to the groups of TD children (TD4-5, TD6-7) to see which group they are most like. Then look at post hoc tests to determine which TD group(s) are matched to the WS and DS groups. DV = overall physical activity score.
- **Power analysis**: Input: G*Power– F tests, ANOVA one-way. Tails: two, effect size f=0.25 (medium), input for effect size: alpha error probability p=.05, power=0.8, number of groups=4 Outcome: N=180 (45 each group).

Question 2

- Is there an association between the amount of physical activity that individuals with WS, DS and typically developing individuals take part in and their motor abilities?

Predictions

- It was predicted that there would be an association between physical activity, as measured by a Physical Activity Questionnaire, and an individual's motor ability, with individuals who score higher on the motor assessment participating in more sports.

Analysis

- Correlation analysis between total score on the physical activity questionnaire and total motor ability raw score.
- **Power analysis:** Input: G*Power– exact, correlation: bivariate normal model. Tails: two, correlation p H1=0.3 (medium), input for effect size: alpha error probability p=.05, power=0.8, correlation p H0=0. Outcome: N=84.

- **Block Construction**

Question 1

- Does the performance of the WS and DS group differ on a block construction task when the motor element of the task is reduced?

Predictions

- It is predicted that that the WS group would perform below all other groups on all small-scale spatial tasks. It was further hypothesised that the WS and DS groups would perform better on the non-motor tasks as they have poor motor ability.
- It was further predicted that there would be a correlation between motor ability and small-scale spatial skills in all groups

Analysis

- Use ANOVA to compare the performance on overall score of block construction of the WS and DS groups to the groups of TD children (TD4-5, TD6-7) to see which group they are most like. Then look at post hoc tests to determine which TD group(s) are a matched group to the WS and DS groups. DV = overall block construction performance. This will be done for both the manual and non-manual block construction task.
- **Power analysis**: Input: G*Power– F tests, ANOVA one-way. Tails: two, effect size f=0.25(medium), input for effect size: alpha error probability *p*=.05, power=0.8, number of groups=4 Outcome: N=180 (45 each group).

Question 2

- Is there an association between block construction performance and motor ability in any group?

Predictions

- It is predicted that there will be a stronger correlation between the manual block construction task and motor ability than between the non-manual block construction task and motor ability.

Analysis

- Correlation analysis between total raw motor score and both manual and non-manual block construction ability.
- **Power analysis:** Input: G*Power– exact, correlation: bivariate normal model. Tails: two, correlation p H1=0.3 (medium), input for effect size: alpha error probability p=.05, power=0.8, correlation p H0=0. Outcome: N=84.

- **Mental Rotation**

Question 1

- Does the performance of the WS and DS group differ on a mental rotation task when the motor element of the task is reduced?

Predictions

- It is predicted that the WS and DS groups would be less accurate than the TD groups, and that all groups would show decreased accuracy with increases in rotation. It was further hypothesised that, with increases in rotation, participants from all groups would show longer response times.
- It was further predicted that there would be a correlation between motor ability and small-scale spatial skills in all groups

Analysis

- Use ANOVA to compare the performance on overall percentage correct score of each mental rotation task of the WS and DS groups to the groups of TD children (TD4-5, TD6-7) to see which group they are most like. Then look at post hoc tests to determine which TD group(s) are a matched group to the WS and DS groups. DV = overall mental rotation performance. This will be done for both the manual and non-manual mental rotation task.
- **Power analysis:** Input: G*Power– F tests, repeated measures, within factors. Effect size f= 0.25 (medium), partial eta squared = 0.06, p=.05, power=0.8, number of groups: 4, number of measurements=5. Outcome: N=24 total sample size.
- Use ANOVA to compare the response times on each mental rotation task for the WS and DS groups compared to the groups of TD children (TD4-5, TD6-7) to see which group they are most like. Then look at post hoc tests to determine which TD group(s) are a matched group to the WS and DS groups. DV = overall mental rotation performance. This will be done for both the manual and non-manual mental rotation task.
- **Power analysis:** Input: G*Power– F tests, repeated measures, within factors. Effect size f= 0.25 (medium), partial eta squared = 0.06, p=.05, power=0.8, number of groups: 4, number of measurements=5. Outcome: N=24 total sample size.

Question 2

- Is there an association between mental rotation performance and motor ability in any group?

Predictions

- It is predicted that there will be a stronger correlation between the manual mental rotation task and motor ability than between the non-manual mental rotation task and motor ability.

Analysis

- Correlation analysis between total raw motor score and both manual and non-manual mental rotation ability.
- **Power analysis:** Input: G*Power– exact, correlation: bivariate normal model. Tails: two, correlation p H1=0.3 (medium), input for effect size: alpha error probability p=.05, power=0.8, correlation p H0=0. Outcome: N=84.

Appendix B

Analysis plan: Study 3

The impact of anxiety on motor ability in WS and DS

Measures	Responses recorded	Dependent variables
British Picture Vocabulary Scale, third edition (BPVS III)	Number of correct responses.	Verbal IQ score (raw)
Ravens Coloured Progressive Matrices (RCPM)	Number of correct responses.	Non-verbal IQ score (raw)
Bruininks-Oseretsky Test of Motor Proficiency, Second Edition, short form (*BOT*2-SF)	Total, fine and gross motor ability.	Total motor standard score. Fine motor raw score. Gross motor raw score. Percentile rank (BOT-2 zone).
Anxiety score	Anxiety self-rating from 1-5 of how worried each participant feels about performing each task.	Anxiety rating score for each participant for each motor and daily living task.
Spence Children's Anxiety Scale	Parents rate their son/ daughter on a scale from 0-3 scale 0= never 1 = sometimes 2 = often 3 = always on a range of questions relating to different areas of anxiety. Subdomains: separation anxiety, social phobia, obsessive compulsive, panic/agoraphobia, physical injury, generalised anxiety	Score out of 114. Although there is no clinical cut off for the Spence, a score of 24 or above has been suggested as an indicator of clinical case-ness, and has been used in previous research as an indication of anxiety in WS (Rodgers et al., 2012).

	Williams Syndrome	**Down Syndrome**
Age range	**8+ years**	**8-35 years**
Number of participants	**20-26**	**18-26**

- **Investigating anxiety levels in Williams Syndrome and Down Syndrome**

Question 1

- Are individuals with WS or DS scoring in the clinically anxious range on the Spence Children's Anxiety Scale?

Predictions

- Williams Syndrome: it is predicted that individuals with WS will show elevated levels of anxiety compared to the general population. This prediction is based on previous studies that have shown that individuals with WS show high levels of anxiety compared to the general population and to other clinical groups (Papaeliou et al., 2012; Stinton, Elison & Howlin, 2010; Woodruff-Borden, Kistler, Henderson, Crawford & Mervis, 2010).
- Down Syndrome: it is predicted that individuals with DS will not show clinical levels of anxiety. This is based on previous research that has shown that individuals with DS do not show elevated levels of anxiety, show anxiety levels at a similar level to the general population, and score lower on anxiety assessments than other clinical groups (e.g. Graham, Rosner, Dykens & Visootsak, 2005; Einfeld, Tonge, Turner, Parmenter & Smith, 1999).
- It is predicted that individuals with WS will score significantly higher on the Spence than individuals with DS based on the above literature.

Analysis

- Spence Children's Anxiety scale – maximum score of 114. Scores above 24 indicate clinical levels of anxiety (Rodgers et al, 2012). Descriptive statistics will show the mean (SD) score for each group.
- T-test will be conducted to examine whether there are significant differences between groups (WS/DS) on level of anxiety.
- **Power analysis:** Previous research has not investigated this relationship; therefore, analysis input is based on anticipated a large effect size. Input: G*Power– t tests, means: difference between two independent means. Tails: two, effect size (d):0.8(large), input for effect size: alpha error probability p=.05, power=0.8. Outcome: N= 52 (26 each group).

Question 2

- Are some areas of anxiety affecting individuals with WS or DS more than others (e.g. specific phobias, general anxiety, etc.)?

Predictions

- Williams Syndrome: it is predicted that individuals with WS will score highly on general anxiety and on anxiety related to specific phobias. This is in line with previous research that has shown that general anxiety and specific phobia are the two areas of anxiety that individuals with WS are most affected by (Leyfer et al., 2006; Leyfer et al., 2009).
- Down Syndrome: it is predicted that individuals with DS will not show any particular area of anxiety that they are most affected by, as it has been found that this population do not have high levels of anxiety (Graham et al., 2005; Einfeld et al., 1999).

Analysis

- Calculate the proportion correct scores for the different areas of anxiety (separation anxiety, social phobia, obsessive compulsive, panic/agoraphobia, physical injury, generalised anxiety) for each group. Descriptive statistics will show the mean score for each area of anxiety for each group (WS and DS).
- T-tests will be used to examine whether some areas of anxiety are affecting the groups more than others in DS and WS, for each area of anxiety (separation anxiety, social phobia, obsessive compulsive, panic/agoraphobia, physical injury, generalised anxiety) using the t-scores for each subdomain.
- **Power analysis:** Previous research has not investigated this relationship; therefore, analysis input is based on anticipated large effect size. Input: G*Power– t tests, means: difference between two independent means. Tails: two, effect size (d):0.8(large), input for effect size: alpha error probability p=.05, power=0.8. Outcome: N= 52 (26 each group).

- **The impact of anxiety on motor performance in Williams Syndrome and Down Syndrome.**

Question 1

- Is there a relationship between total motor score from the BOT2-SF and anxiety score from the Spence?

Predictions

- Williams Syndrome: it is predicted that there will be a correlation between anxiety score and total motor score. This is based on previous research that has shown that individuals with high anxiety perform worse on motor tasks than individuals with low anxiety (e.g. Coombes, Higgins, Gamble, Cauraugh & Janelle, 2009; Erez, Gordon, Sever, Sadeh & Mintz, 2004; Kristensen & Torgersen, 2007; Weinberg & Hunt, 1976).
- Down Syndrome: it is predicted that there will not be an association between anxiety and motor ability in the DS group, as anxiety has not been previously found to be significantly different from scores in the general population in this group.

Analysis

- Split data into groups (WS and DS). Correlation analysis between total score on the Spence with total motor raw score for each group.
- **Power analysis:** Previous research has not investigated this relationship; therefore, analysis input is based on reasonable assumptions of effect size. Input: G*Power– exact, correlation: bivariate normal model. Tails: two, correlation p H1=0.3 (medium), input for effect size: alpha error probability p=.05, power=0.8, correlation p H0=0. Outcome: N=84.

Question 2

- Is the motor profile of strengths and weaknesses in each group explained by anxiety?

Predictions

- Williams Syndrome: It is predicted that balance, which was the task that individuals with WS were found to struggle most with in the previous study is most likely to be related to high anxiety. Indeed, in previous research, it has been shown that individuals with high anxiety were poorer at both static and dynamic balance tasks than individuals without anxiety disorders (Erez et al, 2004).
- Down Syndrome: similar findings are predicted for the DS group. It has been found in previous research that individuals with DS have a particular difficulty in balance tasks (Galli, Rigoldi, Mainardi, Tenore, Onorati & Albertini, 2008; Lai & Fu, 2009; Webber, Virji-Babul, Edwards & Lesperance, 2004). It is therefore predicted that individuals with DS will also show more nervousness and anxiety in the balance tasks, but it is not predicted to be as strongly associated as in WS.

Analysis

- Total Spence score and mean anxiety score will be correlated with the raw score for each subtest on the BOT2-SF for each group. These correlations will then be compared using a Williams-Steiger test (Steiger, 1980). This will allow me to see if some subtests are more affected by anxiety than others for each group. (http://vassarstats.net/rdiff.html or http://comparingcorrelations.org/)
- **Power Analysis:** Previous research has not investigated this relationship; therefore, analysis input is based on reasonable assumptions of effect size. Input: G*Power– exact, correlation: bivariate normal model. Tails: two, correlation p H1=0.3 (medium), input for effect size: alpha error probability p=.05, power=0.8, correlation p H0=0. Outcome: N=84.
- The mean anxiety score (asked at the start of the study before tasks are introduced), for each subtest, for each group will be calculated. This will show if the anticipation of performing some subtests are leading to more anxiety than others, for each group. Repeated measures ANOVA will be used to examine which subtests (Fine motor precision, Fine motor integration, Manual dexterity, Bilateral co-ordination, Balance, Running speed and agility, Upper limb control, and strength) are causing most anxiety for each group (WS, DS).
- **Power analysis main effect of motor subtest:** Input: G*Power– F tests, repeated measures, within factors. Effect size= 0.25 (medium), partial eta squared = 0.06, p=.05, power=0.8, number of groups: 2, number of measurements=8. Outcome: N=16 total sample size.
- **Power analysis interaction between group and subtest:** Input: G*Power– F tests, repeated measures, within-between interaction. Effect size= 0.25 (medium), partial eta squared = 0.06, p=.05, power=0.8, number of groups: 2, number of measurements=8. Outcome: N=16 total sample size.
- ANOVA will be conducted for each group separately (WS, DS) to see if the main effect of subtest on the BOT-2 would disappear after Spence score is covaried out. For the WS and DS groups, subdomain z-scores will be used (8 levels)
- This would allow us to see if the significant weakness in balance could be explained by anxiety in the WS group. This is not expected as it is likely that anxiety is only one factor in the balance problems that people with WS (and potentially with DS) show, and that differences in the structure and function of the cerebellum and basal ganglia (WS: Jernigan & Bellugi, 1990; Jernigan et al., 1993; Jones et al, 2002; Reiss et al., 2000; DS: Baxter et al, 2000; Pinter et al, 2001; Roubertoux, Bichler & Pinoteau, 2005), and muscle hypotonia (WS: Chapman, Plessis & Pober, 1996; DS: Frith & Frith, 1974; Knight, Atkinson &

Hyman, 1966; Molnar, 1978; Rarick & McQuillan, 1977; Davis & Kelso, 1982) are also affecting balance performance.

- **Power analysis main effect of motor subtest:** Input: G*Power– F tests, repeated measures, within factors. Effect size= 0.25 (medium), partial eta squared = 0.06, p=.05, power=0.8, number of groups: 1, number of measurements=8. Outcome: N=16.

Appendix C

Analysis plan: Study 4

The impact of poor motor ability and anxiety on daily living

Measures	Responses recorded	Dependent Variables
1.Bruininks-Oseretsky Test of Motor Proficiency, Second Edition, short form (*BOT*2-SF)	Total, fine and gross motor ability.	Total motor standard score. Fine motor raw score. Gross motor raw score. Percentile rank (BOT-2 zone).
2.Anxiety score	Anxiety self-rating from 1-5 of how anxious each participant feels in anticipation of performing each task.	Average anxiety rating score for each group (WS and DS) for each motor and daily living task.
3.Daily living task performance score	Score out of 7 on the 13 daily living tasks. Participants get the score based on: 1. Motor action (3) 2. Tool grip (1) 3. End state comfort (1) 4. Tool orientation (1) 5. Successful (1) Time taken to complete each task	Total score
4.Vineland Adaptive Behaviour Scale, third edition (VABS III) – daily living	Parents rate their child on a 0-2 scale. 0 = usually 1 = sometimes 2 = never on a range of daily living tasks.	Standardised daily living score for chronological age. Percentile rank based on standard score.
5.Feelings about daily living	Parents will say whether their son/ daughter would feel anxious performing different daily living tasks and then, if they would, why from a list of options: 'motor' 'social' 'negative experience' 'planning' 'other'	Proportion of people with WS or DS find daily living tasks anxiety provoking. What the most common cause of anxiety is for the different groups, i.e. motor, social, planning, etc.

	Williams Syndrome	Down Syndrome
Age range	**8+ years**	**8-35 years**
Number of participants	**20-26**	**18-26**

- **Information gathering of daily living ability in Williams Syndrome and Down Syndrome (Daily living questionnaire)**

Question 1

- What level of competence do individuals with DS and individuals with WS reach on tasks of daily living, and how do the groups compare?

Predictions

- There is very little research into daily living skills in older children and adults with either WS or DS, so it is difficult to make any strong predictions. It has been found that children and adults with WS and DS show difficulties in their daily living skills (e.g. Davis et al, 1997; Gosch & Pankau, 1994; Leonard, Msall, Bower, Tremont & Leonard, 2002; Lin et al, 2015). It is therefore reasonable to assume that individuals in our study with WS and DS will also to show difficulties with their daily living ability, particularly on tasks that require a good mastery of motor skills. However, there is no research to suggest that one group will be more or less able to perform daily living tasks.

Analysis

- Give each category a numerical score: 'cannot do' = 1, 'can do with help' = 2, 'can do on own' = 3. Add these scores up for each category for each group and perform a t-test to see if one group (WS or DS) are more able to perform tasks of daily living.
- **Power analysis**: Input: G*Power– t tests, means: difference between two independent means. Tails: two, effect size (d):0.5(large), input for effect size: alpha error probability p=.05, power=0.8. Outcome: N=128 (64 each group).

Question 2

- Are some daily living tasks more or less difficult for individuals with WS or DS to achieve without assistance?

Predictions

- There is very little research into daily living skills in older children and adults with either WS or DS, so it is difficult to make any strong predictions. It has been found that children and adults with WS and DS show difficulties in their daily living skills (e.g. Davis et al, 1997; Gosch & Pankau, 1994; Leonard, Msall, Bower, Tremont & Leonard, 2002; Lin et al, 2015). It is therefore reasonable to assume that individuals in our study with WS and DS will also to show difficulties with their daily living ability, particularly on tasks that require a good mastery of motor skills.

Analysis

- Use the results of the daily living questionnaire to get the percentage of individuals with WS and the percentage of individuals with DS who 'can do', 'can do with help' and 'cannot do' for each of the 37 daily living tasks. Use this to see the strengths and weaknesses in both groups.
- The 'can do with help' and 'cannot do' tasks will be combined as these items would be considered areas of difficulty.
- If participants, as a group, scored over 75% on a task, this will be considered a strength of the group. If participants, as a group, score below 60% on a task, it will be considered a weakness.

- **Investigation of performance on activities of daily living in Williams Syndrome and Down Syndrome.**

Question 1

- How are individuals with WS and DS performing on their daily living skills?

Predictions

- There is very little research into daily living skills in older children and adults with either WS or DS, so it is difficult to make any strong predictions. It has been found that children and adults with WS and DS show difficulties in their daily living skills (e.g. Davis et al, 1997; Gosch & Pankau, 1994; Leonard, Msall, Bower, Tremont & Leonard, 2002; Lin et al, 2015). It is therefore reasonable to assume that individuals in our study with WS and DS will also to show difficulties with their daily living ability, particularly on tasks that require a good mastery of motor skills.
- Vineland Adaptive Behaviour Scale: it is predicted that individuals with WS and DS will show significantly lower scores on the VABS than would be expected for their chronological age. This is in line with previous research with children and adults with WS and DS using the VABS, which has indicated that these populations show lower daily living ability (e.g. Davis et al, 1997; Gosch & Pankau, 1994; Leonard et al., 2002; Lin et al, 2015).
- Daily living task: it is predicted that individuals with WS and DS will show poor performance on the daily living. This is predicted because of previous findings of low daily living ability in children and adults with WS and DS, particularly in tasks of self-care, which are the types of tasks that will be tested in the daily living assessment.

Analysis

- Vineland adaptive behaviour scale: raw scores on the VABS will be added up for each group (WS, DS). T-test will be conducted to determine whether one group are performing better than the other.
- **Power analysis**: Input: G*Power– t tests, means: difference between two independent means. Tails: two, effect size (d):0.5(large), input for effect size: alpha error probability p=.05, power=0.8. Outcome: N=128 (64 each group).
- The daily living practical assessment will be analysed by getting a performance score out of 7 (possible 3 points for correctly performing the action, and 1 point each for: correct tool grip, correct end-state comfort, correct orientation, and overall successful in completing the task). Time taken to complete the task will

also be recorded. This will allow me to calculate an inverse efficiency score (IES) for each participant, for each task.

- Then use this IES to check for differences between groups on performance on each task using t-test of group (DS, WS) by task (e.g. tying shoe laces, washing up, etc.), i.e. is the WS or the DS group performing better on each of the daily living tasks (e.g. tying shoe laces, washing up, etc.). IV: group (WS or DS), DV: performance on the task.
- **Power analysis**: Input: G*Power– t tests, means: difference between two independent means. Tails: two, effect size (d):0.5(large), input for effect size: alpha error probability p=.05, power=0.8. Outcome: N=128 (64 each group).

- **Investigating the impact of anxiety on daily living in Williams Syndrome and Down Syndrome.**

Question 1

- Is anxiety impacting daily living performance in Williams Syndrome and/or Down Syndrome?

Predictions

- Williams Syndrome – VABS and daily living task: it is predicted that there will be a correlation between Spence anxiety score and daily living ability in WS. This is based on previous research that has found high levels of anxiety in WS (Papaeliou et al., 2012; Stinton et al., 2010; Woodruff-Borden et al., 2010), and research that has found poorer daily living scores (Davis et al, 1997; Gosch & Pankau, 1994; Leonard et al., 2002; Mervis et al, 2001) in this population.
- Down Syndrome – VABS and daily living task: it is predicted that anxiety will not impact daily living ability in the DS group. This is based on previous research that suggests that anxiety is not significantly affecting this population (e.g. Graham et al., 2005; Einfeld et al., 1999). It is thought instead that other factors are likely to impact daily living skills in DS, such as their poor motor ability.

Analysis

- Spence: Total score on the Spence will be correlated with total score on VABS-daily living and on the total daily living score for each group (WS, DS).
- **Power analysis:** Previous research has not investigated this relationship; therefore, analysis input is based on reasonable assumptions of effect size. Input: G*Power– exact, correlation: bivariate normal model. Tails: two, correlation p H1=0.3(medium), input for effect size: alpha error probability p=.05, power=0.8, correlation p H0=0. Outcome: N=84 total (not possible).

- **Investigating the associations between motor ability and daily living skills in Williams Syndrome, Down Syndrome and typical development.**

Question 1

- Is the poor motor ability that is often found in WS and DS associated with difficulties in daily living ability?

Predictions

- It is predicted that those with better motor ability in both groups (WS, DS) will score higher on daily living ability, on both the VABS and on the daily living task.
- It is predicted that the tasks that rely more on motor skills (e.g. doing up buttons, tying shoelaces) will be scored lower in the WS and DS group than tasks which have lower motor demands. This is predicted because of the poor motor ability that has been found in my previous study of individuals with WS, and based on previous literature that has shown both individuals with WS and DS as having deficits in their motor ability (WS: Tsai et al., 2008; Wuang & Tsai, 2017; DS: Alesi, Battaglia, Pepi, Bianco & Palma, 2018; Spano et al., 1999).

Analysis

- Correlation analysis will be conducted between total raw score on the BOT2-SF and total score on the VABS and on the daily living task.
- **Power analysis:** Input: G*Power– exact, correlation: bivariate normal model. Tails: two, correlation p H1=0.3 (medium), input for effect size: alpha error probability p=.05, power=0.8, correlation p H0=0. Outcome: N= 84.

- **Investigating the impact of motor ability and anxiety on daily living skills.**

Question 1.

- Does poor motor ability or high anxiety have more of an effect on daily living ability?

Predictions

- It is difficult to make predictions as no research exists to base predictions on. However, it has been hypothesised in previous research that there is an association between motor ability and daily living skills in both WS and DS (Gosch & Pankau, 1994; Mervis, Klein-Tasman & Mastin, 2001; Volman et al., 2007).
- There has been no research thus far that has hypothesised about the potential association between anxiety and daily living skills.
- It is predicted that, of these two factors (motor ability and anxiety), motor ability will be more likely to affect daily living ability in persons with DS, as anxiety has not been found to be a significant problem in this population (Graham et al, 2005; Haveman et al., 1994; Einfeld et al., 1999).
- However, as both anxiety and motor ability are significant problems in WS, it is difficult to make predictions on which area of difficulty will be most likely to affect daily living skills.

Analysis

- If both motor ability and anxiety are found to correlate with daily living skills, semi-partial correlations will be used to examine whether motor ability or anxiety has more of an effect on daily living skills.
- **Power analysis:** Input: G*Power– F tests, linear multiple regression: fixed model, R^2 deviation from zero. Effect size $f^2 = 0.35$ (large), input for effect size: alpha error probability p=.05, power=0.8, number of predictors = 2. Outcome: N= 30 (each group).