Exploring the impact of Cognitive Health Enhancing Behaviours, Subjective Cognitive Complaints, Fear of Dementia and Generalised Anxiety on Cognitive Function

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Thesis declaration form

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

Signature: 

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Overview

There has been much interest recently in health behaviours that might reduce the risk of neurodegenerative illnesses that cause dementia. Examples of behaviours that potentially enhance (neuro)cognitive health include exercising, maintaining social connections, cognitive activity, and diet. This thesis explores how anxiety mediates the relationship between cognitive health enhancing behaviours and cognitive functioning in healthy adults.

Part I is a systematic literature review examining the impact of psychosocial, cognitive training, and multidomain interventions on cognitive functioning. In total, 31 randomised controlled trials (RCTs) were included in this review.

Part II presents a secondary analysis of data collected from a charity called Food for the Brain (FFB). Structural Equation Modelling (SEM) was used to analyse whether different types of anxiety mediate the relationship between cognitive health enhancing behaviours and cognitive functioning. Exploratory analysis of longitudinal data collected at six, 12 and 24 months after baseline, investigated predictors of change in cognitive health enhancing behaviours over time.

Part III is a critical appraisal that reflects on my experience of co-production and completing the systematic review for the APPLE-Tree project, methodological problems with the measures in the empirical study and the role that clinical psychology has in public health.

Impact Statement

Dementia affected around 47 million people across the world in 2015 (Livingston et al., 2017). There is no current treatment available to cure dementia so there has been a shift of focus to interventions to reduce risk factors of dementia (Livingston et al., 2017).

Through the systematic review, I explored the effectiveness of interventions targeting some risk factors of dementia. The review has directly influenced the content of the APPLE-Tree intervention with the first pilot intervention expected to begin within the year. The protocol for this review is in the public domain (Prospero) and the review itself has been accepted for publication by the Journal Ageing Research Reviews (impact factor = 10.39).

The dataset which has been screened and cleaned by the author for the analysis presented in this thesis has also been used to further explore the psychometric properties of the "Brief-Fear of Dementia" scale, a concept for which the existing scales in the literature have weak psychometric properties. The findings from the main data analysis will be adapted for publication for the Journal of Alzheimer's Disease and they will also be written into a lay report for use by the charity Food for the Brain with the intention of highlighting the importance of considering the individual differences in anxiety when considering cognitive function. It will also highlight the importance of considering how to present feedback to individuals to change their behaviour to reduce risk of dementia.

This thesis also highlights the importance of continuing to investigate factors that may impact an individual's likelihood to make changes to their behaviour in larger, representative samples in order to identify effective public health strategies to reduce dementia risk.

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Part I: Literature Review

Effectiveness of psychosocial, cognitive and multidomain interventions in reducing cognitive decline in older populations: A Systematic Review

Abstract

Aims: To assess the effectiveness of psychosocial, cognitive training and multimodal interventions in reducing cognitive decline in healthy older adults or people with Mild Cognitive Impairment.

Methods: PubMed, EMBASE (Ovid) and PsycINFO (Ovid), CINAHL and Web of Science were searched for studies meeting the inclusion criteria from their earliest record through to 30th April 2019. A modified version of the Critical Appraisal Skills Programme (Critical Appraisal Skills Programme, 2018) was used to assess the quality of studies. Included studies were synthesised using a narrative approach.

Results: Of 2311 unique records identified, 31 studies were eligible for inclusion; 13 psychosocial, nine cognitive training and nine multidomain interventions with a total of 4501 participants. Three studies found a beneficial effect of a psychosocial intervention (creative arts intervention) on cognition but only one at low risk of bias (ROB) included an active control group. No significant effects were found for meditation, goal-based interventions, reminiscence therapy or cognitive stimulation therapy when compared to a socially active control group. Only two cognitive training intervention RCTs were rated as low ROB and neither found a significant effect of intervention on cognition. Six high ROB studies found intensive, frequently delivered, cognitive training was effective in improving cognition. Four multidomain RCTs (rated as lower ROB) found significant effects of combined cognitive, exercise and social interventions; two compared to active control groups and two compared treatment as usual (TAU) control groups.

Conclusions: The identified psychosocial, cognitive and multidomain interventions show limited results for improving cognition in high risk individuals and healthy older adults. More research of high quality is needed to provide conclusions

regarding the effectiveness of these interventions before widespread and costly implementation across services.

Introduction

Dementia and late-life cognitive impairment have become serious global and economic challenges (Livingston et al., 2017). It is estimated that around 47 million people were living with dementia worldwide in 2015. This is likely to increase to 66 million by 2030 and 115 million by 2050 (Prince et al., 2013). In an ageing population, strategies are needed to slow age-related cognitive decline and reduce disease-related cognitive impairment in older adults (Kirk-Sanchez & McGough, 2014). It is argued that there are potentially modifiable risk factors (low education, mental inactivity, depression, diabetes, physical inactivity, and smoking) (Ngandu et al., 2015) that may influence an individual's risk of developing dementia. Livingston et al. (2017) calculated that based on modifiable risk factors, around one third of dementia can be prevented. Therefore, interventions aimed at reducing the risk of cognitive decline have become a priority for clinical research.

Dementia and Mild Cognitive Impairment (MCI)

Dementia is defined as a progressive deterioration in cognitive functioning and activities of daily living beyond what is expected from normal ageing (WHO, 2019). MCI is used to characterise a position between cognition of normal ageing and dementia (Petersen et al., 2001). In order to meet a diagnosis of MCI, individuals must show the following: i) subjective memory complaint, preferably verified by a relative/close friend, ii) objective memory impairment, relative to age, iii) preserved general cognition for age, iv) functioning in daily activities of living, and, v) not meet criteria for a diagnosis of dementia (Petersen et al., 1999). Subjective cognitive complaints refers to everyday concerns regarding cognition such as, remembering events that have happened recently or trouble remembering where belongings are without objective memory impairment (Mitchell, 2008). Studies have found a

progression rate from MCI to dementia of 12% per year compared to incidence rates from a non-MCI sample to dementia at a rate of 1-2% per year (Petersen, 2003).

Potentially modifiable factors and risk of dementia

Factors linked to an increased risk of developing dementia include psychological (anxiety, depression), social (isolation) and cognitive domains (cognitive reserve, education). For example, a cohort study following individuals for a median of 24.7 years found that individuals who experienced one episode of elevated depression scores on the Center for Epidemiological Studies Depression Scale resulted in an 87%-93% increase in dementia risk (Dotson, Beydoun, & Zonderman, 2010). The authors concluded that depression is a significant risk factor for dementia, particularly repeated episodes. Therefore, reducing the risk of recurrence of depression in mid-life adults is of importance in order to prevent or delay the onset of dementia. Furthermore, a systematic review and meta-analysis of social isolation and risk of dementia found that low social participation, less frequent social contact and loneliness were statistically significantly associated with incidence of dementia (Kuiper et al., 2015). A systematic review also identified that clinically significant anxiety (not anxiety related to prodromal dementia symptoms) in midlife was associated with an increased risk of dementia over an interval of at least 10 years (Gimson, Schlosser, Huntley, & Marchant, 2018).

It has also been suggested that cognitive reserve may delay the development of dementia (Stern, 2012). Cognitive reserve is a concept used to describe a person's capacity to maintain normal cognitive functioning in the presence of brain pathology from ageing or disease. It has been suggested that life experiences such as, educational and occupational attainment supply this reserve (Scarmeas & Stern, 2003). Sonnen et al. (2011) highlight that some individuals with neuropathological

indications of Alzheimer's Disease (AD) have not displayed the symptoms of dementia and maintain functioning suggesting some individuals have more tolerance for these neuropathological changes. Education, occupation and leisure activities have been found to increase cognitive reserve (Stern, 2012). This is supported by findings that that those with higher levels of educational and occupational attainment are less likely to develop AD (Gatz et al., 2006; Mortimer & Graves, 1993). Taken together, these findings highlight the importance of targeting these psychosocial and cognitive factors in midlife in order to reduce the risk of the development of dementia.

Systematic reviews of interventions to reduce cognitive decline

A systematic review of 10 cognitive training interventions with 305 participants with MCI found that eight out of 10 studies reported improvements in at least one cognitive outcome (Gates, Sachdev, Singh, & Valenzuela, 2011) with moderate to large effect sizes. The review included both RCTs and non-RCT studies, with all the RCTS being underpowered. Furthermore, the review only included individuals with MCI but it is important to consider intervening with healthy individuals because neurophysiological changes occur before functional impairment is identified (Richard et al., 2012).

A second systematic review investigating memory training and cognitive training in individuals with MCI reported significant improvements in 44% of measures of memory after an intervention (Jean, Bergeron, Thivierge, & Simard, 2010). However, only one of the 15 studies included more than 30 participants in the intervention group; therefore, the studies may have been underpowered. This review also included RCTs, quasi-experimental studies and single case studies.

An earlier meta-analysis of 24 trials including healthy adults and those with MCI found no effect of memory training (Zehnder, Martin, Altgassen, & Clare, 2009). This review only included studies with low risk of bias and had strict exclusion criteria. They also argued that it was not always clear how the outcome measures matched the content of the intervention for the included studies which may have resulted in lower effects being reported.

Richard et al. (2012) posit that RCTs are needed in order to identify the true impact of an intervention; however, the RCTs to date have been of mixed quality (Bier et al., 2015) . RCTs have either not been exclusively included in systematic reviews or have been underpowered.

Whilst there are many reviews looking at the impact of psychosocial interventions on depression or behavioural symptoms of dementia (Regan & Varanelli, 2013; Teri, McKenzie, LaFazia, & Practice, 2005) and cognition in dementia (Cooper, Li, Lyketsos, & Livingston, 2013; Dewey & Saz, 2001; Tsoi, Chan, Hirai, Wong, & Kwok, 2015), there are, to my knowledge, no current systematic reviews looking at the impact of psychosocial and multi-modal interventions on cognitive function and the reduction of risk of dementia.

Aims

This current review aims to extend and focus previous systematic reviews on cognitive interventions for prevention of dementia by including only RCTs and by including studies with populations of healthy older adults and those with MCI. The Lancet review highlights the importance of interventions starting before the onset of any cognitive difficulties since neurophysiological signs of dementia begin before objective symptoms develop (Livingston et al., 2017). Furthermore, by combining cognitive interventions and psychosocial interventions, this review aims to be the

first of its kind to review non-pharmacological interventions that do not overtly address physical health (e.g. through diet or exercise). Multidomain interventions have been included in this systematic review due to them typically including a psychosocial or cognitive component.

Methods

This review reports a subset of data from a larger systematic review. Alongside the APPLE-Tree team at the Institute of Psychiatry, I wrote the protocol and registered it with PROSPERO Prospective Register of Systematic Reviews (CRD42019133614; available at: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42019133614). The larger review reports on interventions targeting physical health (exercise, diet) in addition to psychosocial and multimodal interventions. In contrast, this current review reports psychosocial, multimodal and cognitive training interventions. The APPLE-Tree team decided only to report interventions that focussed on a lifestyle change and the impact on cognitive function; therefore, they did not include cognitive training interventions in their review.

Search strategy

PubMed, EMBASE (Ovid) and PsycINFO (Ovid), CINAHL and Web of Science were searched from their earliest record through to 30th April 2019, limited to English language only. Key terms searched for the databases were: age (Aged OR Middle Aged OR Aged 80 and over, OR Frail Elderly), study type (Randomised Controlled Trial), outcome (Cognitive Dysfunction OR Dementia OR Alzheimer's Disease OR Mild Cognitive Impairment), and modifiable risk factors (Diabetes

Mellitus OR Exercise, OR Body mass index OR Body weight OR Drinking behaviour OR Alcohol drinking OR Smoking OR Smoking cessation OR Social Isolation OR Depression OR Anxiety OR Cardiovascular diseases OR Vascular Disease OR Hypertension OR Diet, Mediterranean). Additional papers were identified through reviewer's searching the references of included articles. If these met the inclusion criteria, these were double-checked by a second reviewer and the results were also tabulated.

Study inclusion and exclusion criteria

Petticrew and Roberts (2008) Population, Intervention, Comparison, Outcomes, Study design (PICOS) approach was used as a framework for drawing up criteria for study eligibility.

Studies were included if, 1) the population were aged over 50 if a healthy population or any age if MCI was present, 2) without dementia, with or without memory concerns, 3) they presented results of a RCT evaluating a non-pharmacological intervention delivered face-to-face or through another modality, 4) included a control or comparison group, 5) a cognitive outcome measure was a primary outcome.

Exclusion criteria consisted of the following: 1) animal research, 2) papers that were not primarily research (e.g. systematic reviews, poster presentations), 3) dementia diagnosis at baseline could not be ruled out or was not adequately assessed, 4) aged less than 50 if healthy adults 5) pharmacological, diet or exercise interventions, 6) not a randomised-controlled trial, 7) no measure of cognitive function as an outcome. Multimodal interventions were also excluded within criteria number five if they did not include a psychosocial or cognitive intervention.

Procedure

The titles and abstracts of the references retrieved by the electronic searches were entered into Endnote and screened for relevance. Papers that were duplicated from the different databases were removed. The total number of papers were divided amongst myself and two further independent researchers. A fourth screener independently checked 20% of each screener's studies against the pre-determined inclusion and exclusion criteria. The list of studies and the decision for exclusion was tabulated in Microsoft Excel. Inter-rater agreement for abstract screening was substantial (ranged between 90.5-97%). All discrepancies were resolved through discussion. Using the same methods, the retrieved articles were assessed for inclusion and checked independently by the fourth rater. The four researchers divided up the papers and extracted data from the included studies. The information was tabulated and checked by one of the other three researchers for accuracy. Discrepancies were resolved by discussion, with the involvement of a third reviewer if necessary. References of included articles were searched for additional papers. If these met the inclusion criteria, the results were also tabulated.

Assessing Risk of Bias (ROB)

The risk of bias of included studies was assessed through responses to six standard quality criteria modified from (Critical Appraisal Skills Programme, 2018). This criteria has been used in previous reviews (Cooper, Ketley, & Livingston, 2014; Livingston et al., 2014; Lord, Livingston, & Cooper, 2015; Mukadam, Cooper, & Livingston, 2011; Scott et al., 2019). Answers to the questions were rated as Yes/No. In order for the paper to be rated as low ROB, the questions below marked with an asterisk had to be answered positively.

1) Were participants randomised to intervention and control groups, using a process that is independent?*

2) Were participants and clinicians, as far as possible, masked to treatment allocation?

3) Were all participants who entered the trial accounted for and an intention-to-treat analysis conducted?*

4) Were follow-up and data collection processes the same for all participants?*

5) Was a power calculation carried out based on one of our specified outcomes of interest (cognition)?

6) Were 45 or more participants included in analyses comparing treatment and control effects?*

Synthesis and analysis

The extracted data from the included articles was tabulated with the following headings: study title, authors, setting and population characteristics, intervention characteristics, N for intervention, control group, N for control group, duration of follow-up, and between-group differences on cognitive outcomes. Follow-up was defined as the longest duration after baseline at which measures were collected.

A narrative synthesis of the findings was utilised. At the synthesis stage, cognitive training interventions were distinguished from cognitive activity/stimulation. Cognitive training interventions were defined as a structured intervention of repeated practice on problem activities using standardised tasks that target specific cognitive domains (Gates & Valenzuela, 2010). Results have been structured according to specific intervention types (psychosocial, cognitive training

and multidomain), risk of bias, and the nature of the content of the comparator (active control group or no treatment control).

Results

The initial search identified 2311 papers, from which 31 papers were included (see Figure 1 for PRISMA diagram).

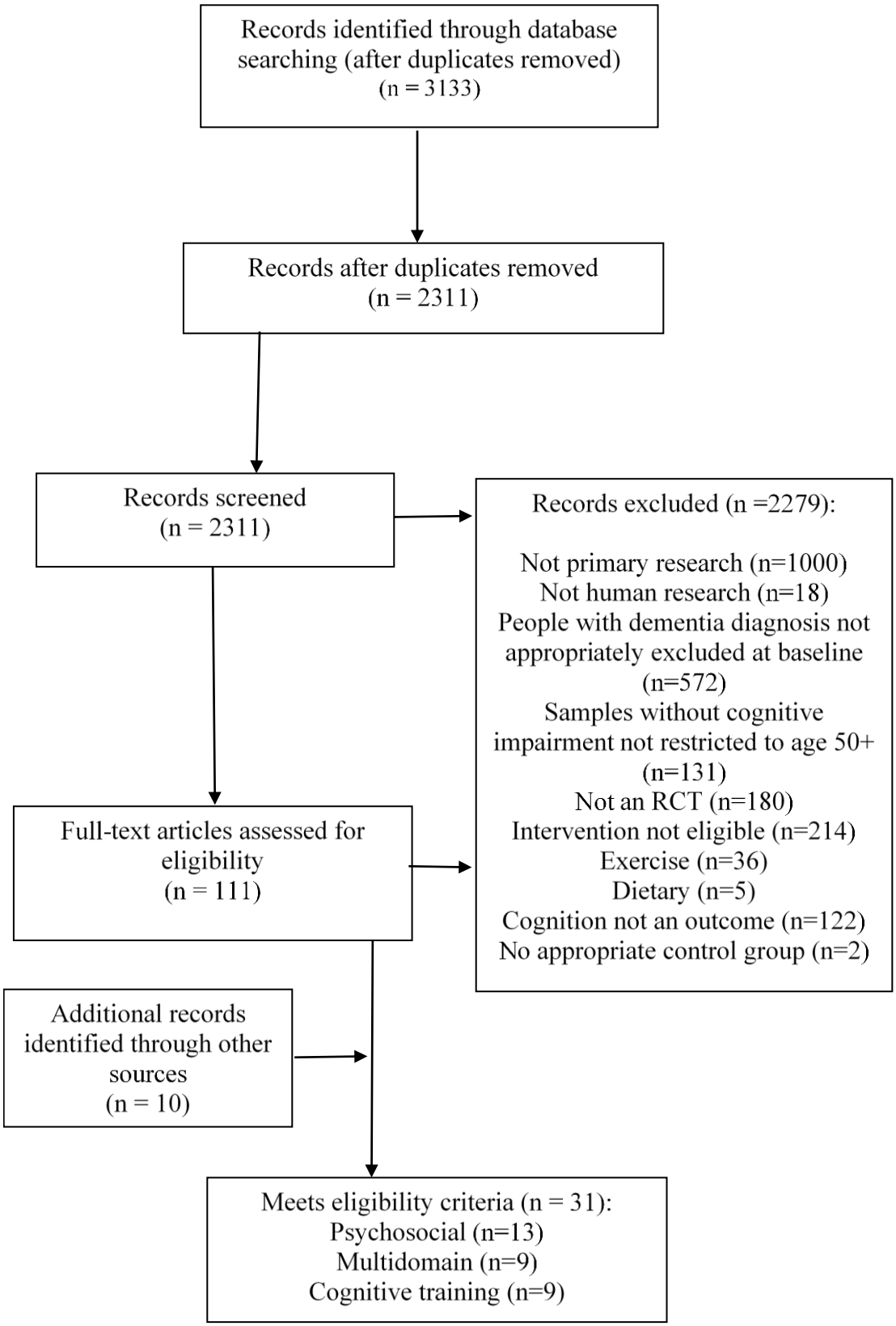

Figure 1. PRISMA diagram of study selection

Quality appraisal

Papers were rated based on their risk of bias (ROB). Those that were rated as low ROB were considered to be of high quality and those that were rated as high ROB were rated as low quality. Two papers (15%) out of 13 from the psychosocial interventions included in this review had lower risk of bias according to the criteria listed above whereas 11 (85%) studies were rated as at higher risk of bias. Two papers (22%) out of nine from the cognitive interventions had lower risk of bias whereas seven (78%) had a higher risk of bias. Of the multidomain interventions, six (66%) were rated as lower risk of bias and three (33%) were rated as having higher risk of bias. A summary of the risk of bias rating for each paper can be found in Table 1.

Table 1

A summary of risk of bias rating for psychosocial, cognitive training and multidomain interventions

Study	1*	2	3*	4*	5	6*	ROB
Psychosocial							
Bugos, Perlstein, McCrae, Brophy, and Bedenbaugh (2007)	X	X	X	✓	X	X	High
Clare et al. (2015)	✓	✓	X	✓	X	✓	High
Dawson et al. (2014)	✓	✓	✓	✓	X	X	High
Duru Asiret and Dutkun (2018)	X	X	X	✓	✓	✓	High
Innes, Selfe, Khalsa, and Kandati (2017)	✓	✓	✓	✓	X	✓	Low
Mackin et al. (2014)	X	✓	X	✓	X	✓	High
Mahendran et al. (2018)	✓	✓	✓	✓	X	X	High
Nakatsuka et al. (2015)	✓	X	X	✓	X	✓	High
Oken et al. (2017)	X	✓	X	✓	X	✓	High

Thiel et al. (2012)	✓	X	X	✓	✓	✓	High
Wahbeh, Goodrich, and Oken (2016)	X	✓	X	✓	X	X	High
Wells et al. (2013)	✓	✓	X	X	X	X	High
Zhao, Li, Lin, Wei, and Yang (2018)	✓	✓	✓	✓	X	✓	Low
Cognitive training							
Bae et al. (2019)	X	X	X	✓	X	✓	High
Ballesteros et al. (2014)	✓	X	X	✓	X	X	High
Barnes et al. (2013)	✓	✓	✓	✓	✓	✓	Low
Finn and McDonald (2011)	X	✓	X	✓	X	X	High
Millan-Calenti et al. (2015)	✓	X	X	✓	X	✓	High
Miller et al. (2013)	X	X	X	✓	X	X	High
Pantoni et al. (2017)	✓	✓	X	✓	X	X	High
Toril, Reales, Mayas, and Ballesteros (2016)	X	X	X	X	X	X	High

Zelinski et al. (2011)	✓	✓	✓	✓	✓	✓	Low
Multidomain							
Bae et al. (2019)	✓	✓	✓	✓	✓	✓	Low
Barnes et al. (2013)	✓	✓	✓	✓	✓	✓	Low
Bruno et al. (2018)	✓	✓	X	✓	✓	✓	High
Diamond et al. (2015)	✓	✓	X	✓	✓	✓	High
Fiatarone Singh et al. (2014)	✓	✓	✓	✓	✓	✓	Low
Klusmann et al. (2010)	✓	✓	✓	✓	✓	✓	Low
Kwok et al. (2013)	✓	✓	X	✓	✓	✓	High
Lam, Chan, Leung, Fung, and Leung (2015)	✓	✓	✓	✓	X	✓	Low
Ngandu et al. (2015)	✓	✓	✓	✓	✓	✓	Low

1) Independent randomisation* 2) Masked allocation 3) Intention to Treat Analysis* 4) Consistent data collection* 5) Power calculation 6) N≥45*;✓=Yes

X= No *A positive affirmation was needed to rate as low ROB

Participant characteristics

Across the 31 studies, there were a total of 4501 participants, 1062 in the psychosocial interventions, 943 in the cognitive training interventions and 2496 in the multidomain interventions. Participants' age varied from 50-90 years old across the studies except one study (Pantoni et al., 2017) that included individuals 18 and older with MCI and small vessel disease. Two studies (Duru Asiret & Dutkun, 2018; Klusmann et al., 2010) excluded men; the remaining studies included both women and men. The countries in which the studies were undertaken varied (British, American, Canadian, Australian, German, Spanish and Chinese); however, the majority of participants were from white westernised countries.

Thirteen out of 31 studies included participants with a diagnosis of MCI (confirmed by a clinician using pre-set criteria for MCI and/or neuropsychological testing). Eighteen of the studies included healthy older adults with or without subjective memory complaints. The majority of studies in the psychosocial (n= 11), cognitive (n=7), and multidomain (n=7) categories included participants living independently in the community.

Psychosocial interventions

Study characteristics

Psychosocial interventions included: four meditation/mindfulness/yoga interventions (Innes et al., 2017; Oken et al., 2017; Wahbeh et al., 2016; Wells et al., 2013), three creative therapies (Bugos, 2005; Mahendran et al., 2018; Zhao et al., 2018), one reminiscence therapy (Duru Asiret & Dutkun, 2018), two problem-solving therapies (Clare et al., 2015; Mackin et al., 2014), one occupation-based training (Dawson et al., 2014) and two psychoeducation and cognitive stimulation therapy (Nakatsuka et al., 2015; Thiel et al., 2012). Nine (69%) of the 13 studies

investigated group-based interventions whereas the other four studies utilised individual-based interventions (Bugos et al., 2007; Duru Asiret & Dutkun, 2018; Mackin et al., 2014; Oken et al., 2017). The frequency and length of the interventions ranged from weekly sessions to daily sessions and from six weeks to six months. Table 2 provides a summary of study characteristics and results for psychosocial interventions.

Table 2

Summary of study characteristics and outcomes for psychosocial interventions

Study	Setting and population	Intervention	N	Control group	N	Follow-up	Between group differences on cognitive outcomes
Active Control							
Clare et al. (2015) Wales	People aged 50+, living and functioning independently recruited from a community Agewell centre	90 minute, Bangor Goal Setting Interview to identify ≤5 SMART goals related to physical or cognitive activity, physical health, diet or social engagement. 1. Goal setting (GS); 2. GS + mentoring (GM):GS + 5 follow up phone calls from the researcher, bi-monthly to review progress and	GS- 24 GM-24	90 minute interview (general discussion/ information about activities and health)	27	12 months	MoCA – NS, *p*= .46 CVLT Immediate recall- NS, *p*= .31 CVLT delayed recall- NS, *p*= .55 TMT- NS, *p*= .46 Verbal Fluency - NS, *p*= .19

		problem-solve. Participants free to engage in activities at centre/ elsewhere					
Dawson (2014) Canada	Community dwelling older adults with cognitive complaints but no objective MCI, dementia or depression, recruited from Toronto research centre	3 (1 hour) group and 9 (1 hour) individual sessions, by trained research assistant, over 8 weeks. Education about self-management, successful aging and an occupation-based meta-cognitive strategy-training program	10	3 group, 9 (1 hour) individual sessions: brain health education and cognitively stimulating exercises	9	3 months	DKEFS TMT - NS DKEFS Tower test - NS Verbal fluency - NS

Innes (2017) USA	Community dwelling adults aged 50+, with MCI (confirmed by clinician) or Subjective cognitive deficits (SCD)	Self-guided (using a CD) Kirtan Kriya Meditation, a multisensory (motor/physical and visualisation) practice. 12 minutes/day for 3 months, then at their discretion for next 3 months	27	Relaxing instrumental music. 12 minutes/day for 3 months, then at their discretion for the ensuing 3 months	28	6 months	MFQ– NS (p<0.1) TMT A/B – NS (p<0.1) DSST - NS (p<0.1)
Mackin (2014) USA	Community-dwelling adults (aged 60+) with major depression (DSM-IV) and executive dysfunction, recruited by	12 weekly individual Problem-solving sessions, from clinical psychologists / social workers: participants set psychotherapy treatment goals, discussed and evaluated how to reach them, created and evaluated action	110	12 weekly individual supportive therapy, from clinical psychologists / social workers focussing on warmth, empathy,	111	9 months	Hopkins Verbal Learning Test (HVLT-R)- NS Executive function: - NS DRS-IP Wisconsin card sorting test- NS SCWT (Colour word trial)- NS

	advertisements and from psychiatric clinic	plans. Four PhD level served as therapists.		support and active listening.			TMT (Parts A & B)-NS
Nakatsuka et al. (2015) Japan	Community dwelling People aged >75 with CDR 0.5	Cognitive Intervention computer based.12 group sessions and 12 homework. Included quizzes, games and puzzles. Once a week, 60 minutes.	45	Physical Activity (group 2) Group Reminiscence Approach (group 3)	PA- 38 GRA-44	12 weeks	MMSE- $p< 0.005$ TMT-A- $p< 0.005$ Word fluency- $p< 0.005$ (within groups) Between groups - NS
Thiel et al. (2012) Germany	Community dwelling 65-89 healthy older adults.	Cognitive Training (CT)- Eight Weekly organised sessions, of 90 minutes. Group sessions 10-12. Topics included discussions and recommendations for healthy eating to optimise	114	CT plus counselling (Group 2) and TAU Controls (Group 3)	45	6 months	ADAS-Cog- NS $\chi 2(3, n=159)=4.10, p=0.250.$

		cognitive function, dementia risk factors, coping strategies with memory difficulties, in addition to cognitive stimulating games. Additionally education in relation to motivation and self-regulation was provided.					
Wahbeh (2016) USA	Portland Metropolitan area. Recruited through flyers at a community retirement home. 16, 65-90 year olds	6 x weekly 1 hour online meditation group & 30 minutes of daily home practice. Based on mindfulness based cognitive therapy and stress reduction. Online enquiries were answered by facilitators.	8	6 x weekly 1 hour online group. Participants watched & discussed a video; & listened to podcasts about healthy living	8	6 weeks	Simple reaction time- NS, *p*> .20 Flanker- NS, *p*> .20 Letter-number sequencing- NS, *p*> .20 Verbal fluency letter- NS, *p*> .20 RAVLT- NS, *p*> .20

		Participants received weekly reminder calls, but completed sessions 2-6 on their own					
Zhao (2018) China	People aged 60+ with self-reported memory complaints meeting DSMIV MCI criteria, recruited from a public tertiary outpatient clinic.	25 group sessions of drawing and storying telling (creative expression) over 16 weeks, facilitated by professional therapists.	48	25 social activation group sessions over 16 weeks, facilitated by occupational therapists; including cognitive strategy training	45	6 months	MoCA- F=21.47, p<0.001* CVAVLT immediate/delayed recall = F= 4.81/3.98, p= 0.023/0.012*; CVAVFT – F= 3.91, p=0.01*; DST- F=23.35, p< 0.001* TMT A/B- F= 3.29, p=0.030*

Treatment as Usual							
Bugos (2007) USA	Community-dwelling adults (aged 60-85), no dementia, not experienced musicians	Weekly 30 min individual piano lessons, with 3 hours independent practice each week (which was recorded).	16	TAU	15	6 months	WAIS-III: Digit Span, Block Design & Letter-Number sequencing – NS; Digit Symbol- $F(2, 55) = 4.68$, $p<0.015$; TMT A- $F(2, 58)$, $p<0.01$; TMT B- $F(2, 55)= 4.44$, $p<0.03$*
Duru (2018) Turkey	Women (aged 50+) recruited from a Family Health Centre; without a dementia/ psychiatric	8 x weekly in-home individual reminiscence therapy (30-45 mins); topics included: childhood and family life, food and cooking, days out and holidays.	27	TAU	23	8 weeks	MMSE – NS, $p= 0.389$

	diagnosis, MMSE 24+						
Mahendran (2018) Singapore	Community dwelling people with MCI (Petersen criteria) recruited from a cohort study. Aged 60-85yrs	1 hour weekly groups for 3 months then fortnightly for 6 months, by trained staff. (1) Art therapy: Guided viewing and cognitive evaluation of art; narration of thoughts; visual art production. (2) Music reminiscence therapy: listening, remembering & discussing music	1= 22 2= 24	TAU	22	9 months	Mean change for RAVLT memory domains (Group 1 vs TAU): (d=0.308; 90% CI 0.0868, 0.548; *p*= 0.035); for Group 2 vs TAU -NS.
Oken (2017) USA	Community-dwelling people	6 x weekly, 60-90 min, individual meditation, facilitated	66	Waitlist control	68	2 months	SCWT; Flanker attention Test

	recruited by University adverts; aged 50-85 & perceived stress scale score >9	by a research assistant. Based on mindfulness based cognitive therapy and stress reduction. Home practice advised, and supported by audio recordings					Controlled oral word associations letter category & verbal fluency, letter-number sequence, reaction time tests - NS
Wells (2013) USA	People with MCI (objectively determined) recruited from USA Medical centre, aged 55-90)	8 x 2 hour weekly mindfulness-based stress reduction, and mindful movement (yoga) sessions and a mindfulness retreat day; Home practice (30 min/d) with standard guided audio recordings.	9	TAU	5	8 weeks	ADAS-Cog - NS, p=.46; RAVLT (total 1-5)- NS, p= .24; TMT Part A/B - p=0.04/0.01* (favoured control); Controlled word association test, Animal & Boston Naming- NS

ADAS-COG: Alzheimer's Disease Assessment Scale- Cognitive Subscale; CAIDE: Cardiovascular Risk Factors, Aging and Dementia Risk Score; COWAT: Controlled Word Association Test; CVAVLT: Chinese version of the Auditory verbal learning test; CVAVFT; Chinese version of the Auditory verbal fluency test; DKEFS: Delis-Kaplan Executive Function System; DRS-IP: Mattis Dementia Rating Scale-2 Initiation/Perseveration subscale; DSST: Digit symbol Substitution Test; EFT: Erickson Flanker Test; FCSRT; The Free and Cued Selective Reminding Test; HVLT-R: Hopkins Verbal Learning Test; IADL: Instrumental Activities of Daily Living; MFQ: Memory Functioning Questionnaire; IQCODE: Informant Questionnaire on Cognitive Decline in the Elderly; MIC: Memory Inventory for Chinese; MMSE: Mini Mental State Examination; MoCA: Montreal Cognitive Assessment; NCGG-FAT: National Centre for Geriatrics and Gerentology Functional Assessment Tool; NTB: Neuropsychological test battery; NTB; P: Petersen Criteria; RAVLT: Rey auditory-verbal learning test; RBMT; Rivermead Behavioural Memory Test;

SCWT: Stroop Colour and Word Test; SDST: Symbol-Digit Substitution Test; TEA: Test of everyday attention; TICSm: Modified Telephone Interview for Cognitive Status; TMT: Trail Making Tests; UFOV: Usual Field of View; WAIS: Wechsler Adult Intelligence Scale; WMI-II, VPA: Wechsler Memory Scale Verbal Paired Associations.

Results on primary outcomes in bold. * statistically significant between –group difference; unless stated differences favour the intervention; Follow-up= longest duration after baseline at which measures were collected.

Psychosocial interventions compared to active control groups

Eight studies were identified that compared psychosocial interventions to active control conditions. One study of low risk of bias found a significant effect (Zhao et al., 2018). After 6 months, 25 group sessions of drawing and story-telling over 16 weeks led to a significant improvement in MoCA scores in a Chinese population with MCI compared to a social activation control group of 25 sessions. A study of higher risk of bias also found significant results of a psychosocial intervention on cognition (Nakatsuka et al., 2015). A 12-week group-based cognitive stimulation intervention on the computer had a significant impact on Trail Making Tasks and Word Fluency but not compared to the control groups (physical activity and group reminiscence therapy) at 12 weeks. Therefore, it is difficult to conclude the mechanism by which the cognitive training affected cognitive function in this study. It is possible the effect of social interaction was the significant mechanism.

There were six studies that did not find a significant effect of a psychosocial intervention compared to an active control. The interventions were: Kirtan Kriya meditation (Innes et al., 2017), meditation/mindfulness (Wahbeh et al., 2016), goal setting/problem solving (Clare et al., 2015; Dawson et al., 2014; Mackin et al., 2014) and cognitive stimulation (Thiel et al., 2012). Of these, only one (Innes et al., 2017) was of low risk of bias.

Psychosocial interventions compared to treatment as usual

Five studies compared an intervention to TAU, two of which found significant differences between intervention and control. All were rated as high risk of bias. In a study in Singapore, Mahendran et al. (2018) investigated the impact of

two creative art interventions: art therapy and music reminiscence therapy. Art therapy involved guided viewing and evaluation of artwork and visual art production whereas music reminiscence therapy involved listening, remembering and discussing different music. They found that 18 group sessions of art therapy, weekly for one hour over three months and then fortnightly for six months had a significant impact on Rey Auditory Verbal Learning Tasks (RAVLT) after nine months compared to treatment as usual. However, music reminiscence therapy did not provide significant results on cognition (Mahendran et al., 2018). Weekly 30 minute individual piano lessons, with three hours independent practice each week produced a significant effect on the WAIS-III Digit symbol and Trail Making Tasks after six months, compared to treatment as usual (Bugos, 2005). Individual reminiscence therapy for women did not produce a significant effect on MMSE scores compared to TAU after eight weeks (Duru Asiret & Dutkun, 2018) and no significant differences between an individual meditation intervention and TAU was found in cognitive function measures (Oken et al., 2017). Wells et al. (2013) found a significant effect of a group-based mindfulness intervention on executive functioning measures but this favoured the control group.

Cognitive training interventions

Study characteristics

Of the nine cognitive training studies, three specified they used or adapted the Luminosity cognitive training tool (Ballesteros et al., 2014; Finn & McDonald, 2011; Toril, Reales, Mayas, & Ballesteros, 2016). Other studies used Telecognition (Millan-Calenti et al., 2015), Dakin's Brain Fitness (Miller et al., 2013), APT-II (Pantoni et al., 2017), Posit Science corporation (Barnes et al., 2009) and FIT Brain programme (Oh, Seo, Lee, Song, & Shin, 2018). All but one study (Barnes et al.,

2009) involved using a computer device. Three studies conducted cognitive training in a group setting (Ballesteros et al., 2014; Barnes et al., 2009; Toril et al., 2016) whereas six studies asked participants to complete cognitive tasks independently. The length of training varied from six weeks to 20 weeks with frequency of sessions ranging from twice a week to five times a week. All studies measured cognitive outcomes at the end of the intervention with the exception of two which measured cognitive outcomes three months after (Zelinski et al., 2011) and 12 months after. See Table 3 for a summary of study characteristics and results for cognitive training interventions.

Table 3

Summary of study characteristics and outcomes for cognitive training interventions

Study	Setting and population	Intervention	N	Control group	N	Follow-up	Between group differences on cognitive outcomes
Active Control							
Ballesteros et al. (2014) Spain	Community dwelling. healthy older volunteers	20 x 1 hour cognitive training "games" over 10-12 weeks designed with the purpose of improving the user's cognitive; sessions in a laboratory. Group based.	20	3 x 2 h sessions to discuss age-related topics	20	12 weeks	Processing speed (p<0.001)* attention p<0.05)*, alertness (p<0.001)*; Rey copy, WCST, Corsi and Jigsaw task: NS; WMS Faces: NS; Family pictures p<0.05*
Barnes et al. (2009) USA	Memory clinic; aged 50+ with MCI diagnosis.	Participants asked to complete 100min/d, 5d/wk for 6 weeks of cognitive training at home, with weekly support phone calls; 7	22	Passive computer activities such as reading, listening and visuospatial	25	6 weeks	RBANS NS, CVLT-III verbal learning, COWT, Boston Naming Test: NS.

		exercises designed to improve processing speed, and accuracy in the auditory cortex. Group based.		game for the same amount of time / duration.			
Toril et al. (2016) Spain	Older adults recruited from senior centre	15 1-h video game training sessions with games (Lumosity), designed with the purpose of improving cognition at a senior centre over 7-8 weeks. Group based.	19	Monthly meetings to talk about usual activities	20	2 & 5 months	DST B: p = 0.03*; Corsi blocks: p=0.001*; Jigsaw puzzle task: p = 0.001*; WMS Family pictures I and II: p= 0.001*; Faces I/II (p=0.07/0.04*). DST F =NS
Zelinski et al. (2011) USA	Community dwelling. Healthy older adults, 65+	Participants asked to complete 1 hour a day, 4-5x/ week, total of 40 hours over 8-10 weeks of cognitive training at home,	242	Active Control watching a video on topics such as	245	3 month follow up	RBANS NS; Processing speed p<0.001*; Memory index score p=0.01*; RAVLT p=0.004*; RBMT NS; WMS: DST B: NS;

	with MMSE 26+	designed to improve speed and accuracy of auditory information processing		literature, arts and history.			WMS: Letter number sequencing p=0.03*
Treatment as Usual							
Finn and McDonald (2011) Australia	Community dwelling clients of memory clinic, aged 60+ with MCI, MMSE 23+	30 cognitive training designed, 4-5x a week to improve attention, processing speed, visual memory and cognitive control (Luminosity)	8	Wait list group	8	11 weeks	CANTAB, improved visual sustained attention (p=0.004)*; visual learning, recognition, working memory, attention: NS
Millan-Calenti et al. (2015) Spain	Independently living adults aged 65+. MMSE 24+	12 weeks x 2 (20 minutes) weekly sessions using computer cognitive training called Telecognition. Group.	80	TAU	62	12 weeks	MMSE: p<0.001*

Miller et al. (2013) USA	Retirement community, aged 62+ living independently with memory concerns; MMSE 24+	Computer cognitive training 5x/week, 20-25 minutes/day for 8 weeks: memory, language, visuospatial, reasoning/ problem-solving, and calculation; adjusted to performance; Goal: 40 sessions/2 months. Individual.	38	Waiting list	36	2 & 6 months	Delayed memory: ($F(2,72) = 4.7$, $p = 0.01$)*; immediate memory and language (fluency): NS
Oh et al. (2018) Korea	Adults aged 50+ with subjective memory complaints, MMSE 24+,	2 Cognitive training conditions each with 15-20 mins/day schedule, 5 days/week for 8 weeks; 1. SMART: 10 training tasks, attention, memory and working memory; 2. FIT Brains: web and smartphone, focus,	1)18 2)19	Waitlist control	16	8 weeks	Attention, memory, working memory and executive functioning quotients: NS; Stroop (word) and attention (commission errors): $p<0.05$*

	own a smartphone	speed, memory, logic, visual tasks. Individual.					
Pantoni et al. (2017) Italy	Included patients were diagnosed as affected by MCI, attentional deficit, and small vessel disease	40 x 2hr sessions in 20 weeks of individual cognitive training by a neuropsychologist; tasks focussed on complex attentional control and working memory systems, eg alphabetizing words. Individual.	23	TAU	22	6 &12 months	RAVL (immediate): $p = 0.032$* (12 months); 6 months: NS MoCA, MMSE, RAVL (recall), Stroop, TMT, DSST, ROCF, visual search, short story, verbal fluency: NS

ADAS-COG: Alzheimer's Disease Assessment Scale- Cognitive Subscale; CAIDE: Cardiovascular Risk Factors, Aging and Dementia Risk Score; CANTAB: Cambridge Automated Neuropsychological Test Battery; COWAT: Controlled Word Association Test; CVAVLT: Chinese version of the Auditory verbal learning test; CVAVFT; Chinese version of the Auditory verbal fluency test; DKEFS: Delis-Kaplan Executive Function System; DRS-IP: Mattis Dementia Rating Scale-2 Initiation/Perseveration subscale; DSST: Digit symbol Substitution Test; EFT: Erickson Flanker Test; FCSRT; The Free and Cued Selective Reminding Test; HVLT-R: Hopkins Verbal Learning Test; IADL: Instrumental Activities of Daily Living; MFQ: Memory Functioning Questionnaire; IQCODE: Informant Questionnaire on

Cognitive Decline in the Elderly; MIC: Memory Inventory for Chinese; MMSE: Mini Mental State Examination; MoCA: Montreal Cognitive Assessment; NCGG-FAT: National Centre for Geriatrics and Gerentology Functional Assessment Tool; NTB: Neuropsychological test battery; NTB; P: Petersen Criteria; RAVLT: Rey auditory-verbal learning test; RBMT; Rivermead Behavioural Memory Test; SCWT: Stroop Colour and Word Test; SDST: Symbol-Digit Substitution Test; TEA: Test of everyday attention; TICSm: Modified Telephone Interview for Cognitive Status; TMT: Trail Making Tests; UFOV: Usual Field of View; WAIS: Wechsler Adult Intelligence Scale; WMI-II, VPA: Wechsler Memory Scale Verbal Paired Association;

Results on primary outcomes in bold. * statistically significant between –group difference; unless stated differences favour the intervention; Follow-up= longest duration after baseline at which measures were collected.

Cognitive training interventions compared to active controls

Four studies compared a cognitive training intervention to an active control group. Neither of the two studies rated as lower risk of bias found significant intervention effects on their primary cognitive outcomes (Barnes et al., 2009; Zelinski et al., 2011). One study asked participants with MCI to complete 100 minutes per day, five days a week for six weeks of cognitive training. Exercises were designed to improve processing speed. They did not find a significant result on the RBANS (Barnes et al., 2009). Furthermore, a study of healthy older adults were asked to complete 40 hours over 10-12 weeks (roughly five times a week) of cognitive training designed to improve their processing speed and auditory information processing. They also found no significant effect of intervention on the RBANS (Zelinski et al., 2011).

Both higher risk of bias studies found significant effects of a cognitive training intervention on cognition compared to an active control (Ballesteros et al., 2014; Toril et al., 2016). Twenty, one hour cognitive training games significantly improved healthy Spanish participants processing speed, attention and alertness compared to an ageing discussion group (Ballesteros et al., 2014). Toril et al. (2016) found significant improvements in visuospatial working memory and episodic memory measures compared to a control group of monthly meetings for general discussions.

Cognitive training interventions compared to treatment as usual

Five out of nine cognitive training intervention studies used a non-active control condition such as waitlist controls or usual care. They were all rated as higher risk of bias. Four of the five studies found significant effects on one or more measure of cognition either immediately post-intervention or after a longer duration of follow-

up. There was considerable variation in the amount and duration of cognitive training undertaken.

One of the studies using the Luminosity cognitive training programme showed significant improvement on sustained visual attention measures (CANTAB) after 11 weeks of completing 30 different designs 4 to 5 times per week. However, no significant differences were found on other measures of attention, working memory and visual learning recognition (Finn & McDonald, 2011). Miller et al. (2013) found a computerised cognitive training programme completed five times a week, 20-25 minutes per day for eight weeks produced significant improvements on delayed memory, compared to a wait list control at six months.

Pantoni et al. (2017) asked participants diagnosed with MCI to complete 40, two-hour sessions over 20 weeks of individual cognitive training facilitated by a neuropsychologist. Tasks focused on complex attentional control and working memory. At six months, no significant differences were found between the intervention and control group. However, at 12 months, a significant difference between the groups (favouring the intervention group) was found in RAVLT. Healthy Spanish adults living independently completed 12 weeks of 20 sessions (two to three times a week) of Telecognition and showed significant improvements on an overall score of cognition (MMSE) (Millan-Calenti et al., 2015). However, cognitive outcome measures were only completed at the end of the intervention (Ballesteros et al., 2014; Millan-Calenti et al., 2015) so it is unclear if these results would be sustained.

Multidomain interventions

Study characteristics

The multidomain interventions varied in their components. Five studies combined a cognitive/computer training intervention with an exercise intervention (Barnes et al., 2013; Bruno et al., 2018; Fiatarone Singh et al., 2014; Klusmann et al., 2010; Lam et al., 2015), two studies combined a psychoeducation component and a cognitive training intervention (Diamond et al., 2015; Kwok et al., 2013), one study combined a cognitive element, exercise element and a social component (Bae et al., 2019), and one study combined nutrition, cognitive and exercise interventions (Ngandu et al., 2015). The length of interventions ranged from 12 weeks to one year with follow-up periods ranging from 12 weeks to 24 months. Only two studies (Diamond et al., 2015; Kwok et al., 2013) did not measure cognitive outcomes past the end of the intervention. See Table 4 for a summary of study characteristics and results for multidomain interventions.

Table 4

Summary of study characteristics and outcomes for multidomain interventions

Study	Setting and population	Intervention	N	Control group	N	Follow-up	Between group differences on cognitive outcomes
Active Control							
Bae (2019) Japan	Adults with MCI aged 60+: from cohort study, score ≥ 1.5 SD below norm in 1+ NCGG-FAT cognitive domains. MMSE >24; No dementia or	90-minutes, 2x/week for 24 weeks, of any centre activity group, with physical, cognitive and social activities attended in equal proportions. Groups of 4-5, facilitated by two non-clinical, trained staff	41	Two 90 minute health education classes	42	24 weeks	NCGG-FAT- Spatial working memory- *p*= 0.024*, Memory, TMT A/B, SDST, MMSE- all NS

	functional dependency						
Barnes (2013) USA	Inactive, aged 65+, community residing adults subjective cognitive concerns; no self-reported dementia diagnosis; TICm 19+	1. Individual, home based mental activity. 60 min/d, 3 d/wk for 12 weeks. Games to enhance speed and accuracy of visual and auditory processing. Difficulty adjusted continuously based on performance. 2. Exercise intervention group, 1 hour exercise classes 3 d/wk	1) 32 2) 31	1. Answered questions on home DVDs, watched 60 min/d, 3 d/wk for 12 wks. 2. Group stretching, strength training & relaxation. HR monitored, aim for resting levels	1) 31 2) 32	12 weeks	Composite score from RAVLT (Verbal fluency letter & category, DSST, TMT A & B, EFT, UFOV)- NS

		for 12 weeks. Aerobic, strength, stretching and relaxation. HR monitored with a target of 60-75% of the participants age. Classes by certified exercise instructor.					
Fiatarone (2014) Australia	Community dwelling, people aged 55+, diagnosis of MCI (P) CDR<1; MMSE 23-29, recruited from electoral roll	Training supervised by researchers in 2 x weekly, 60-100 minute groups for 6 months; Progressive resistance training (PRT): high intensity training with resistance machines; Computer cognitive training (CT) targeted memory, executive function, attention and processing speed	PRT-22 CT- 24 CT & PRT-27	1 hour of sham CT (nature videos & answered questions) & stretching (sham PRT)	27	18 months	CT vs sham CT & Intervention vs sham– NS; PRT vs sham exercise: ADAS-Cog- NS; WAIS-III Matrices p=0.02* ES −0.04 (−0.44, 0.36); other cognitive battery tests NS

Klusman (2010) Germany	German-speaking women from Berlin. Included if they made no more than 4 errors on the MMSE (20)	75 x 90 minute group manualised sessions over 6 months of: 1. Using computers (to write, play, calculate, draw and surf the internet, email, and edit images and videos). 2. Exercise: aerobic endurance, strength, flexibility training, balance and coordination.	1) 92 2) 91	Life as usual	76	6 months	RBMT immediate & delayed recall (p = .007/ .01) NS, FCSRT long delay (p = .02)*, TMT B/A (p = .04)* FCSRT short delay, Stroop Test & semantic verbal fluency: NS
Lam (2015) Hong Kong	Elders' social centres; aged 60+ with subjective memory & objective	1 hour group sessions, 3 x/week for 1 year: Cognitive group (C): reading, discussing newspapers, playing board games; Physical (P) group: stretching and toning exercises, mind body (tai chi),	C = 145 P = 147	-Social group (S)- 3 one hour social activity sessions a week. (active control).	S = 131	12 months	CDR-SOB (sum of boxes) - NS ADAS-COG, CMMSE, Digit span, Visual span, CVFT, TMT, MIC – NS

	memory, verbal fluency or attention span impairment. No dementia diagnosis; CDR <1	and aerobic exercise (cycling); Integrated cognitive-physical group (CP): 1 cognitive & 2 mind body exercise in a week.	CP= 132	Included tea gathering, film watching)			
Ngandu (2015) Finland	Community-dwelling people aged 60-77, CAIDE 6+ MMSE 26+; no dementia diagnosis made/ suspected	3 individual & 7-9 group sessions with nutritionists - discussions/ exercises to facilitate healthy diet changes; gym-based, tailored exercise, by physiotherapists, progressive muscle strength (1-3 x/ week) and aerobic exercise (2-5 x/ week). Individual computer	631	General health advice	629	24 months	NTB score improvement intervention>control Between-group difference per year: 0·022 (95% CI 0·002–0·042, p=0.030).* Secondary outcomes – NTB:

		cognitive training (CT) for 2x 6 month blocks of 3/week, 10-15 min sessions; 10 group sessions by psychologists: education, memory strategies, checking individual CT progress & visit to local support group.					Executive functioning *p*= 0.039*; Processing Speed z score - *p*= 0.029*; memory- NS
Treatment as Usual							
Bruno et al. (2018) Italy	People aged 65-89, MMSE Score > 20; CDR = 0.5, MCI confirmed by neurological exam, recruited from GPs, health centres, adverts	2 x 1 hour sessions of supervised cognitive training and 1 x 1 hour physical (aerobic, balance and strength) training 3 x a week; in small groups (n=10) supervised of trained and experienced personnel, including	55	TAU	58	7 months	ADAS-Cog mean difference within groups− 2.17 (SE = 0.42; 95% CI (− 2.99, − 1.34)

		physiotherapists and personal trainers.					
Diamond et al. (2015) Australia	The healthy brain ageing clinic in Sydney. Older adults at risk of cognitive decline (individuals seeking help for new onset cognitive impairment and or major depression) (50+)	Twice weekly, 7 week HBA-CT treatment. One hour psychoeducation group programme covering cognitive strategies and modifiable lifestyle factors followed by one hour computerized Cognitive Training.	36	TAU waitlist	28	N/A	Verbal learning and memory, RAVLT, The Logical Memory subset, RCFT, Language generativity, WAIS, TMT, EMQ, GDS, PSQI. Between-group differences- NS. Intervention associated with improvements in verbal memory (p=0.03), self-reported memory (p=0.03), mood (p=0.01) and sleep (p=0.01).

Kwok et al. (2013) Hong Kong	Community dwelling elderly. MMSE >23 60+	1 hour per session, once a week for 8 weeks administrated by either a social worker or an occupational therapist of each centre. The Active Mind training program included education on memory deterioration and dementia, attention training, verbal fluency and association, mnemonics, method of loci, environmental awareness, lifestyle redesign, and memory aids. Homework was assigned after each lesson to reinforce learning and practice in daily life.	86	TAU	90	N/A	CDRS, MMSE, SF12. CDRS score (treatment: 12.24 ± 11.57 vs control: 4.37 ± 7.99; p= 0.001)* SF12 score (treatment: 7.82 ± 13.19 vs control: 3.18 ± 11.61; p = 0.014)*.

CAIDE: Cardiovascular Risk Factors, Aging and Dementia Risk Score; COWAT: Controlled Word Association Test; DSST: Digit symbol Substitution Test; EFT: Erickson Flanker Test; FCSRT; The Free and Cued Selective Reminding Test; HVLT-R: Hopkins Verbal Learning Test; IADL: Instrumental Activities of Daily Living; MFQ: Memory Functioning Questionnaire; IQCODE: Informant Questionnaire on Cognitive Decline in the Elderly; MIC: Memory Inventory for Chinese; NCGG-FAT: National Centre for Geriatrics and Gerentology Functional Assessment Tool; NTB: Neuropsychological test battery; NTB; P: Petersen Criteria; RBMT; Rivermead Behavioural Memory Test; SDST: Symbol-Digit Substitution Test; TEA: Test of everyday attention; TICSm: Modified Telephone Interview for Cognitive Status; TMT: Trail Making Tests; UFOV: Usual Field of View; WAIS: Wechsler Adult Intelligence Scale; WMI-II, VPA: Wechsler Memory Scale Verbal Paired Associations.

Results on primary outcomes in bold. * statistically significant between –group difference; unless stated differences favour the intervention; Follow-up= longest duration after baseline at which measures were collected.

Multidomain interventions compared to active controls

All six multi-domain versus active control studies were rated as lower risk of bias (Bae et al., 2019; Barnes et al., 2013; Fiatarone Singh et al., 2014; Klusmann et al., 2010; Lam et al., 2015; Ngandu et al., 2015). Of these, only two found significant benefits from the intervention (Bae et al., 2019; Ngandu et al., 2015), and only one found a significant impact on a primary cognitive outcome measure (Ngandu et al., 2015). Both interventions were extensive and intensive with cognitive, physical and social elements and long duration follow-ups. Three other high quality multi-domain interventions (Barnes et al., 2013; Fiatarone Singh et al., 2014; Lam et al., 2015) did not find a significant intervention effect on cognitive outcomes. These studies either did not complete measures after the end of intervention or there was a shorter duration between the end of intervention and the completion of the final outcome measures. It is possible that the effects of the intervention might be seen at a later point but it was also noticeable that the length of intervention was shorter than those that found a significant effect.

Multidomain interventions compared to treatment as usual

Three studies compared a multidomain intervention to TAU and two studies showed significant improvements compared to TAU at the end of the intervention phase (Diamond et al., 2015; Kwok et al., 2013). Bruno et al. (2018) collected outcome measures seven months after the end of the intervention and did not find a significant between-groups effect of cognitive and physical activity intervention. The two studies that found a significant effect did not complete any post-intervention follow-up measures beyond those collected at the end of the intervention so it is unclear whether the benefit of the intervention as maintained.

Discussion

Summary of results

This review explored the effectiveness of psychosocial, cognitive training and multidomain interventions on change in cognitive outcomes in healthy older adults and adults with MCI. In total, 13 psychosocial interventions, nine multidomain interventions and nine cognitive interventions were included in this review of randomised controlled trials.

Psychosocial

There is only limited evidence that a psychosocial intervention has some benefits to cognition. Only one study of low risk of bias comparing a creative group (Zhao et al., 2018) found a significant effect on cognition compared to an active control. Whilst there was further evidence of the creative arts significantly improving cognitive function, this was compared to a treatment as usual group and the studies were rated as high risk of bias (Bugos et al., 2007; Mahendran et al., 2018). As social activity was not controlled for in these two studies it is unclear whether the interventions were superior to social contact. This is supported by a further six studies that found no significant differences between an intervention and an active control group (Clare et al., 2015; Dawson et al., 2014; Innes et al., 2017; Mackin et al., 2014; Thiel et al., 2012; Wahbeh et al., 2016).

It is possible the mechanism of action from creativity to increased cognitive function is through the cognitive stimulation aspects of creativity or through its influence on mood. However, information on whether depression was controlled for in the included studies was not formally extrapolated so it is difficult to conclude improvements on mood as a mechanism of change. Some information on whether depression was controlled for or included in the studies has been captured through

the information tabulated on study design or the sample characteristics- Mackin et al. (2014) did not find any significant effect on cognitive functioning of a problem-solving or supportive therapy intervention targeting depression for individuals with late-life depression. These results may therefore suggest that depression is not the mechanism for change in cognitive function which highlights the importance of further research to investigate the potential mediating role of known factors (anxiety, depression and social contact) that influence cognition (Dotson et al., 2010; Gimson et al., 2018; Kuiper et al., 2015).

Cognitive training

RCTs investigating the impact of cognitive training on cognition show some beneficial results (Ballesteros et al., 2014; Finn & McDonald, 2011; Millan-Calenti et al., 2015; Miller et al., 2013; Pantoni et al., 2017; Toril et al., 2016). However, all of these studies were rated as high risk of bias and hence conclusions should be made cautiously. Two studies of lower risk of bias did not find a significant effect of a cognitive intervention on cognition compared to an active control (Barnes et al., 2009; Zelinski et al., 2011). Therefore, it is difficult to rule out social contact as a mechanism for change in the interventions that did not include an active control. Furthermore, only two studies (Pantoni et al., 2017; Zelinski et al., 2011) measured cognition past the end of the intervention; therefore, it is unclear whether these benefits are sustained long-term.

Multidomain

There is some evidence for the effectiveness of multidomain interventions on cognitive functioning. The majority of the studies were rated as low risk of bias. Two studies, rated as low risk of bias found a significant effect of a multidomain intervention on cognition outcomes compared to active controls (Bae et al., 2019;

Ngandu et al., 2015). The combination of the interventions differed; physical health, cognitive training and exercise (Ngandu et al., 2015), and cognitive training, exercise and social activation (Bae et al., 2019). Both interventions were extensive and intensive with cognitive, physical and social elements. Two further studies showed significant improvements compared to TAU at the end of the intervention phase (Diamond et al., 2015; Kwok et al., 2013). However, it is unclear whether these benefits would be maintained as they did not complete follow-up measures after the end of the intervention. Whilst there are positive effects of combining interventions on cognitive functioning, these studies are well funded and the interventions are very intensive which may not be sustainable when funded by the public sector.

Strengths and limitations

A strength of this review is the rigorous procedure for systematically searching for studies. Two independent researchers searched the studies for the exclusion criteria and evaluated the risk of bias using an adapted version of the CASP (Critical Appraisal Skills Programme, 2018). All discrepancies were discussed with a third reviewer. Therefore, it is likely that bias has been limited in relation to the selection procedure of studies for this review. Results could only be synthesised narratively due to the wide variation in quality of studies and frequency and duration of interventions. There were only two psychosocial interventions, two cognitive interventions and six multidomain interventions rated as low risk of bias, highlighting the need for higher quality studies. Richard et al. (2012) argue that high quality RCTs with long-term follow up are needed in order to provide conclusions regarding optimal interventions for people at high risk of developing dementia. This is of importance given the need for evidenced beneficial effects of interventions for Public Health England (Livingston et al., 2017).

Whilst the systematic searching can be considered a strength of the methodology of this review, two recent systematic reviews (Bhome, Berry, Huntley, & Howard, 2018; Zhang et al., 2019) highlighted studies in their inclusion criteria that would have met criteria for this review; however, they were not identified by the search strategy.

Additionally, the interventions were categorised into psychosocial, cognitive training and multidomain; however, there is a lot of overlap in the psychosocial and multidomain interventions. Due to having multiple aspects to some of the psychosocial interventions, they could have quite easily been categorised as multidomain which makes it difficult to make firm conclusions regarding interventions termed as psychosocial or multidomain specifically.

This review extracted between-group differences to differentiate the effects of an intervention on cognitive functioning. However, this may have missed important within-group changes. The majority of the RCTs reported whether the mean difference between the intervention and control group was significant at a pre-defined endpoint; if affirmative, the intervention was deemed effective. However, this may mean there were no actual improvements in the intervention group; indeed, there may have been a decline but not a decline as large as the control group. This has important implications for future research as more RCTs that report the direction of change and between-group differences are needed as this was not always available in the current studies.

Neither fidelity information nor adherence was extracted in this review. Therefore, it is difficult to know how well interventions were adhered to and whether non-significant findings relate to poor adherence. There is a need to research factors that are associated with adherence to interventions or uptake of behaviours known to

reduce the risk of cognitive decline. This is important to consider for the implications on clinical practice because interventions need to be realistic in their frequency, duration and ability to evoke behaviour change. It is important to have data on this so that Public Health England can implement a realistically targeted intervention (WHO, 2019).

Furthermore, a limitation of this review is that it neglected to extrapolate information on factors known to increase the risk of dementia such as ethnicity, depression and anxiety. This has implications for this review as it is difficult to highlight the possible confounding factors that may contribute towards the mechanism of change in an intervention. It is also possible that factors such as anxiety and depression may have implications for adherence to interventions through motivation so it is not only important to consider these as mechanisms of change in an intervention but to also consider their confounding role in adherence to these interventions.

Epidemiological research shows that individuals from a black ethnic background have a higher incidence rate of dementia than individuals from white ethnic backgrounds (Pham et al., 2018). This may be due to individuals from black ethnic backgrounds experiencing more socioeconomic predictors (less formal education, lower income, poorer occupational conditions) of dementia and experiencing greater levels of cardiometabolic risk factors (diabetes, obesity) of dementia (Pham et al., 2018). However, the majority of studies in this review included a white westernised population with the minority being from East Asia, which may reduce the generalisability of the results of the studies. Only two studies showed a significant effect of a psychosocial intervention on cognitive function; however, both these studies were in Eastern populations (Singapore and China) so it

is necessary to understand the generalisability of these interventions in other populations also.

Implications for future research

Psychosocial

Only two of the psychosocial intervention studies were rated as lower risk of bias (Innes et al., 2017; Zhao et al., 2018) suggesting the need for higher quality studies on the impact of psychosocial interventions on cognition. Two studies suggest a benefit of creative art groups on cognitive function outcomes at six months for individuals with MCI (Mahendran et al., 2018; Zhao et al., 2018). The results show promising effects for people at high risk of dementia; however, with more research identifying the course of dementia may begin years before symptoms of cognitive impairment (Livingston et al., 2016), it is necessary for further research to ascertain the benefits of psychosocial interventions in healthy older adults also.

Whilst some research has begun to establish an association with depression, social isolation and anxiety with an increased risk of dementia (Dotson et al., 2010; Gimson et al., 2018; Kuiper et al., 2015), this review did not formally extrapolate this information. Given the associations with risk of dementia, further high-quality intervention studies are needed to ascertain the effect of targeting these risk factors on cognitive function and the mediating role of these on the effectiveness of interventions or adherence to them.

Cognitive training

Six studies (Ballesteros et al., 2014; Finn & McDonald, 2011; Millan-Calenti et al., 2015; Miller et al., 2013; Pantoni et al., 2017; Toril et al., 2016) showed a significant effect of a cognitive intervention but they were all rated as high risk of bias because a lack of independent randomisation, small sample size (ranged from

16-84), and participants were not followed-up. Further research is needed to address these limitations of current studies to provide high quality studies.

There were only two cognitive training intervention studies of low risk of bias (Barnes et al., 2009; Zelinski et al., 2011) and neither study found a significant effect of intervention on cognitive outcomes. Neither study collected measures further than after the end of the intervention highlighting the importance of further studies investigating the impact of interventions on cognition long-term to ascertain whether changes are sustained or shown later.

Multidomain

Three studies rated as low risk of bias found a significant difference in cognition between an intervention group and control group, favouring the intervention group (Bae et al., 2019; Klusmann et al., 2010; Ngandu et al., 2015). The FINGER trial (Ngandu et al., 2015) was a 24 month intervention. Whilst significant results were found with shorter interventions of six months (Bae et al., 2019; Klusmann et al., 2010), when a similar intervention was compared to a socially active control group, there were no significant differences between groups (Lam et al., 2015). Therefore, it is important for future research to consider comparing to socially active control groups in order to identify the beneficial component of the intervention. This will have important clinical implications if it is social interaction that provides benefits. Furthermore, the FINGER trial was the only intervention to find significant benefits in their primary cognitive outcome. It is the longest intervention identified for this review and therefore, future research might benefit from ascertaining whether this length is necessary to produce a significant intervention effect. According to Livingston et al. (2017), it is important that interventions are efficient and cost-effective.

Clinical implications

Psychosocial interventions involving creativity may make a promising contribution to improving cognitive function of individuals with MCI (Mahendran et al., 2018; Zhao et al., 2018). However, the majority of studies rated as lower risk of bias did not find a significant effect of an intervention compared to an active control group whereas two out of three studies comparing TAU found a significant intervention effect on cognition. It is therefore important to consider whether the agent of change in these interventions is social interaction. This is further highlighted in a multidomain study that found that combining cognitive interventions and physical exercise interventions produced beneficial results on cognition over 6-12 months compared to no intervention but not compared to a social activity group (Lam et al., 2015). This may highlight the benefit of regular social activity and the importance in promoting this as an intervention in an older population.

Cognitive training interventions may improve cognition when delivered two to three (Ballesteros et al., 2014; Millan-Calenti et al., 2015; Pantoni et al., 2017; Toril et al., 2016) or four to five times (Finn & McDonald, 2011; Miller et al., 2013) a week. This is important to consider for economic reasons due to the increasing cost of dementia care (Livingston et al., 2017). It suggests there may not be a need for four to five sessions a week if two to three produces significant results. Despite positive benefits on cognition, given the high risk of bias amongst these studies, it is difficult to conclude that this should be a priority for funding without evidence from high quality studies.

Many of the multidomain studies provide numerous sessions (two to three times a week) and it is possible that attrition may be higher in community services compared to RCTs where attempts to minimise this is made. It may therefore be

important to trial such interventions in services first to establish their efficiency in clinical services.

Interventions targeting risk factors known to increase the risk of dementia focus on factors amenable to change. However, these interventions neglect factors that are outside one's control. For example, Koster et al. (2005) found lower socioeconomic status predicted greater cognitive decline (as measured by the MMSE) in older adults aged 70 to 79. Whilst the significant effects of these lifestyle interventions highlight areas individuals can make changes, it is important that the wider social and political issues of inequality that increase the risk of dementia are not neglected.

Conclusion

This systematic review was, to my knowledge, the first of its kind to compare the effectiveness of psychosocial, cognitive and multidomain interventions (including cognitive/psychosocial components) on cognitive function outcomes. This review highlighted that a creative art group may be beneficial in improving cognition for individuals with cognitive impairment. The quality of evidence for cognitive training as an intervention was low. Higher quality studies are needed to provide conclusive results of its effectiveness in halting cognitive decline. There is evidence that combining cognitive, social and exercise interventions have a beneficial impact on cognition in those with memory complaints. Future research would be improved by providing higher quality studies through independent randomisation, larger samples and collection of follow-up measures after the end of intervention. This review is unable to explain the non-significant findings of some interventions as it did not consider confounding factors, such as adherence. Future research would

benefit from investigating what contributes to individuals engaging in health behaviour change in order to provide effective risk reduction interventions.

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Part II: The Empirical Paper

The mediating impact of anxiety, fear of dementia and subjective cognitive complaints on cognitive function and cognitive health behaviour change

Abstract

Aims: Understanding behavioural factors that might increase the risk of dementia and what influences individuals to change those lifestyle behaviours known to increase dementia risk, is a global health priority. The aim of this study is to assess the mediating impact of anxiety, fear of dementia and subjective cognitive complaints on cognitive function and cognitive health behaviour change using an online cognitive function test.

Methods: A secondary data analysis was conducted on data collected from an online Cognitive Function Test (CFT) and related lifestyle questionnaire on a website from a UK charity (Food for the Brain; FFB). This CFT produces a composite cognitive function score and tailored lifestyle advice. A longitudinal prospective cohort study design repeatedly tested healthy participants (aged 50-65 years) at baseline, six, 12 and 24 months. Participants completed GAD-7, Brief-FoD, SCC, CFT and lifestyle questionnaire measures at baseline. CFT and lifestyle questionnaires were repeated at six, 12 and 24 months. Structural Equation Modelling (SEM) was used to test the hypothesised directional and mediational pathways leading from lifestyle behaviours to CFT mediated by SCC, Brief-FoD and GAD-7. Multilevel modelling was used to explore the predictors of behaviour change over time.

Results: The structural equation model showed that cognitive health enhancing behaviours significantly predicted cognitive function at baseline and that generalised anxiety and fear of dementia mediated this relationship. Longitudinal analyses indicated that feedback received at baseline was associated with later changes in sugar intake.

Conclusions: There is some support for the Health Belief Model that suggests there must be perceived benefits of healthy behaviour to evoke health behaviour change.

However, there is limited support for the role of anxiety in changing behaviour over time.

Introduction

Dementia risk reduction

Dementia is a progressive condition characterised by a decline in cognitive and adaptive functioning beyond normal ageing (WHO, 2019). Due to the increasing incidence of dementia worldwide and the lack of effective treatments (Livingston et al., 2017), Public Health England (PHE) have issued evidence-based recommendations to reduce the risk of dementia: eat a balanced, healthy diet; stop smoking; maintain a healthy weight; exercise regularly, keep alcohol to a minimum and remain socially active (Public Health England, 2018). For the purpose of this study, I will refer to these behaviours as cognitive health enhancing behaviours (CHEB) due to their suggested positive impact on reducing the risk for cognitive decline. Interventions targeting CHEBs have begun to be delivered to healthy individuals or people with mild cognitive impairment (MCI; see chapter 1 for definition) but effect sizes varied for improvements across cognitive domains: memory (0.17), reasoning, (0.26) and processing speed (0.87) (Plassman, Williams, Burke, Holsinger, & Benjamin, 2010).

Prevention interventions and adherence

A systematic review by the APPLE-Tree team (Whitty et al., 2020) of lifestyle interventions (exercise, diet, physical health, and psychosocial) on cognitive function found that exercise interventions over four months, thrice weekly had a moderate effect on global cognition in individuals with and without MCI (Lautenschlager et al., 2008). There was inconsistent evidence for a significant effect of a Mediterranean diet on cognition between six-33 months but there was a significant effect of a combined, two-year intervention of dietary, exercise, cognitive and social training on global cognition in individuals with and without MCI (Ngandu

et al., 2015). Although this review did not measure adherence formally, one study found that moderate effects were only apparent with 78% adherence to the exercise (Lautenschlager et al., 2008).

Additionally, a systematic review of the effect of physical exercise on cognitive functioning in individuals with MCI or dementia found increases in the Mini-Mental State Examination (MMSE), Alzheimer's Disease Assessment Scale Cognitive Subscale (ADAS-Cog) and Clinical Dementia Rating Sum of Boxes (CDR-SOB) in individuals with MCI (but not for those with dementia) on global cognition, executive function, delayed recall and attention (Öhman, Savikko, Strandberg, & Pitkälä, 2014). The most commonly used forms of exercise were: walking, Tai Chi, dancing and strength training combined with aerobic training. They noted that interventions with longer durations, more sessions per week and a good adherence to the program appeared to be essential for a positive outcome, with those individuals who showed greater adherence showing greater increases in cognitive functioning (Öhman et al., 2014).

The systematic review presented in chapter 1 showed mixed results for the effectiveness of cognitive training on cognitive function. Six studies showed that cognitive training significantly improved cognitive function (Ballesteros et al., 2014; Finn & McDonald, 2011; Millan-Calenti et al., 2015; Miller et al., 2013; Pantoni et al., 2017; Toril, Reales, Mayas, & Ballesteros, 2016). However, there were significant methodological issues with these studies as there was a lack of independent randomisation, small sample size (ranged from 16-84), and participants were not followed-up. Two studies of higher quality in this review did not find a significant effect of a cognitive intervention (Barnes et al., 2009; Zelinski et al., 2011). Although adherence was not measured in this review, similarly to exercise

studies, there are suggestions that adherence to cognitive interventions may impact their effectiveness. Zelinski et al. (2011) found the statistically significant benefits of a computerised-cognitive training intervention compared to a control group were not maintained at a three-month follow-up. The authors suggest that the effects of the cognitive training waned over time without continued reinforcement from the training programme highlighting the importance of continued adherence to a programme.

Furthermore, systematic reviews exploring the impact of the Mediterranean diet on cognitive function, found a stricter adherence to a Mediterranean diet was associated with reduced risk of MCI and dementia (Singh et al., 2014; van de Rest, Berendsen, Haveman-Nies, & de Groot, 2015). The authors hypothesise it may be a result of strong evidence that shows the diet lowers vascular risk factors such as, hypertension and coronary heart disease or because of underlying biological mechanisms that are yet to be thoroughly investigated.

In summary, results of interventions targeting different CHEBs such as exercise, cognition and diet have shown mixed results regarding their effectiveness in improving cognitive function. It is possible that a lack of a significant impact of an intervention on cognition is a result of individuals' not adhering to lifestyle changes which is supported by results showing greater adherence leads to greater changes in cognitive function (Marseglia et al., 2018) and studies with poor adherence not finding a significant effect (Ansai & Rebelatto, 2015). Consequently, in order to create realistic, effective interventions to reduce the risk for cognitive decline and dementia, research needs to consider what impacts an individual's motivation to change and maintain healthy behaviours as this may need to be targeted in future

design of interventions. Health Psychology models may provide some insight into this.

Health psychology models

Health psychology models suggest that the presentation of the benefits of changing health behaviour is not always enough to ensure individuals will engage in beneficial behaviour change (Becker, 1974). Factors such as anxiety (Maloney, Sattizahn, & Beilock, 2014) and family history of disease (Kessler, Bowen, Baer, Froelich, & Wahl, 2012) have been identified as contributing to individual differences in the likelihood of taking part in health behaviours. Therefore, they may partly explain the mixed evidence for the effectiveness of reducing the risk of dementia through lifestyle interventions (Plassman et al., 2010).

There are various health behaviour models posited to describe behaviour change (Armitage & Conner, 2000) such as, the health belief model (HBM) (Abraham, Sheeran, & Henderson, 2011), the theory of planned behaviour (TPD) (Ajzen, 1991) and the transtheoretical model of behaviour change (Prochaska, Johnson, & Lee, 2009). Whilst they have their differences, the HBM and TPD both emphasise the importance of motivation, self-efficacy and perceived barriers to changing a health behaviour (Armitage & Conner, 2000). The Health Belief Model (HBM) is one of the most widely applied (Abraham, Sheeran, & Henderson, 2011).

The Health Belief Model

The HBM suggests that various factors combine additively to influence the likelihood of performing a health behaviour (Becker, 1974). These factors include perceived susceptibility of the disease, perceived severity, perceived benefits of an alternative behaviour and perceived barriers to this (Becker, 1974). This theory suggests that individuals are more likely to change their behaviour if they are more

anxious regarding the likelihood of developing the disease, there is a high severity of the disease, if the perceived benefits of behaviour change are high and the perceived barriers are low, there are cues to action and they have strong self-efficacy (Becker, 1974). Cues to action refers to strategies designed to instigate readiness (e.g. reminder text messages or a friend receiving a diagnosis of dementia) whereas self-efficacy refers to an individuals' confidence in their ability to take action (Glanz, 1997). Both these factors highlight the importance of the use of feedback to evoke behaviour change.

The Theory of Planned Behaviour

The TPB suggests that behaviour is predominantly determined by intention (motivation to perform a particular behaviour), subjective norms (global perception or social pressure) and perceived behavioural control (e.g. resources, time, money) (Ajzen, 1991). This theory argues that coupled with perceived behavioural control, the more one intends to perform a behaviour, the more likely they are to perform it. Attitudes (positive or negative of a behaviour) and subjective norms determine the intention of a behaviour (Ajzen, 1991).

The transtheoretical model of behaviour change

The transtheoretical model of behaviour change is a framework that is used to understand how individuals progress towards behaviour change. This model argues there are six stages of behaviour change: precontemplation, contemplation, preparation, action, maintenance, and termination. These stages describe behaviour starting from no intention to act within the next six months to having one hundred percent confidence of no relapse (Prochaska, Johnson, & Lee, 2009).

Evaluation of Health Psychology Models

Health psychology models have been widely used in the development of health interventions related to healthy eating and exercise (Orji, Mandryk, & Vassileva, 2012; Peng, 2009). Despite this, there are strengths and limitations of these models.

Some research shows that the HBM determinants have limited predictability of behaviour (Orji, Vassileva, & Mandryk, 2012). A study investigating physical activity uptake in healthy older adults investigated how HBM variables differed across stages of readiness (precontemplation, contemplation, preparation, action and maintenance) (Sas-Nowosielski, Hadzik, Górna, & Grabara, 2016). They found partial support for the HBM (Sas-Nowosielski et al., 2016). The authors found that perceived barriers and self-efficacy were most strongly related to stages of change whereas the belief that they were susceptible to diseases based on living a sedentary lifestyle, the belief that diseases would be harmful to their life and that being physically active would prevent these diseases were weak predictors of stages of change (Sas-Nowosielski et al., 2016).

Whereas the TPB has been shown to be able to predict behaviours such as alcohol consumption, smoking, exercising, breast-examination, and getting medical check-ups (Armitage & Connor, 2001). A meta-analysis of 185 studies found the TPB accounted for 27% variance in behaviour and 39% variance in intention. Prediction for self-reported behaviour was superior to prediction of observed behaviour (Armitage & Connor, 2001).

The HBM and transtheoretical model have been criticised for neglecting to consider the impact of wider social and cultural influences on behaviour change and placing responsibility entirely within the individual (Abraham et al., 2011). The TPB

however, does not solely rely on personal agency to describe behaviour as it does consider wider societal influences that might impact on perceived behavioural control. On the other hand, this theory only considers wider societal issues as an indirect effect on cognitions regarding behaviour change and suggests that when cognitions are controlled for, these societal issues have limited direct impact (Armitage & Connor, 2000).

Furthermore, the transtheoretical model has been criticised for putting human behaviour into discrete stages when it is often versatile and multidimensional (Lenio, 2006). In addition, it has been suggested that whilst this model is able to describe what behaviour might look like at each stage, it is less able to describe why individual's have moved between stages and what enables this (Lenio, 2006).

The TPB has also been widely criticised for assuming a direct association between intention and behaviour (Armitage & Connor, 2000). Researchers have suggested including variables such as, personal and moral norms, affect and anticipated regret, desire and need, past behaviour and self-identity would improve the predictive validity of this model (Armitage & Connor, 2000).

Despite some limitations of the HBM, it can be understood to consider the role of feedback and of anxiety in the performance of healthy behaviour as the HBM stipulates that if an individual is more anxious regarding the likelihood of developing a disease, they are more likely to perform a healthy behaviour. The HBM highlights that feedback (through positive reinforcement, information, or reminders) can also increase health behaviours through self-efficacy.

In summary, the HBM and transtheoretical model have been criticised for not including wider societal issues in their explanations of behaviour whereas the TPB has been criticised for being over-simplistic in assuming a direct link between intention and behaviour. Whilst research has shown predictive validity of all these models, the HBM is able to account for the role of anxiety and feedback in behaviour change which is important for this study.

Anxiety and dementia

Anxiety is an important consideration when designing risk reduction interventions for dementia. Firstly, dementia is one of the most feared diseases (Alzheimer's Society, 2016). The Fear of Dementia (FOD) has been found to be associated with personal experiences of dementia, previous family history of dementia, perceived risk and perceived ability to cope (Kessler et al., 2012). Secondly, there is an added complexity when considering anxiety in this disorder as unlike most other health disorders, dementia is characterised by impaired cognitive functioning but anxiety has also been found to impair cognitive functioning and decision-making in older adults (Schultz, Moser, Bishop, & Ellingrod, 2005). Therefore, anxiety might not just impact the uptake of health behaviours in at risk populations but also cognitive function. Lastly, trait anxiety has been found to increase with age (Beaudreau & O'Hara, 2008) so it is particularly important to consider the role of anxiety in the uptake of health behaviours in an older population for whom interventions are targeted. The complex interaction of anxiety, cognitive health enhancing behaviours and cognitive functioning is explored below.

Anxiety, Fear of Dementia and Cognitive Health Enhancing Behaviours

Literature suggests that anxiety plays a key role in influencing health behaviour (Maloney et al., 2014) with various mechanisms of action being

suggested. Firstly, anxiety increases perceptual sensitivity to threatening stimuli (Öhman, Flykt, & Esteves, 2001). Research from Fox, Russo, Bowles, and Dutton (2001) supports this as they found that individuals induced to feel more anxious were less able than non-anxious individuals to withdraw their attention from threatening cues to attend to non-threatening cues. This suggests anxiety could increase attention to health threatening cues (e.g. symptoms).

Secondly, anxiety also has the potential to negatively impact an individual's motivation to change their behaviour. During distress, individuals often turn to self-soothing and mood-altering behaviours such as drinking alcohol or eating high-fat foods, and anxiety typically lowers one's resistance to temptation (Mayne, 1999).

Lastly, trait anxiety has been linked to the activation of the behavioural avoidance system and impaired reasoned decision-making processes (Maloney et al., 2014). For example, anxious individuals exhibit more difficulties with considering alternative decisions which may mean that individuals struggle to choose between alternative effective health behaviours (Aspinwall & Taylor, 1997). Anxiety arousal often increases a preference towards short-term benefits at the cost of long-term gains which may affect efforts to make choices that promote long-term health benefits (Gray, 2004).

Fear of Dementia (FOD) is considered to be a separate concept to trait anxiety (French, Floyd, Wilkins, & Osato, 2012). Kessler et al. (2012) argue that whilst theories suggest a moderate level of fear is necessary to engage in screening and health behaviours in most diseases compared to a low (which leads to denial) or high level (which leads to avoidance), this may be different for FOD. FOD may impact the extent to which individuals engage in screening, particularly given this is a disease with no cure. A study carried out by the Alzheimer's Society (2016) found

that 56% reported delaying screening for up to a year due to FOD. It may be important therefore, to consider the impact of both trait and state anxiety (specifically anxiety regarding dementia) in relation to cognitive functioning and how these impact the uptake of health behaviours.

Anxiety and cognitive functioning

Not only does anxiety potentially influence health behaviour, but it may also affect cognitive function. This is an added complication when considering the impact of anxiety in lifestyle interventions designed at targeting cognitive functioning and dementia risk reduction. Research into various types of anxiety (e.g. trait and state anxiety) shows that anxiety causes changes in one's physiology, as well as negative thoughts and ruminations that occupy working memory resources needed to succeed on cognitively demanding tasks (Maloney et al., 2014). Furthermore, evidence suggests an association between anxiety and cognitive performance in older adults (Beaudreau & O'Hara, 2008). For example, older adults (aged between 50-84 without cognitive impairment), who report higher levels of state, trait and other anxiety symptoms perform more poorly on global cognitive function tests on screening assessments than those who do not exhibit high anxiety scores (Schultz et al., 2005).

Cognitive functioning and cognitive health enhancing behaviours

Associations have been found between dietary intake (Scarmeas, Stern, Tang, Mayeux, & Luchsinger, 2006), activity levels (Taaffe et al., 2008) and cognitive functioning. However, evidence for the effect of lifestyle factors on cognitive functioning is not irrefutable. Plassman et al. (2010) concluded that longitudinal prevention studies have been inconclusive in determining the effect of lifestyle factors on dementia risk. These inconclusive findings may indicate that the longitudinal relationship between CHEBs and cognitive function may not be a direct,

causal relationships (Public Health England, 2017). There may be other factors that influence cognitive function, which may have a direct association or which may mediate the relationship between lifestyle changes and cognitive function. According to the research presented above, it is possible that anxiety may be associated with uptake of health behaviours but also the continued practice of them.

Summary

Results from dementia risk reduction and prevention studies have been inconsistent as these studies have shown problems with adherence to these interventions; therefore, it is important to investigate what impacts and influences the uptake of health behaviours in order to provide realistic and effective interventions to reduce risk of dementia.

There is research that individually shows 1) the association between cognitive health enhancing behaviours and cognitive functioning, 2) anxiety and cognitive functioning and 3) anxiety and uptake of cognitive health enhancing behaviours (see Figure 1 for schematic diagram of the relationships).

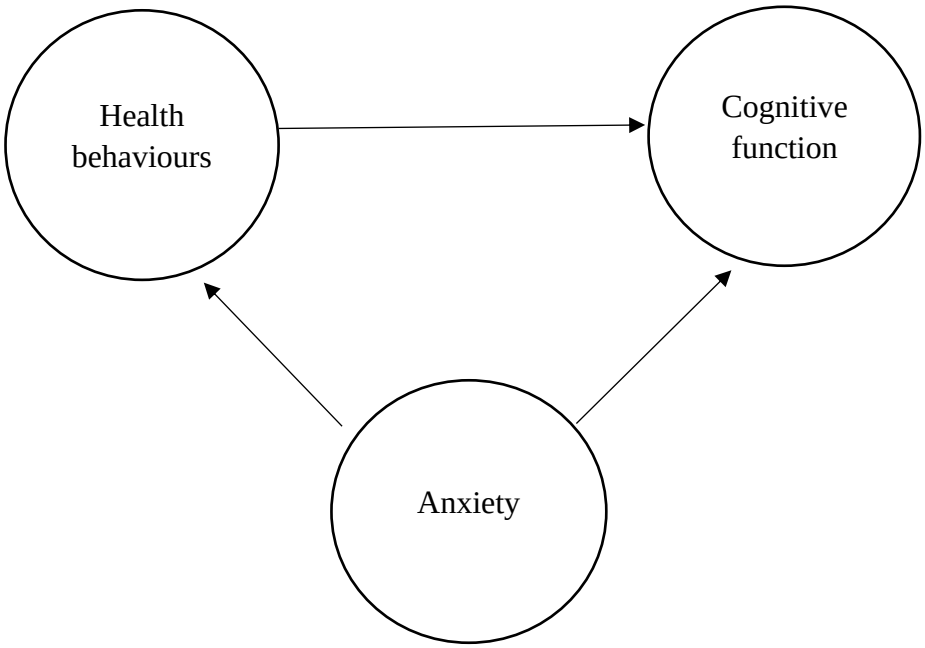

Figure 1. Schematic diagram showing the relationship between anxiety and cognitive function, anxiety and cognitive health enhancing behaviours, and cognitive health enhancing behaviours and cognitive function.

To my knowledge, there are no studies examining the combined relationship between cognitive functioning, anxiety, and multiple cognitive health enhancing behaviours.

Aims

The current study will firstly address this gap by testing the cross-sectional mediational relationships between anxiety, cognitive functioning and cognitive health enhancing behaviours using data from the online Cognitive Function Test (CFT) collected by the not-for-profit charity Food for the Brain. Furthermore, this study will explore the impact of anxiety and feedback on changes in cognitive health enhancing behaviours over time.

Research questions

The study aims to address the following research questions:

1) Does general anxiety, fear of dementia and subjective cognitive complaints mediate the relationship between cognitive health enhancing behaviours and cognitive function?
2) Do anxiety measures predict change in cognitive health enhancing behaviours over time?

Method

This thesis presents a secondary data analysis of data collected through a website for a UK charity (Food for the Brain; FFB) which offers assessment of cognitive function and provides tailored lifestyle advice to the general population. This was a longitudinal two-year cohort study design.

Participants

Recruitment procedure

Participants are healthy adults between the age of 50-65 years of age who spontaneously made their way to the Food for the Brain (FFB) charity website that provides nutritional advice for individuals wanting to change their wellbeing and mental health. An advertisement for this study was placed on the FFB website. As part of the partnership between UCL and FFB, participants were invited to take part in the study via an information page on the FFB website and by promotional emails sent by the charity to the people on their contact list. A link from the advert directed participants to the UCL-hosted Qualtrics webpage that included participant information sheets and consent forms (Appendix A). Questions on these forms

screened for eligibility criteria. Participants meeting the inclusion criteria and consenting to take part were asked to complete the baseline measures (Brief Fear of Dementia (Brief-FoD) and Generalised Anxiety Disorder-7 (GAD-7) questionnaires). Upon completion, they were directed to the FFB website to complete the Cognitive Function Test (CFT), Subjective Cognitive Complaints (SCC) measure, a lifestyle questionnaire and demographic information.

Participants were emailed by the charity at six, 12 and 24 months to ask them to complete the CFT again. The additional questionnaires from UCL (Brief-FoD and GAD-7) were not completed again after baseline.

Eligibility

Inclusion criteria were as follows:

- Aged between 50 and 65
- Have access to a computer or smartphone and internet connection at home
- Fluent in English
- Have spontaneously made their way to the FFB website and agreed to FFB terms that include:
    I. I wish to complete the CFT
    II. I give consent for the charity to use my data to calculate a test result
    III. I give consent to store my data for me to undertake future comparisons
    IV. I give consent for my data to be used anonymously for these research purposes

Exclusion criteria were as follows:

- History of neurological or psychiatric conditions likely to substantially affect cognition (e.g. Dementia)
- Sensory deficits
- Mobility limitations that would prevent or restrict the delivery of the assessment or intervention (e.g. uncorrected vision or hearing loss)

Measures

Cognitive Function Test

The Cognitive Function Test (CFT) is a self-administered online test designed to assess various cognitive domains; executive function, episodic memory and processing speed, known to be predictive of Alzheimer's Disease (AD), the most common type of dementia (Bublak et al., 2011; Weintraub, Wicklund, & Salmon, 2012). Episodic memory was measured through a novel item recall and placing task (Anderson, de Jager, & Iversen, 2006). Processing speed was measured through an adapted version of the Pattern and Letter Comparison Speed Test (PCS) (Salthouse, 1992). Executive function was measured through a novel symbol matching test that asked participants to match mathematical symbols with digits (Trustram Eve & de Jager, 2014) . The CFT produces a composite score of these domains at the end of the test and this score was provided to the participant. This is considered in relation to one's age and classified into one of three categories:

- Green: Little or no cognitive impairment (CFT score range: 110-43)
- Amber: Potential risk for cognitive impairment (CFT score range: 42-38)
- Red: Mild Cognitive Impairment (CFT score range: $\leq$37)

Participants are informed that an amber and red rating indicates an individual is performing below the expected cognitive functioning for their age and that a green rating indicates an individual is performing as expected for their age.

The CFT has been validated in a pilot study against pen and paper tests used in memory clinics nationally (Trustram Eve & de Jager, 2014). Strong correlations (r= .75) between pen and paper tests and the CFT show concurrent validity and the four subtests and total CFT show good internal consistency (Cronbach's Alpha = 0.73) (Trustram Eve & de Jager, 2014).

Lifestyle Questionnaire

A questionnaire investigating lifestyle behaviours (termed Cognitive Health Enhancement Behaviours (CHEB) in this paper) was developed by FFB and embedded within the CFT. Please see Appendix B for the full list of questions. It is a self-reported questionnaire identifying the frequency of various lifestyle habits identified as potential risk factors for AD (Livingston et al., 2017). At the end of the CFT, tailored lifestyle advice is provided online, covering six prevention areas: physical, social and mental activity, B vitamins, caffeine, antioxidant, sugar and fish and seeds intake. For clarity, the term risk reduction has been used throughout this thesis until now as used by Public Health England (Fenton & Newton, 2016); however, the term prevention has been used by FFB on their charity website so this term is used only to address the measures used by FFB to aid the reader in understanding how information was presented to participants. In addition to a CFT RAG rating, individuals also receive a Red, Amber, or Green (RAG) rating for each domain for their lifestyle habits and a personalised lifestyle prevention plan highlighting their weakest area in relation to prevention steps which they were emailed. This was calculated based on a weighted score for each individual,

generated within the FFB online test. However, the computation of the weighted score is the intellectual property of FFB and was not available for this project. As there was limited publicly available information to determine how or why specific weightings were used, the CHEB RAG rating was not utilised for this project. Instead, the raw score for each question was used and a total score was calculated. The higher the score, the better an individual has performed on the given lifestyle behaviour. The range of scores for each lifestyle category were: sugar (4-20), fish (4-20), antioxidants (6-30), caffeine (5-25), B vitamins (6-30), social stimulation (4-20) and exercise (3-15). Psychometric properties were not available for this scale as it has not been previously validated.

Subjective Cognitive Complaints

Subjective Cognitive Complaints (SCC) is a scale embedded within the CFT (Appendix C). Participants were asked seven questions regarding concerns of their cognitive functioning. Questions included concerns about their memory, forgetting where they placed things, names of close friends or relatives, words, whether participants had become lost in unfamiliar environments, whether family members reported any concerns about their memory or whether there was a family history of dementia. Questions were answered Yes/No and affirmative scores were added up to complete a total SCC score between 0-7. Psychometric properties were not available for this scale.

Brief Fear of Dementia

The Brief Fear of Dementia scale (Brief-FoD) is a 12-item measure of fear of developing dementia ((Saunders et al., Manuscript in preparation) Appendix D). The Brief-FoD is derived from the 17 questions which make up the "General Fear" subscale of the Fear of Alzheimer's Disease scale (FADS; (French et al., 2012)) with

the term ‘Alzheimer’s Disease’ replaced with ‘dementia’ in each of the items. Analysis of these 17 questions in a sample of 45-65 years from the UK and North America show very high correlation between a number of items, and excluding five highly correlating items results in a briefer and psychometrically robust measure of the Fear of Dementia (Pak, 2015). Internal consistency of both the 17-item (alpha=0.97) and 12-item (alpha=0.96) versions of the scale were found to be high in this previous analysis. Each item was rated on a 5-point likert scale (never, rarely, sometimes, often, always) giving a score between 0-4. The total Brief-FoD score ranges from 0-48.

Generalised Anxiety Disorder- 7 scale

This seven-item questionnaire asks about anxiety symptoms experienced in the last two weeks (Appendix E). Each item has a rating of 0 (not at all) to 3 (nearly every day). Possible scores range from 0-21, with 21 indicating high levels of anxiety. A score of five indicates mild levels of anxiety and is considered symptomatic of anxiety in this sample. It is used widely as a measure of global anxiety difficulties and demonstrated good internal consistency and convergent validity (Spitzer, Kroenke, Williams, & Löwe, 2006).

Demographics

Demographic information in the form of identified gender, ethnic background, and employment, were also collected through the online-CFT.

Ethics

This project is a secondary data analysis and hence additional ethical approval was not needed for this thesis. This project is covered under the ethical approval (data protection: Z6364106/2017/08/75) granted by the UCL Division of

Psychology and Language Science (CEHP/2017/563). A copy of the ethical approval letter can be found in Appendix F. Data Safe Haven was used to store data securely with all analyses completed through this software.

Statistical analysis plan

To examine the baseline data, Structural Equation Modelling (SEM) was used to test the cross-sectional directional and mediational pathways leading from CHEBs to CFT mediated by SCC, Brief-FoD and GAD-7.

As one or more of the dependent variables are defined as categorical, a Weighted Least Squares Estimate (WLSMV) was used in Mplus (Geiser, 2012). Analysis of the baseline data took place in two stages. Firstly, Exploratory Factor Analyses (EFAs) were run for the lifestyle questionnaire, SCC and Brief-FoD on a random 50:50 split of data. A polychoric factor analysis was used for the lifestyle questionnaire as the individual questions were considered ordinal variables.

An oblique (promax) rotation was performed for the CHEB utilising Stata16 (StataCorp, 2019) as Costello and Osborne (2005) argue that factors are rarely uncorrelated in the social sciences as behaviour rarely functions independently of one another. This is supported by correlational data in the results section of this paper and from evidence for the correlation between health behaviours, suggesting that individuals' who partake in one exercise are more likely to partake in a healthier diet (Joo, Williamson, Vazquez, Fernandez, & Bray, 2019). To initially identify the number of factors and items to retain, scree plots were analysed for eigenvalues above one (Costello & Osborne, 2005; Kaiser, 1960). The following criteria were also identified: factor loadings greater than 0.30, no item cross-loadings, no factors with fewer than three item loadings and all retained items to share the same conceptual meaning (Costello & Osborne, 2005). Once a suitable EFA solution was

identified for SCC, Brief-FoD and the lifestyle questionnaire, the factor structures were tested with Confirmatory Factor Analyses (CFAs) on the other half of the split dataset. The data-driven CFA model derived from EFA was compared to a theory driven measurement model to ensure a model of best fit was used for subsequent data analysis. This theory-developed model consisted of factors derived from the APPLE-Tree systematic review (Whitty et al., 2020). This review found there to be four main risk factors that interventions targeted: psychosocial (including social activity and cognitive activity), exercise, diet and physical health. An EFA on GAD-7 was not completed as it's psychometric properties have already been explored (Spitzer et al., 2006) and it is a widely used measure for generalised anxiety. Recommendations regarding goodness-of-fit-indices in SEM suggest using multiple measures of fit as the chi-square statistic is dependent on sample size so can reject well-fitting models in moderately large samples (Hu & Bentler, 1999). Three measures of fit were used:

- Comparative Fit Index (CFI): represents the extent to which the model fits the data better than a null model. A value greater than 0.90 suggests the model fits the data well (Hu & Bentler, 1999).
- Standardised Root Mean Square Residual (SRMR): identifies the standardised difference between observed and predicted correlations for the hypothesised model. A value less than 0.08 indicates the model fits the data well (Hu & Bentler, 1999). More stringent criteria suggests a cut-off of less than 0.05 (Schermelleh-Engel, Moosbrugger, & Müller, 2003).
- Root Mean Square Error of approximation (RMSEA): measures the extent to which the hypothesised model fits the data. A cut-off value as close to 0.06 suggests the model fits the data well (Hu & Bentler, 1999).

In the second stage of the analysis, the structural model was evaluated, keeping the components of the measurement model. This allowed for estimation of both the direct and indirect paths between CFT, CHEB, SCC, Brief-FoD and GAD-7. This tested whether latent CHEB would affect an observed CFT variable directly or mediated by SCC, Brief-FoD and GAD-7. The standardised beta values and 95% confidence intervals were considered to ascertain whether direct and indirect effects are present. An upper and lower confidence interval that does not span zero is considered significant. Bias corrected bootstrap Confidence Intervals (CI) are reported for the direct and indirect effects, as opposed to *p* values as these are reported to be more accurate than relying on the *p* value as they take into account possible non-normality in the sampling distribution and it provides information about the size of the effect (Wood, 2005).

To analyse the longitudinal data, multilevel modelling using Stata (StataCorp, 2019) was performed. Multilevel modelling was used as it accounts for clustering of data, i.e. data from the same individual collected over time, as well as potential correlations of individual responses over time (Field & Wilcox, 2017).

Multilevel modelling was used to investigate whether individuals change their CHEBs over time and whether any factors at baseline assessment were associated with changes. Modelling was carried out in two stages. Firstly, a growth curve model was utilised to analyse the impact of personalised feedback on cognitive functioning received at baseline (CFT RAG status at baseline) on individual's CHEBs over time. Individual CHEB scores were calculated based on the factors identified from the exploratory factor analysis of the baseline data. For each of the five lifestyle variables (FVEG, FISHM, SUPP, ACT and SUG), the questions that made up each factor were added together to produce a total raw score for the longitudinal data,

producing five individual observed variables for these five lifestyle variables. For clarity, the five lifestyle variables totalled from the raw scores were renamed so their long form was used for the longitudinal analysis (e.g. fruit/veg, fish/meat, sugar, activity and supplements). Age and gender were included in the MLMs as covariates in the growth curve models. In the second stage, baseline anxiety measures were added to the growth curve model as covariates to assess their impact on the relationship between feedback at baseline and CHEB over time.

Software

Pre-processing of the data were performed using SPSS 25 (SPSS, 2017). Stata 16 (StataCorp, 2019) was used to complete the polychoric factor analysis for the lifestyle questionnaire and multi-level modelling for the longitudinal analyses. The SEM was performed using Mplus 8 (Muthén & Muthén, 2017).

Power

It has been argued that it is difficult to have generalised guidelines for sample-size requirements for Structural Equation Modelling (SEM) in the behavioural sciences because they are not model specific and may result in under- or overestimating sample size requirements (Wolf, Harrington, Clark, & Miller, 2013). A data simulation study identifies how the number of latent variables and indicators, strength of regressive paths, type of model and degree of missing data affected the sample size requirements (Wolf et al., 2013). In the most conservative scenario, the minimum number of observations needed was 460. The current study has over 1000 observations; therefore, power was considered to be satisfactory for analysing the baseline data.

Similarly to SEM, a suitable sample size for multi-level modelling is widely debated. However, Łaszkiewicz (2013)'s simulation study found the unbiased

estimates of the fixed effects parameters can be obtained even with extremely small samples (number of groups and group size) of around 10.

Results

Data screening and cleaning

The following items within the lifestyle questionnaire were reverse coded to ensure a higher score for each question was associated with healthier lifestyle choices: 1, 2, 4, 14-17, 19, 20, 23 (see Appendix B).

Little's Missing Completely at Random (MCAR) test (Little, 1988) was used to analyse missing data, with test results suggesting data was MCAR (p= .780). Missing data was handled in the Structural Equation model and multilevel modelling as described below.

Demographic information

Demographic information for the participants at baseline, six, 12 and 24 months can be found in Table 1.

Table 1

Demographic information for participants at baseline, 6 months, 12 months and 24 months

Characteristics	Baseline		6 months		12 months		24 months	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Age (Years)	1134	58 (5)	160	58 (4)	338	59 (4)	187	58 (4)
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Ethnicity								
White British/Mixed British	689	60.7	111	68.9	229	67	123	65.8
White Irish	51	4.5	5	3.1	11	3.2	5	2.7
Other White	256	22.6	35	21.7	59	17.3	40	21.4

Black Caribbean/Black Africa/Other Black	9	0.8	1	0.6	1	3.0	0	0
Mixed Other	10	0.9	1	0.6	0	0	1	0.5
Indian/British, Indian/Pakastani/British Pakastani/Other Asian/Mixed White and Asian	22	1.9	5	3.1	5	1.5	3	1.6
Mixed White and Black African	13	1.1	4	2.5	3	0.9	3	1.6
Missing	91	8.0	3	1.8	35	10.2	13	7.0
Gender								
Male	224	19.7	30	18.6	55	16.1	30	16.0
Female	737	64.9	121	75.2	222	64.9	130	69.5

Missing	174	15.3	10	6.2	65	19.0	27	14.4
Occupation								
Full Time	400	35.2	54	33.5	108	31.6	74	39.6
Part Time	336	29.6	46	28.6	109	31.9	53	28.3
None	378	33.3	57	35.4	117	34.2	57	30.5
Missing	21	1.9	4	2.5S	8	2.3	3	1.6

Descriptive data

Table 2

Mean and Standard Deviations for SCC, Brief-FoD, GAD-7, CHEB and CFT at baseline, six, 12 and 24 months

Measure	Baseline		Six months		12 months		24 months	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
SCC Total	1130	2.89 (1.68)	-	-	-	-	-	-
Brief-FoD Total	1134	21.03 (11.75)	-	-	-	-	-	-
GAD-7 Total	1134	4.63 (4.69)	-	-	-	-	-	-

CFT Total	1122	55.40 (12.38)	160	60.40 (11.71)	339	61.8 (10.88)	186	62.73 (11.79)
Sugar Total	1134	14.70 (2.29)	161	11.43 (1.97)	342	11.42 (1.98)	187	11.20 (1.88)
Fish Total	1134	13.28 (3.39)	161	11.31 (3.17)	342	11.34 (3.22)	187	11.53 (3.10)
Antioxidant Total	1127	23.84 (3.99)	160	23.33 (3.35)	341	22.96 (3.39)	187	23.05 (3.60)
Caffeine Total	1127	19.06 (2.95)	160	10.90 (1.98)	341	10.91 (1.78)	187	10.82 (1.73)
B Vitamin Total	1118	13.23 (4.05)	159	13.51 (3.66)	339	13.51 (3.98)	186	14.35 (4.32)
Activity Total	1118	24.64 (4.74)	159	25.65 (4.43)	339	25.27 (4.62)	186	25.84 (4.74)

	N	%	N	%	N	%	N	%
CFT RAG rating								
Red	93	8.2	7	4.3	7	2.0	6	3.2
Amber	77	6.8	5	3.1	9	2.6	5	2.7
Green	953	84	148	91.9	323	94.4	175	93.6
Missing	12	1.1	1	0.6	3	0.9	1	0.5
GAD Total								
Asymptomatic	680	59.9	-	-	-	-	-	-

Symptomatic	455	40.1	-	-	-	-	-	-

SCC= Subjective Cognitive Complaints; Brief-FoD= Brief Fear of Dementia scale; GAD-7 = Generalised Anxiety Disorder Questionnaire, CHEB= Cognitive Health Enhancing Behaviours; CFT= Cognitive Function Test; CFT RAG rating = Cognitive Function Test, Red, Amber, Green rating.

Research question 1

Data collected at baseline was utilised to investigate the following research question: Does general anxiety, fear of dementia and subjective cognitive concern mediate the relationship between cognitive health enhancing behaviours and cognitive function?

Data distributions

Data from SCC, Brief-FoD, GAD-7 and the six lifestyle categories prior to factor analysis (sugar, fish, antioxidants, caffeine, B vitamins, social activity and exercise) were not normally distributed whereas CFT was normally distributed. All data met assumptions of homoscedasticity, multicollinearity and linearity required for linear regression; therefore, the variables that were not normally distributed were not transformed for the structural equation model. Non-parametric correlational tests were used to explore the relationships between SCC, Brief-FoD, and GAD-7.

Preliminary analysis

Preliminary analysis of the SCC, Brief-FoD, GAD-7, CFT and CHEB (prior to factor analysis, seen in Table 3) were run to establish their relationship. As some of the variables were not normally distributed, Spearman's rho correlation tests were performed.

A significant negative correlation was found between SCC and Sugar, Fish, Antioxidants and Activity Total and Brief-FoD and Fish intake. A significant positive correlation was found between Brief-FoD and GAD-7 and CFT and all CHEB. The CHEB were all significantly correlated with each other.

Table 3

Correlation results for SCC, Brief-FoD, GAD-7, CFT and CHEB at baseline

	SCC	Brief-FoD	GAD-7	CFT	Sugar	Fish	Antioxidants	Caffeine	B Vitamins	Activity
SCC	-	.006	-.018	-.045	-.067*	.063*	-.154**	.026	-.016	-.103**
Brief-FoD		-	.416**	.029	.027	-.076*	.042	-.007	.039	-.012
GAD-7			-	.000	.001	-.052	.031	-.005	.625	.040
CFT				-	.066*	-.057	.079**	-.094**	.043	.075*
Sugar					-	-.104**	.143**	.071*	.116*	.075*
Fish						-	-.438**	.150**	-.355**	-.280**
Antioxidants							-	-.103**	.379**	.334**

Caffeine	-	.022	-.177**
B Vitamins		-	.149**
Activity			-

SCC= Subjective Cognitive Complaints (5-item scale); Brief-FoD= Brief Fear of Dementia scale; GAD-7 = Generalised Anxiety Disorder Questionnaire, CHEB= Cognitive Health Enhancing Behaviours; CFT= Cognitive Function Test; CFT RAG rating = Cognitive Function Test, Red, Amber, Green rating

*Correlation is significant at p value <.05 (two-tailed) **Correlation is significant at p value <.01 (two-tailed)

Measurement model

Internal consistency was measured by Cronbach's alpha and according to Nunnally (1978)'s proposed cut-offs for reliability, internal consistency was poor for the SCC (.601) and CHEB (.521). However, it was excellent for the Brief-FoD (.961), GAD-7 (.909) and CFT (.891). Exploratory Factor Analyses (EFAs) were conducted for SCC, Brief-FoD, and CHEB, on a random 50:50 split of the data, as they had not been previously validated. GAD-7 has been previously validated and only the CFT total (observed variable) was used in the model so an EFA was not required.

Missing data analysis was not conducted at this stage as Mplus uses robust measures to manage missing data. The mean and variance adjusted weighted least squares (WLSMV) extraction procedure was used in Mplus as it is a robust estimator that manages data that is not normally distributed and provides model fit indices for categorical data (Brown, 2015).

SCC

Examination of the scree plot found two eigenvalues above one (Appendix G). The rotated component matrix revealed that the Subjective Cognitive Complaints scale contained two factors that explained 24% of variance with factor loadings ranging from .359 to .666 with no dual loadings. Item 5 (*Do you ever lose your way?*) did not load onto a factor so this was removed from subsequent analyses. Only one item loaded onto Factor 2 which was *'Do you have a family history of dementia?'* Therefore, this item was removed from the SCC measure as it did not fit the pre-agreed criteria that a factor must have at least three items (Costello & Osborne, 2005). As there is evidence to suggest this is a risk factor for dementia (Huang, Qiu, von Strauss, Winblad, & Fratiglioni, 2004) and has a direct link with

anxiety regarding the disease (Tang et al., 2017), this item was instead controlled for in the model as a covariate. One factor explained 28% of the variance with factor loadings ranging from .398 to .674 (see Appendix G).

Brief-FoD

Examination of the scree plot found one eigenvalue above one (Appendix H). The factor analysis gave a rotated component matrix revealing that the Brief-FoD scale had one factor that explained 68% of the variance with factor loadings ranged from .758 to .896 (see Appendix H).

CHEB

Exploratory factor analysis

Upon examination, the CHEB scale consisted of some questions that were repetitive which may have resulted in participants' scores on these questions being counted twice. Hence these were removed before EFA was completed. The questions removed (and kept) were: *"How much alcohol do you drink in a week?"* (How much red wine do you drink a week?*), "How many caffeinated coffees do you drink per day?"(* How many cups of tea, coffee and cola or caffeinated drinks do you consume each day in total?) and *"How often do you do mildly energetic exercise?"* (How often do you do moderate energetic exercise?). Examination of the scree plot found five eigenvalues above one (Appendix I). The polychoric factor analysis gave a rotated component matrix revealing that the CHEB scale had five factors. Initial factor loadings ranged from .325 to .938 explaining 88% of the variance. Four questions did not load onto a factor: *"How often do you read, watch TV or youtube, listen to the radio, play games, do the crossword or suduko?", "How many cups of tea, coffee and cola or caffeinated drinks do you consume each day in total?", "How much red wine do you drink in a week?" and "Do you smoke cigarettes and if so,*

how many?" A further item (*"How many cups of green tea or herbal tea do you drink a day?"*) loaded onto Factor 1 but did not fit with the conceptual meaning of 'Fruit and Vegetables' so this item was also removed. The five factors were conceptualised as: supplements, fruit and vegetables (including wholegrains and seeds), fish and meat, activity, and sugar. The final factor loadings ranged from .348 to .933 explaining 98% of the variance (see Appendix I).

Confirmatory factor analysis

Following the EFA, a Confirmatory Factor Analysis (CFA) was completed on the other half of the random split of data. This included the latent variables: SCC total, Brief-FoD total, GAD-7 total, fruit and vegetable total (FVEG), activity total (ACT), B vitamins total (BVIT), sugar total (SUG) and a fish and meat total (FISHM). This model (Appendix J) was found to have an acceptable fit, χ^2 (1147)= 1902.47 , p<0.001; CFI= 0.984; RMSEA = 0.034; SRMR = 0.053. All factor loadings were statistically significant (p< 0.001), suggesting that all latent variables were adequately operationalised by the selected items.

To ensure a model of best fit was used for the structural equation model, this was compared against a measurement model derived from theory. Therefore, a measurement model developed from the APPLE-Tree systematic review (Whitty et al., 2020) of various lifestyle interventions targeting risk factors for dementia was utilised in order to establish whether this was a better fit of the data (Appendix K). This systematic review identified four lifestyle intervention categories: diet, physical health, psychosocial and exercise. The theory-driven measurement model used these categories and is also an acceptable fit, χ2 (1356)= 2816.55, p<0.001; CFI= 0.97; RMSEA = 0.044; SRMR = 0.067. However, as the data-driven measurement model presented in the previous paragraph meets the more stringent criteria for model fit

(Schermelleh-Engel et al., 2003), this was the model utilised for the structural equation model.

Construction of the Structural Equation Model

Evidence suggests anxiety influences individuals' uptake of health behaviours, that anxiety influences cognitive functioning and that lifestyle behaviours influence cognitive functioning (see Figure 1). The SEM explored these relationships whilst controlling for the potential effect of a family history of dementia. As current research suggests that there is not consistent evidence for a direct effect between healthy lifestyle behaviours and cognitive function, an indirect effect between these measures was also hypothesised. This postulated that anxiety measures would mediate the relationship of CHEB on cognitive function. A second-order latent variable called Cognitive Health Enhancing Behaviours (CHEB) was estimated to allow this effect to be tested. See Appendix L for the hypothesised SEM.

Structural Equation Model

The SEM testing the direct and indirect effect of CHEB on cognitive function was utilised. The SEM was an acceptable fit, $\chi 2$ (1261)= 5262.044, $p<0.001$; CFI= 0.963; RMSEA = 0.053; SRMR = 0.074. It is noteworthy that the model fit is worse than the measurement model. This is likely due to the addition of a single second-order latent factor (CHEB) to the model. This practical decision was necessary to run the full SEM model with indirect effects for three anxiety variables, as without the second-order CHEB variable, 15 rather than 3 indirect effects would have been included in a single model. Standardised Beta values, and bias corrected bootstrap confidence intervals for the direct effects and indirect effects are shown in Table 4 and Table 5. See Figure 1 for the SEM model.

Table 4

Beta and bias corrected bootstrap confidence intervals for direct effects

Direct effects	β	Bias corrected bootstrap confidence intervals (95%)
CFT on		
SCC	-0.077	-0.150, 0.004
Brief-FoD	-0.542	-1.269, -0.290
GAD-7	-1.021	-1.846, -0.522
CHEB	1.702	1.551, 2.050
SCC on		
CHEB	-0.010	-0.098, 0.075
Brief-FoD on		
CHEB	0.618	0.517, 0.824
GAD-7 on		
CHEB	0.754	0.606, 0.893

SCC= Subjective Cognitive Complaints (5-item scale); Brief-FoD= Brief Fear of Dementia scale; GAD-7 = Generalised Anxiety Disorder Questionnaire, CHEB= Cognitive Health Enhancing Behaviours; CFT= Cognitive Function Test; CFT RAG rating = Cognitive Function Test, Red, Amber, Green rating

B=standardised beta coefficient

Table 5

Beta, and bias corrected bootstrap confidence intervals for indirect effects

Indirect effect	β	Bias correct bootstrap confidence intervals (95%)
CFT on CHEB via SCC	0.001	-0.006, 0.007
CFT on CHEB via Brief-FoD	-0.335	-1.059, -0.153
CFT on CHEB via GAD-7	-0.770	-1.658, -0.318

SCC= Subjective Cognitive Complaints (5-item scale); Brief-FoD= Brief Fear of Dementia scale; GAD-7 = Generalised Anxiety Disorder Questionnaire, CHEB= Cognitive Health Enhancing Behaviours; CFT= Cognitive Function Test; CFT RAG rating = Cognitive Function Test, Red, Amber, Green rating

B=standardised beta coefficient

Cognitive Health Enhancing Behaviours

Cognitive Health Enhancing Behaviours (CHEB) significantly predicted Brief-FoD total (β= 0.618, 95% CI [0.517, 0.824]), and GAD total (β= 0.754, 95% CI [0.606, 0.893]). CHEB also significantly predicted cognitive function (β= 1.702, 95% CI [1.551, 2.050]). Prediction refers to the statistical relationship between two variables and does not infer causation.

Anxiety measures

GAD total (β= -1.021, 95% CI [-1.846, -0.522]) and Brief-FoD (β=-0.542, 95% CI [-1.269, -0.290]) significantly predicted cognitive function (CFT). SCC did not significantly predict cognitive function. Tests of the indirect effects showed that GAD (β=-0.770, 95% CI [-1.658, -0.318]) and Brief-FoD (β=-0.335, 95% CI [-1.059, -0.153]) significantly mediated the relationship from CHEB to cognitive function. The indirect effect from CHEB to cognitive function via SCC was not significant.

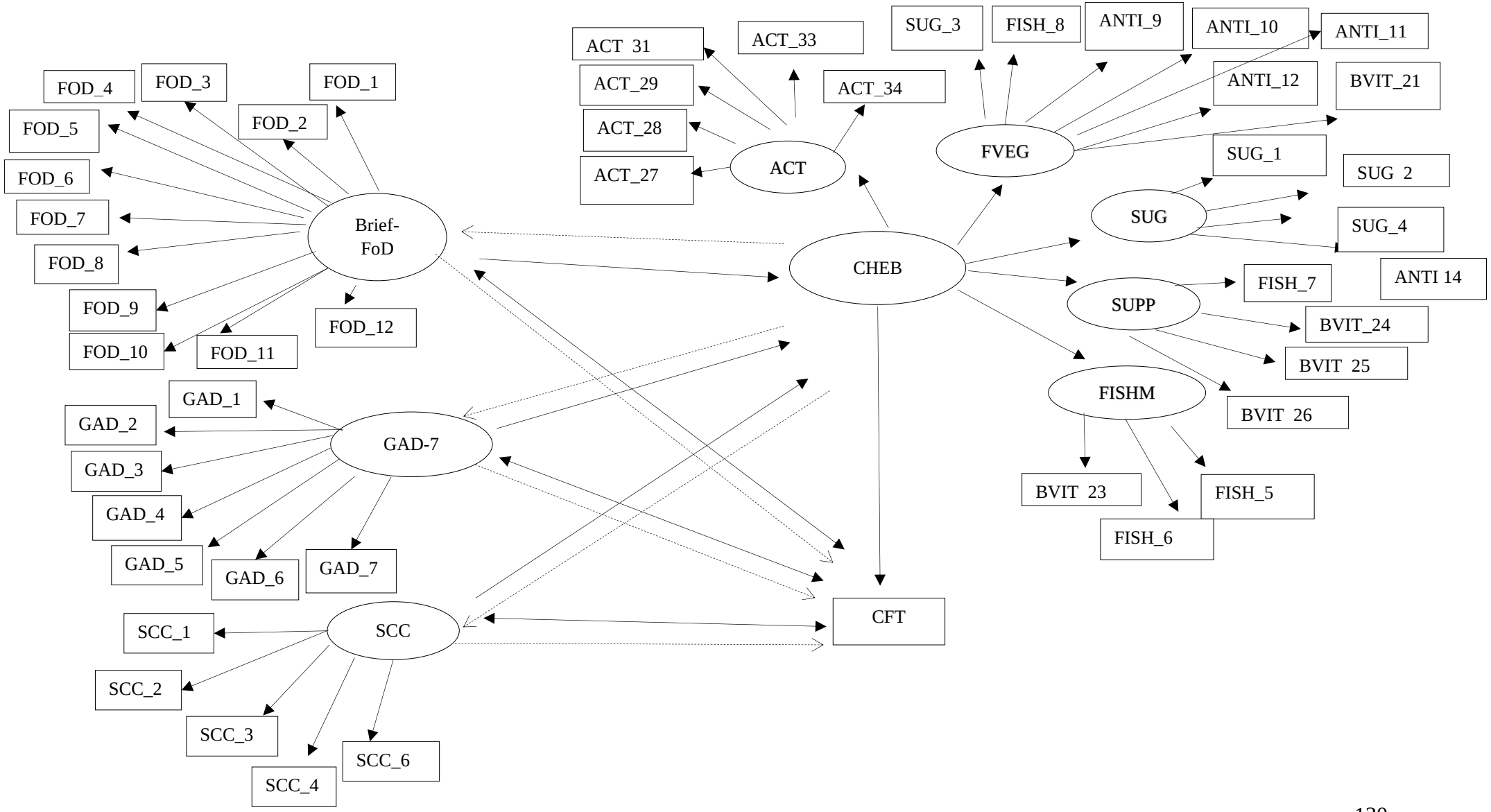
Brief-
FoD
FOD_1
FOD_2
FOD_3
FOD_4
FOD_5
FOD_6
FOD_7
FOD_8
FOD_9
FOD_10
FOD_11
FOD_12
GAD-7
GAD_1
GAD_2
GAD_3
GAD_4
GAD_5
GAD_6
GAD_7
SCC
SCC_1
SCC_2
SCC_3
SCC_4
SCC_6
CHEB
CFT
ACT
ACT_27
ACT_28
ACT_29
ACT 31
ACT_33
ACT_34
FVEG
SUG_3
FISH_8
ANTI_9
ANTI_10
ANTI_11
ANTI_12
BVIT_21
SUG
SUG_1
SUG 2
SUG_4
SUPP
FISH_7
ANTI 14
BVIT_24
BVIT 25
FISHM
BVIT 26
BVIT 23
FISH_5
FISH_6

Figure 2. SEM showing cross-sectional relationships between cognitive functioning, lifestyle behaviours and anxiety measures at baseline.

CHEB = Cognitive Health Enhancing Behaviours, Brief- FoD= Brief-Fear of Dementia, GAD-7 = Generalised Anxiety Disorder scale, SCC= Subjective Cognitive Concern, ACT= Activity total, FISHM= Fish/meat total, FVEG = Fruit/vegetables/wholegrains total, SUPP= supplements total, SUG= Sugar total, SCC_7= Family history of dementia, not included in diagram but was included as a covariate.

KEY: indirect effect = -----, direct effect = ——

Research question two

Exploratory analyses of the longitudinal data were utilised to investigate whether individuals change their behaviour over time and potential predictors of this.

Preliminary analyses

Across all timepoints, CHEBs (fruit/veg, fish/meat, sugar, supplements and activity) were not normally distributed. Brief-FoD and GAD-7 were not repeated after baseline; therefore, non-parametric tests were used for preliminary analysis.

Mann-Whitney U Tests and a Chi-Square test were completed to establish whether there were differences between individuals who only completed baseline measures and those who completed follow-up measures at any timepoint. Significant differences in age, CFT, and fish/meat were found between the groups. There were no significant differences between the groups in gender, GAD-7 total, GAD-7 categorised into asymptomatic/symptomatic, Brief-FoD, activity, sugar or supplements. See Table 6 for the results and direction of effects. Table 7 presents proportional data on individuals who completed baseline only measures and those who completed follow-up measures at any timepoint for GAD-7 categorised into asymptomatic and symptomatic and for the CFT RAG rating. This was to identify the characteristics of individuals who did not complete further tests after baseline.

Table 6

Mann-Whitney U test results for participants who only completed baseline and those who completed further tests

Characteristic	Z	*P* value	Median (N)	
			Baseline only	Follow-up
CFT Total	-5.61	<.001	54 (704)	58 (419)
Age	-3.29	<.001	58 (713)	59 (416)
Brief-FoD	0.42	0.68	21 (713)	20 (416)
GAD	-0.14	0.89	3 (713)	3 (406)
Fruit/veg	-1.74	0.08	26 (703)	27 (418)
Fish/meat	-2.92	<.001	8 (703)	8 (418)

Activity	-1.82	0.07	16 (703)	16 (418)
Sugar	0.85	0.39	11 (709)	11 (421)
Supplements	-0.30	0.77	5 (703)	6 (418)
	X^2	*P* value	Frequency (%)	
Gender (males, females)	2.80	0.09	153 (25), 455(75)	71 (20), 277 (80)
GAD-7 (Asymptomatic, symptomatic)	0.01	0.93	427 (60), 286 (40)	248 (35), 454 (65)

Table 7

Proportional data on Generalised Anxiety and CFT RAG rating for participants who only completed baseline measures and those who completed further tests

Characteristic	Baseline only (N, %)	Follow-up (N, %)
GAD-7		
Asymptomatic	427 (59.9)	248 (59.6)
Symptomatic	286 (40.1)	168 (40.4)
CFT RAG		
Red	78 (11.1)	15 (3.6)
Amber	58 (8.2)	19 (4.5)
Green	568 (80.7)	385 (91.9)

Multilevel modelling

In total, 416 participants were included in the longitudinal analysis. Missing data was handled using Restricted Maximum Likelihood (REML) as estimates are reported to be less biased than Maximum Likelihood estimates when the number of groups is small and data was missing completely at random (Boedeker, 2017). As the number of participants in groups decreased over time, REML was utilised. However, as the gender variable was missing for 176 cases (15.8%) for those who completed follow-up measures, 'missing' was recoded as a separate dummy category, which meant that these participants would not be excluded from models due to listwise deletion. Alternative methods of missing data imputation were not considered appropriate for this kind of socio-demographic variable.

Model 1 found that participants did not significantly change any of the five lifestyle behaviours over 24 months. However, a significant interaction effect between time and baseline RAG rating was found for sugar total. The growth rate from baseline across time for sugar in the Amber rag rating group was –0.45 (95% CI [-0.86, -0.03]) and for the Green rag group was -0.33 (95% CI [-0.65, -0.01]), compared to the red by time interaction. The interaction effect shows that individuals change in sugar total over time differed depending on the baseline RAG rating. Coefficients and 95% confidence intervals can be found in Table 7. Figure 3 depicts the relationships between time and RAG rating for sugar and shows that individuals in the red rag group increased their sugar intake total score (a higher sugar total denotes healthier behaviour), whereas Amber and Green rag rating groups decreased their sugar intake score over time. In other words, the red feedback group decreased their sugar intake compared to the amber and green group over time.

Table 8

Multi-level modelling results for the effect of time and RAG feedback on CHEBs for individuals who completed the CFT at baseline, 6, 12 and 24 months

	Dependent variable	FVEG		FISHM		ACT		SUG		SUPP	
		B	95% CI	B	95% CI	B	95% CI	B	95% CI	B	95% CI
	Time Slope	-.11	-0.77, 0.55	-0.15	-0.47, 0.16	0.05	-0.48, 0.57	0.19	-0.12, 0.50	0.07	-0.53, 0.67
Time-fixed variables											
	RAG Rating										
	Red[a]	-	-	-	-	-	-	-	-	-	-

	Amber	2.28	-0.91, 5.48	-0.19	-1.61, 1.23	0.80	-1.99, 3.59	**1.51**	**0.20, 2.81**	1.77	-1.01, 4.54
	Green	1.99	-0.42, 4.40	-0.43	-1.51, 0.64	1.07	-1.04, 3.17	0.88	-0.10, 1.87	0.46	-1.64, 2.55
Interaction effects											
	RAG# timepoint										
	Red[a]	-	-	-	-	-	-	-	-	-	-
	Amber	0.69	-0.19, 1.58	0.42	0.00, 0.85	-0.08	-0.78, 0.62	**-0.45**	**-0.86, -0.03**	0.46	-0.35, 1.26
	Green	0.31	-0.37, 0.98	0.26	-0.06, 0.58	0.12	-0.42, 0.65	**-0.33**	**-0.65, -0.01**	0.12	-0.50, 0.73
Covariates											
	Gender										
	Male[a]	-	-	-	-	-	-	-	-	-	-
	Female	**1.50**	**0.36, 2.64**	**-0.58**	**-1.08, -0.08**	0.26	-0.75, 1.28	-0.28	-0.74, 0.17	-0.07	-1.06, 0.91

Missing	0.60	-0.85, 2.05	**-0.67**	**-1.31, -0.03**	0.12	-1.17, 1.41	-0.50	-1.07, 0.09	-0.57	-1.82, 0.70
Age	0.03	-0.07, 0.13	0.04	0.00, 0.09	0.08	-0.00, 0.16	-0.50	-0.09, 0.13	-0.57	-1.83, 0.68

B, Beta coefficient.

[a] denotes reference category

Significant estimates are denoted in bold as indicated by a CI that does not span 0.

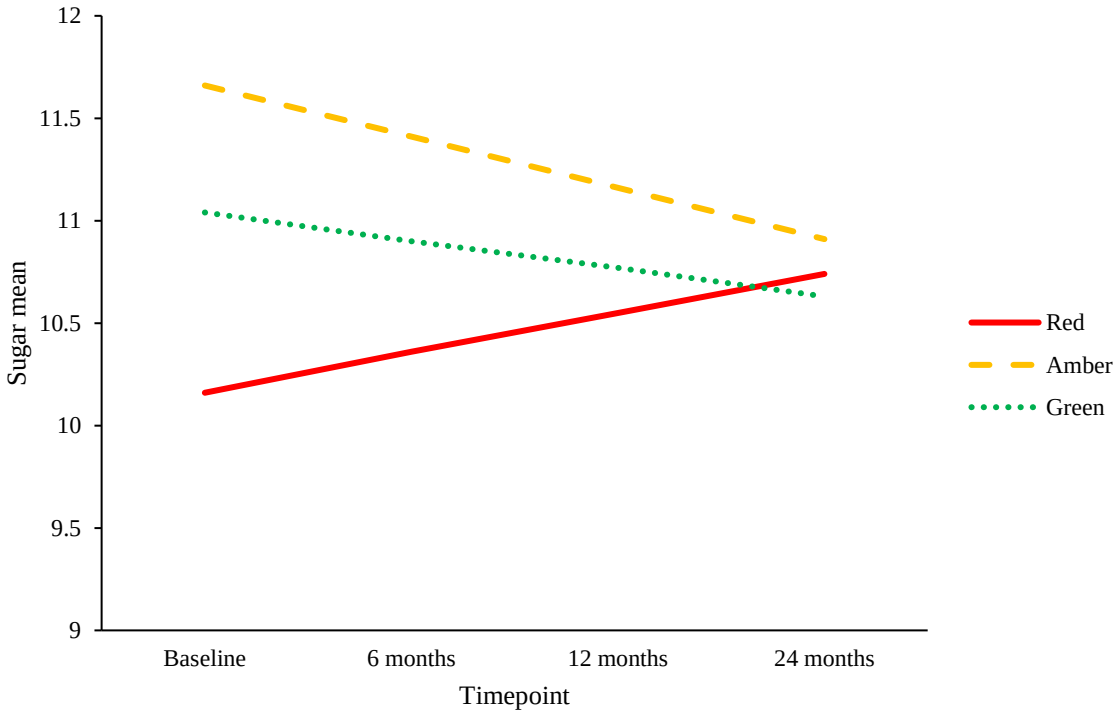

Figure 3. Mean sugar score across the four timepoints for individuals in the Green, Amber and Red RAG rating group (higher score indicates healthier behaviour)

Model 2 introduced baseline Brief-FoD and GAD-7 as covariates to investigate their impact on the relationship between RAG rating group and change in CHEB across time. There were no significant effects of Brief-FoD or GAD and they did not cause any significant changes in the model or interaction effects. See Table 9 for the estimates and 95% confidence intervals.

Table 9

Multi-level modelling results for the effect of time and RAG feedback on CHEBs with anxiety covariates for individuals who completed the CFT at baseline, 6, 12 and 24 months

	Dependent variable	FVEG		FISHM		ACT		SUG		SUPP	
		B	95% CI	B	95% CI	B	95% CI	B	95% CI	B	95% CI
	Time Slope	-0.11	-0.77, 0.55	-0.15	-0.47, 0.16	0.05	-0.47, 0.57	0.19	-0.12, 0.50	0.07	-0.53, 0.67
Time-fixed variables											
	RAG Rating										
	Red[a]	-	-	-	-	-	-	-	-	-	-
	Amber	2.27	-0.93, 5.47	-0.19	-1.61, 1.23	0.81	-1.98, 3.60	**1.50**	**0.20, 2.80**	1.77	-1.01, 4.55
	Green	1.98	-0.43, 4.39	-0.44	-1.50, 0.63	1.07	-1.04, 3.17	-0.33	-0.11, 1.86	0.45	-1.64, 2.55

Interaction effects	RAG#timepoint										
	Red[a]	-	-	-	-		-	-	-	-	-
	Amber	0.69	-0.19, 1.58	0.43	0.00, 0.85	-0.08	-0.79, 0.62	**-0.44**	**-0.86, -0.03**	0.45	-0.36, 1.26
	Green	0.31	-0.36, 0.98	0.26	-0.06, 009	-0.12	-0.42, 0.65	**-0.33**	**-0.65, -0.01**	0.11	-0.50, 0.73
Covariates											
	Gender										
	Male[a]	-	-	-	-	-	-	-	-	-	-
	Female	**1.49**	**0.35, 2.64**	**-0.59**	**-1.09, -0.09**	0.28	-0.73, 1.29	-0.29	-0.74, 0.16	-0.07	-1.05, 0.92
	Missing	0.57	-0.89, 2.03	**-0.68**	**-1.32, -0.04**	0.13	-1.16, 1.42	-0.51	-1.09, 0.07	-0.58	-1.83, 0.68
	Age	0.03	-0.06, 0.13	0.05	0.01, 0.09	0.07	-0.01, 0.16	**-0.05**	**-0.08, -0.10**	-0.01	-0.09, 0.07
	GAD	0.03	-0.07, 0.13	0.00	-0.04, 0.05	0.00	-0.09, 0.09	0.02	-0.02, 0.06	0.01	-0.07, 0.10

Brief-FoD	0.01	-0.03, 0.05	0.02	-0.00, 0.03	-0.02	-0.06, 0.01	0.01	-0.01, 0.24	-0.02	-0.06, 0.15

B, estimated parameter

[a] denotes reference category

Significant estimates are denoted in bold as indicated by a CI that does not span 0

Discussion

Interpretation of findings

This project aimed to consider the cross-sectional mediational relationship between cognitive function, cognitive health enhancing behaviours, fear of dementia, subjective cognitive complaints and generalised anxiety. Furthermore, it explored what influences individuals to engage in health behaviour change longitudinally.

Structural Equation Modelling showed CHEB significantly predicted cognitive function at baseline and that fear of dementia and generalised anxiety mediated this relationship. CHEB significantly positively predicted CFT score showing that higher reported healthy behaviours were associated with higher cognitive function. A mediation effect was also found for GAD-7 and Brief-FoD for the relationship between CHEB and CFT at baseline. Standardised coefficients show for every unit increase in CHEB, a -0.770 change in CFT was found as a result of GAD and a -0.335 change in CFT was found as a result of Brief-FoD. This suggests that anxiety negatively impacts the relationship between CHEB and CFT. In other words, when CHEBs increases, anxiety decreases which in turn increases cognitive function.

Multilevel modelling was used to identify what impacts individuals to change their behaviour over time. Individuals received feedback after their initial baseline test to inform them whether they were in the red, amber, or green category for cognitive function. Whilst CHEB alone did not significantly change across time, the longitudinal analysis identified an interaction effect between feedback category and sugar over time, suggesting that individual's change in sugar intake over time depended on what feedback they were given at baseline on their CFT. Individuals in

the red RAG group decreased their sugar intake over time whereas individuals in the amber and green RAG group increased their sugar intake over time. By 24 months, individuals in the red RAG group had decreased their intake below individuals who received a green RAG rating at baseline.

No significant interaction effects were found for the other four lifestyle factors (fruit/veg, fish/meat, activity, and supplements). Neither fear of dementia nor generalised anxiety were found to influence change in health behaviour over time, nor were there any interaction effects of feedback and time.

It is possible that a mediation effect was not found for the anxiety measures longitudinally because another variable may be better considered as a mediator. For example, behaviour could be a mediator that acts on anxiety. It could be that the relationship between anxiety and cognitive function is mediated or moderated by CHEB as it might be expected that lower anxiety leads to greater cognitive function depending on behaviour. This relationship could also be stronger if behaviour is healthier. This is of course speculative as the analysis in this study does not allow for exploration of this but if this were the case, this would have significant clinical implications (discussed below).

Theoretical interpretation

The Health Belief Model (HBM) suggests that individuals are more likely to change their behaviour if they are more anxious regarding the likelihood of developing the disease, there is high perceived severity of the disease and the perceived benefits of behaviour change are high (Becker, 1974). This project explored the role of anxiety in behaviour change and the impact of receiving feedback about the benefits of behaviour change. The findings did not support the HBM's premise that the more anxious an individual is of developing the disease, the

more likely they are to change their behaviour as neither the Brief-FoD nor GAD-7 predict change in CHEB over time. However, the mean GAD-7 score for participants at baseline was in the asymptomatic range with 60% of the sample reporting anxiety below the mild level. This was proportional across time (see Table 7 in results) as 60% of the participants who completed further tests were also asymptomatic. Therefore, it is unlikely that those who were more anxious dropped out over time. Instead, it is possible the sample identifies as a largely non-anxious population which may partly explain the non-significant results for the anxiety measures. The anxiety measures were also only collected at baseline. Therefore, it is possible that changes in Brief-FoD and GAD-7 may predict changes in CHEB over time, but this thesis was unable to measure this. There was some support that presenting the perceived benefits of a behaviour change leads to changes in CHEB as a significant interaction effect was found for sugar intake between time and the feedback received.

Comparison to available literature

Some of the findings of this study support previous findings within the literature. They highlight the potential complexity of considering anxiety in dementia compared to other health disorders as there is not only the possibility of anxiety influencing the uptake of CHEBs, but also its impact on cognitive function. The results of the SEM identified that state anxiety (Brief-FoD) and general anxiety (GAD-7) significantly mediated the relationship between CHEB and CFT. It was found that higher levels of these anxiety measures were associated with lower cognitive function. This reflects similar findings from Schultz et al. (2005) who found that adults who displayed higher state and trait anxiety scores performed more poorly on global tests of cognition.

Literature that has investigated the role of anxiety in health behaviour change suggests that the higher the anxiety, the less likely the behaviour is to occur as anxiety activates the avoidance system (Mayne, 1999). The exploratory analysis of the longitudinal data did not find a significant effect of anxiety on CHEB over time so it is difficult to comment on how anxiety may have influenced behaviour change. However, there was a significant interaction effect between time and feedback received for sugar intake with those in the red group decreasing their intake and those in the amber and green group increasing their intake. Whilst the mechanism for this change is unclear, it is possible the mechanism for change is through fear as receiving a red feedback may have elicited greater fear of dementia. However, this would be in contrast to theoretical conceptions from Kessler et al. (2012) that suggest that too much fear leads to avoidance in health behaviours.

Clinical and policy implications

This study identified that general anxiety and fear of dementia do mediate the relationship between CHEB and cognitive function. Although this is cross-sectional, it still raises possible implications for public health policies. Whilst the focus has been on risk reduction through lifestyle interventions, it is possible that interventions also need to address anxiety to allow for the potential benefits of change in cognitive health-enhancing behaviours on cognitive function. This may identify why some risk reduction interventions have not been effective as they do not account for individual differences in anxiety and fear of dementia.

Furthermore, the exploratory analysis may suggest that online feedback can result in changes in health behaviour which may have implications for how feedback is given and the mode in which interventions are delivered. This may be increasingly

important in a time when social contact has been limited and digital working has been optimised.

As discussed in the interpretations of the findings, if anxiety were in fact better thought of as the independent variable and behaviour thought of as a mediator, this would have clinical implications. This would suggest that behaviour would need to be the area of intervention with a consideration of anxiety. For example, if anxiety were high and cognitive function was low, behaviour might be a better area for intervention as it does not rely on higher cognitive processes to address anxiety through cognitive therapy. Therefore, in contrast to above, this might suggest that anxiety does not need to be directly addressed in interventions.

Limitations

To my knowledge, this is the first study to look at the combined relationship between cognitive functioning, anxiety, and multiple cognitive health-enhancing behaviours which is important to consider in order to provide evidence for effective public health interventions. However, there are psychometric limitations with the measures used in this project which has implications for the conclusions that can be drawn. The SEM did not compute when looking at the individual effects of different lifestyle factors. Therefore, whilst the cross-sectional data highlighted that CHEBs do predict CFT, it is not possible to ascertain which lifestyle factors are effective. This is important to distinguish to identify the important agents of change to establish what needs to be implemented in a public health intervention. Further support to distinguish these lifestyle factors comes from the longitudinal data that showed significant interaction effects only for sugar.

The item selection required within the lifestyle factors to ensure sound psychometric properties also has implications. Many items had to be removed as they

did not load onto a factor, such as items on alcohol and caffeine consumption. It is also possible that there are confounds to the activity lifestyle factor as social activity and exercise loaded onto the same factor, but some exercise can contain a social component. Therefore, it is difficult to conclude the mechanism by which activity may influence cognitive function as it could be through exercise, social interaction, or both. There were also a couple of items with factor loadings < 0.50 which has been regarded as an unacceptable factor loading (Kaiser, 1974). Overall, the factor loadings varied greatly and there were few between 0.70 and 0.80 which is regarded as good (Kaiser, 1974). This highlights potential implications with the validity of the measure and hence the conclusions made from this measure.

Additionally, whilst participants also received a RAG rating for each lifestyle behaviour, these were not usable so the CFT RAG rating was used instead. However, the lifestyle RAG ratings may have impacted the decision to change behaviour more so than feedback on cognitive function. Furthermore, the SEM did not consider factors known to increase the risk of dementia such as age, ethnicity and educational attainment (Livingston et al., 2017).

The exploratory analysis of the longitudinal data suggested that individuals did not change their CHEB over time. However, the majority of people in the study were given a green feedback rating at baseline (80.6%) so it is possible that the lack of change is because the cognitive function test attracted mostly healthy individuals. No significant effects of anxiety measures were found for feedback group across time points. Attrition in these groups was not proportional as the percentage of participants in the red (11.1%) and amber (8.2%) group at baseline decreased to 3.5% and 4.5% respectively whereas the percentage of the green group increased from baseline (80.6%) to follow-up (91.9%) suggesting that a higher number of

participants who had a good CFT score remained in the study. It might be expected that those who received red and amber ratings may have been more anxious about their cognitive function and lifestyle behaviours; therefore, it is possible the groups were too small and the study was not powered to detect an effect.

This sample consisted of mostly white British (or other), female participants which is not representative of the population at risk of dementia. Individuals from a black ethnic background have a higher incidence rate of dementia than individuals from white ethnic backgrounds (Pham et al., 2018). Furthermore, this study did not consider socioeconomic status but Koster et al. (2005) found lower socioeconomic status (SES) predicted greater cognitive decline (as measured by the MMSE) in older adults aged 70 to 79. It is also possible that this SES may explain the different incidence rates of dementia within different ethnicities (Pham et al., 2018). This project failed to address the potential confounds of behaviour change, such as poverty, motivation and resources. It is possible that those at risk of lower cognitive function are those from lower SES backgrounds and have less resource to make changes to their behaviour. It is notable that this sample all had a smartphone or computer and access to the internet which people from lower SES may not have had access to. They were also individuals with time and motivation to engage in a lengthy assessment of their cognitive function. It is also possible however, that online health promotion attracts individuals from certain ethnic backgrounds or SES which raises an important area for future research to consider how best to engage those individuals most at risk of dementia.

There are also other mechanisms that may impact the relationship between CHEB and cognitive function which were not explored in this thesis. Risk factors for dementia such as, social isolation, loneliness, and physical disabilities or impairment

may be important to consider. In particular, the intersectionality between variables are important to consider, for example, individuals of LGBT+ and immigrants have been found to experience greater social isolation and loneliness so it is important to consider how this impacts risk of dementia and cognitive function (Kuiper et al., 2015). This may be because of language barriers, stigma, or discrimination. Furthermore, a sedentary lifestyle is a risk factor for dementia (Livingston et al., 2017), therefore, it is also important to consider factors outside an individuals' control that may have an impact on cognitive function, such as disability that might impact an individual's ability to make behaviour change. These are important factors to consider when considering individual agency in reducing dementia risk. As this study was a secondary data analysis, access to this information was not possible but future research could consider this.

Future research

This project has begun to explore the mediational relationship between cognitive health enhancing behaviours, cognitive function and anxiety. It investigated what influences individuals to change behaviour over time. This is important as there have been mixed findings for the effectiveness of risk reduction interventions and poor adherence has been suggested as a possible reason for this (Livingston et al., 2017; Öhman et al., 2014; Singh et al., 2014).

This project identified that the sample is under-representative of the general population at risk of dementia as it consisted of predominantly white individuals. Future research could address this by recruiting participants across social and cultural backgrounds to inform interventions applicable to a wider population. Through recruiting individuals from a more representative population of those at risk of dementia, future analysis can begin to analyse sub-groups by ethnicity to better

understand if certain interventions are more effective for certain sub-groups. This will enable more effective interventions that are targeted towards those most at-risk of dementia. Additionally, this may also be important to consider for gender. It is of paramount importance that a better understanding of risk reduction interventions is gained to understand who they are effective for to ensure research is directed towards sub-groups where they are less effective to address this gap.

Furthermore, future research could aim to address the psychometric limitations of the lifestyle questionnaire in this study by developing a psychometrically robust tool to evaluate individual's CHEB. There was only one question in the current measure that asked about cognitive activity which had to be dropped from analysis as it did not load onto a factor in the factor analysis. However, this is important to continue to investigate as the systematic review from this thesis highlights there are mixed results of the effectiveness of cognitive activity on cognitive function.

It is possible that cohort studies could be used to address the limitations of not considering other alternative factors that influence behaviour change and dementia risk. Through following cohorts, this may increase understanding of how particular factors such as, social isolation and physical disability and impairment impact later cognitive function.

Conclusions

To my knowledge, this is the first study to examine the combined relationship between cognitive functioning, anxiety, and multiple cognitive health-enhancing behaviours purported to reduce the risk of dementia. There was cross-sectional evidence of the mediating impact of generalised anxiety and fear of dementia on the relationship between CHEB and cognitive function but this was unable to distinguish

for what types of lifestyle behaviours. There was no evidence that anxiety impacted on CHEB change over time. However, small sample sizes within the feedback groups may have resulted in the study being underpowered to detect an effect between anxiety and feedback on CHEB over time. Future research may benefit from devising suitable psychometric measures to distinguish between different health behaviours and focussing on how to recruit individuals who are more representative of an at risk population with dementia. Nonetheless, the findings in this study have implications for the importance of continuing to understand how anxiety may impact the uptake of health behaviours in order to provide effective public health interventions.

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Part III: Critical Appraisal

Introduction

This thesis enabled me to combine two professional interests: dementia prevention and health promotion/public health. In this critical appraisal, I will reflect on the process of completing the systematic review and the empirical study. Firstly, I will reflect on the challenges of balancing the perspectives of multiple, diverse stake holders through my experiences of co-production and methodological challenges from the empirical paper. Secondly, I will discuss the contribution of clinical psychology and my results to Public Health.

Balancing the perspectives of multiple and diverse stake holders

Co-production and Patient and Public Involvement (PPI)

I completed a systematic review for the APPLE-Tree project that is aiming to develop a comprehensive intervention for older adults targeting all main risk factors for dementia, including physical health, diet, exercise and psychosocial. I chose to write up a smaller version of this systematic review for my thesis that did not include physical health interventions.

I was invited to attend the co-production meetings for APPLE-Tree to present the findings from the systematic review and to understand how the findings are used. Co-production is an approach in which power and responsibility for the project is shared equally amongst the researchers, practitioners and public (Hickey et al., 2018). In this co-production team, there were practitioners (psychiatrists, clinical psychologist, mental health practitioners), researchers (research assistants, research fellows) and representatives from the public (those with lived experience of dementia and those caring for individuals with dementia).

Prior to joining these meetings, I had not experienced co-production in research. I was curious as to how it would work in practice as I had read articles that suggested the way it was used varied amongst projects (Hickey, 2018). I also wondered how the power would be shared amongst those involved in co-production.

I was invited to present the findings from the systematic review in a co-production meeting to inform the design of an intervention targeting risk factors for dementia. I had no previous experience of presenting research findings and I was initially nervous and daunted by so many "experts in the field" in one room. However, I really valued this experience as I learnt the importance of being able to disseminate findings to a mixed audience. I was asked by service users in the co-production team to clarify on some terms and language I used in the presentation. This was a valuable lesson to learn the importance of using clear and concise language and to limit the use of "jargon" psychology language to make the findings more accessible. I found the discussions in the co-production meetings to be rich and I particularly valued hearing different views from different disciplines.

In a later co-production meeting, I was able to witness how the systematic review had been used to inform the design of an intervention. This felt very rewarding to see how it had been utilised. In previous experiences of research, I had only ever completed specific parts of the research and hence, I had not seen how this fitted into the larger process of research. I particularly enjoyed seeing how the systematic review contributed to this process.

I previously heard mixed views on how successfully co-production had been utilised in previous research projects due to the difficulties in recruiting representative populations for research. I noticed this in the co-production team as the team consisted of mostly white, middle class women. There was only one black

person in the team who happened to be male. Individuals from a black ethnic background have a higher incidence rate of dementia than individuals from white ethnic backgrounds (Pham et al., 2018) and data from The Rotterdam study found a similar incidence rate of dementia for men and women (Ruitenberg, Ott, van Swieten, Hofman, & Breteler, 2001). Therefore, it would have been more representative to have more men and individuals from BAME backgrounds. However, I was aware this was not a problem unique to APPLE-Tree and that individuals from a BAME background were often underrepresented in research (Newington & Metcalfe, 2014).

Reflecting on the Social GRRAACCES (Burnham, 1992) and intersectionality helped me to consider why this might be. I considered white privilege and how this might suggest that BAME backgrounds are less likely to get to the opportunities for higher level education and they may have less access to the world of research, including the knowledge to know research groups such as this exist. Furthermore, socio-cultural factors such language barriers or culture-specific stigma around certain diseases may also have played a role in the under-representation of people from BAME backgrounds in the research.

I noticed a pattern of fluctuation of power during the meetings depending on the topic and stage of the research. It appeared the researchers held more of the power when delivering the evidence from the research although papers were shared by all members of the team and this contributed to the synthesis of all the evidence. However, what I noticed was that when the draft design of the intervention was evaluated by the team, the power appeared to shift to the public. Researchers and practitioners were keen to hear their views on what enabled an effective and realistic intervention. For example, it was commented that some of the exercise examples in

the intervention were not representative of exercise for ethnic minorities. The gentleman reported that in his culture, collective exercise was preferred over exercise completed individually. The researchers responded with gratitude for his input and were keen to change the intervention based on his feedback. Whilst I perceived the power fluctuated across the meetings dependent on the topic, as a white middle class women in higher education, I wondered whether this was my perception rather than necessarily experienced by the public who made up the co-production team.

Experiencing the use of co-production increased my curiosity about the impact of it on the research, on those involved, and the wider community and organisations. Unfortunately, as the APPLE-Tree project was in its initial stages, I would not be able to see the impact longer-term of co-production as the project will span a few years. Interest in patient and public involvement (PPI) has expanded hugely to many countries now involving service users in research (Brett et al., 2014). This is very promising as it has been suggested that PPI can result in better quality research and greater relevance due to the unique perspectives that service-users can bring (Brett et al., 2014). However, I was curious as to how PPI is evaluated and how difficult it would be to measure its effectiveness. I wondered what an effective use of co-production would look like for APPLE-Tree; whether this would be being able to design an effective intervention for participants from BAME backgrounds or to encourage people from BAME backgrounds to take part in the evaluation of this intervention. A systematic review by INVOLVE (Staley, 2009) highlighted that PPI had a positive impact on recruitment of participants to clinical trials. The review suggests this may be because information given to potential participants is improved, recruitment procedures are more sensitive to the needs of the participants, those

involved encourage peers to take part, and they enhance the credibility of the research project and researchers.

Methodology

A series of methodological decisions related to the measures had to be made in this thesis that are likely to have had an impact on the project. Completing a secondary data analysis of data from a third party and not being involved in the designing of measures resulted in some challenges. Firstly, it presented difficulties with carrying out valid analyses of data from questionnaires that had not previously undergone any psychometric development (apart from the Cognitive Function Test (CFT)). Secondly, it was difficult to know how to update FFB about the psychometric limitations of their questionnaires.

Various decisions had to be made during this thesis which will be discussed in turn. Embedded within the CFT were seven contextual questions (termed Subjective Cognitive Complaints in this thesis) and 34 lifestyle questions. Factor analyses of the SCC questions and Lifestyle Questionnaire indicated problems with bringing the questions together as a 'measurement tool'. Secondly, due to quite a few questions from the lifestyle questionnaire not loading onto a factor, some questions were omitted from the analysis which were relevant for a clinical psychology thesis.

On appearance, the SCC measure looked strong due to its consideration of various areas that might contribute to subjective cognitive concerns such as, memory, disorientation, and collateral views. Measures of subjective cognitive complaints have previously been criticised for being loosely defined and not adequately correlating with Alzheimer's Disease biomarkers (La Joie et al., 2016). Unfortunately, the factor analysis produced two factors, with only one item in one of the factors. "Do you have a family history of dementia?" was removed from the

measure as it loaded individually and was controlled for in analyses. The item “Do you ever lose your way?” did not load onto a factor which left only questions about memory concerns in this measure for the subsequent analyses. No significant results were found for this measure and its impact on the uptake of health behaviours or cognitive function. It is possible this was because the resulting measure lacked validity as it only addressed memory concerns rather than multiple determinants of subjective cognitive concern.

Participants completing the CFT online receive feedback on six lifestyle areas: fish and seeds, antioxidants, sugar, supplements, caffeine and physical, mental and social activity. However, the factor analysis of the lifestyle measure did not produce these factors. Instead, it revealed five factors: fish and meat, sugar, physical and social activity, supplements, fruit and vegetables. The reliability of the measure was also poor.

Considering how to use the measure took much longer than I anticipated. This is for two reasons- I had to learn how to use statistics packages not taught on the clinical psychology doctorate course and because I was cautious about feeding back the psychometric limitations of the scales used to FFB. Having only had previous experience of SPSS, this required lots of extra reading and attendance at training courses in order to learn how to use Mplus. Furthermore, a polychoric factor analysis was completed on the lifestyle questionnaire because of the ordinal and categorical variables, which cannot be completed in Mplus (the programme chosen for the Structural Equation Modelling); therefore, I also learnt how to use Stata in order to complete the polychoric factor analysis.

I took longer to investigate the psychometric properties of the measures because I wanted to be able to provide a comprehensive summary of the

psychometric properties of the scales used to the data-provider. From a statistical perspective it was necessary to use the factors produced (rather than the factors from Food for the Brain, FFB) in order to use this measure in the structural equation model (SEM) but I wondered how this would be received and how this would impact future research from the third party.

Having had no previous experience of developing scales or analysing psychometric properties, I was nervous to feedback the limitations of the scales to FFB. However, through researching this topic, I began to understand how difficult it is to develop psychometrically-sound measures and I wondered whether through having a shared understanding of this difficulty, my results could be used to inform a more valid and reliable measure for FFB. Song, Son, and Oh (2015) highlight how complicated it is to design a valid and reliable questionnaire due to the necessity of appropriately operationalised concepts, well-worded questions, clear formatting response options, and piloting of the questionnaire.

Furthermore, I experienced tension when using the word "prevention" in my empirical paper when referring to FFB's lifestyle measure as I felt this was a strong claim to make; although it is a known aim to try to find interventions that will prevent the development of dementia due to there being no cure for this disease, it was not scientifically evidenced that the FFB's CFT and subsequent feedback was able to do this yet. Therefore, I continued to use the term "risk reduction" throughout my empirical paper and clarified when using the term "prevention" in my methods section, that this was a term used by FFB.

Overall, it has been challenging balancing multiple, diverse stake holders within this project. It has been helpful to consider who has an interest in this project and who will be impacted from the outcomes of the study. When I presented the

results of the systematic review to APPLE-Tree, they were well received but I wondered whether this was because of the usefulness of this information in their overall aim to design an intervention. I also felt I had a clear idea of what APPLE-Tree expected from me. The public stakeholders at APPLE-Tree reminded me of the importance of ensuring results are disseminated in an understandable way. Managing and communicating the psychometric limitations of the scales to FFB felt more challenging as I was aware, as stakeholders, that they had greater influence over the project as they were providing the data for me to complete this thesis. As I joined the project one year into it, I had limited contact with FFB at the beginning of the project so I was unsure of what they were expecting in terms of feedback from the results. In hindsight, having conversations with the stakeholders prior to starting the research about their expectations regarding the feedback may have reduced my anxiety about communicating some of the limitations of the measures as we could have discussed how to communicate the limitations prior to completing the project.

Contribution of Clinical Psychology to Public Health

Completing the systematic review for the APPLE-Tree team and my own empirical paper has enabled me to consider the contribution of clinical psychology to public health. Public health refers to measures used to prevent disease, promote health and prolong life (Acheson, 1988). It aims to do this by tackling preventable diseases at the individual, organisational and social level.

The biomedical model is no longer thought of as a comprehensive way of understanding health and disease; instead, advances towards a biopsychosocial understanding have been made (Wahass, 2005). Clinical Psychology plays a role in understanding not only how biological, behavioural and social factors influence health and illness but also the impact of mental health on illness. Clinical

Psychologists are trained to perceive how behavioural and cognitive functions interact to affect behaviour and how these outcomes can be changed (Wahass, 2005) but they are also trained in research to understand these factors. Therefore, it seems highly relevant that clinical psychology contributes to the development of interventions and public health campaigns to change health behaviour.

This project has explored anxiety and its impact on the uptake of health behaviours and cognitive functioning. It has shown that addressing anxiety may be one way of increasing individual's engagement with health behaviours which in turn, has an impact on cognitive functioning. I considered how this could be utilised within in public health and it highlighted to me the importance of adapting public health campaigns to account for individual differences. Whilst it is difficult for these campaigns to consider all individual nuances, it is important that clinical psychology disseminates this research to show why campaigns may be less effective for some individuals. Therefore, clinical psychology's understanding of mental health appears to have an important contribution to public health. I reflected on the difficulty of targeting an intervention with the aim to reach the largest population whilst accommodating individual differences. It does appear this would make the interventions the most effective and perhaps, in the long term, cost-effective.

During this project, I had continuously reflected on the role of clinical psychology in public health but whilst writing up my thesis, the Covid-19 pandemic had been announced and it felt more pertinent than ever to consider the partnership between the two disciplines. This highlights how important clinical psychology is in implementing effective public health interventions. What was notable however, in the public health campaign to stop the spread of Covid-19 was that the behaviours needed to do so were significant risk factors for difficulties with mental health, for

example, social isolation. Whilst these were necessary to protect the health of the population, they are likely to have long lasting effects on individuals. Clinical psychology has been quick to begin research looking into the impact of the pandemic on mental health. It can help to identify how people's mental health, their attitudes towards others and their beliefs about the virus change as the pandemic changes but also how these changes are related to appropriate changes in health-related behaviour. This pandemic has highlighted the important role that human behaviour plays in the spread of the virus; therefore, it is important to understand what impacts human behaviour in these times to implement effective public health campaigns.

Not only is social isolation a risk factor for mental health difficulties, but it is also a risk factor for dementia. Sanctions on social activity have been stricter for the over 70s due to their vulnerability of having greater complications if they get the virus. Whilst public health's immediate concern is to stop the spread of the virus, clinical psychology is able to use its expertise in research to hold these individuals in mind to push for public health to provide interventions to mitigate these risks and to provide effective care to those struggling with the effects of the pandemic.

Conclusion

This project has enabled me to gain further insight into how clinical psychology can contribute to public health by providing understanding of human behaviour and what impacts it. Methodological challenges with some measures in the empirical paper meant I was unable to investigate how specific lifestyle behaviours impacted cognitive functioning or were impacted by anxiety measures. This was disappointing as this would have provided richer results to derive conclusions from. Witnessing co-production was a valuable lesson for me and highlighted how necessary it is for the ownership of research to be shared amongst researchers,

practitioners and those utilising the interventions. However, it emphasised there are difficulties with gaining representative populations for co-production and reflecting on the Social GRRAACCES helped me to consider why this might be.

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Appendices

Appendix A- Information, consent and debrief forms

UCL

Information Sheet for Participants in Research Studies

Title of Project:

An evaluation of an online supported Cognitive Function Test for cognitive screening and its role for cognitive health promotion.

Investigators:

Glorianne Said, Dr Elisa Aguirre, Dr Georgina Charlesworth

UCL, Gower Street, London, WC1E 7HB +44 (0)20 7679 2000

We would like to invite you to participate in this research project directed by researchers at UCL. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. If you decide to take part in this study, you can still stop at any time without giving a reason. Before you decide if you would like to take part, it is important for you to read the following information carefully.

In this study, we are investigating the effects of completing an Online Cognitive Function Test provided by Food for the Brain website, a not-for-profit charity which provides nutritional and well-being advice in order to promote mental and physical health. The UCL research is independent of Food for the Brain's website including the Cognitive Function Test, lifestyle questionnaire and cognitive health intervention. The aim of the research programme that will be carried out at UCL is to assess the impact of taking the CFT test and receiving lifestyle recommendations in terms of behaviour change and associated attitudes towards cognitive health. We will be asking you to complete a questionnaire in order to assess the effects that the test can have in terms of behaviour change and psychological outcomes including anxiety and dementia worry. In total, the survey should take about 20 minutes to complete. You will be directed back to the Cognitive Function Test link afterwards. This test consists of four parts and it will take approximately 15 minutes to complete.

In order to thank you for your time and participation in this study, you will have the chance to be entered into a prize draw for £100 in vouchers for a retailer of the winner's choice.

All data will be handled according to the Data Protection Act 1998 which means that the personal information that you give for this survey will only be used for the purposes of the survey and will not be transferred to an organisation outside of UCL. All data will be kept

confidential and anonymous. Only members of the research team will be able to access this information. In discussing the study's results we will not name any participants, or publish anything that could leave any participant identifiable.

This study has been approved by UCL Clinical, Educational and Health Psychology Department's Ethics Committee.

[Project ID No]: CEHP/2017/563

Informed Consent for Participants in Research Studies

(*This form will be completed by the participant after reading the Information Sheet.)*

This study is interested in the views of people aged 50 or over and under 65

Please tick (x) appropriate box:

☐ I am 50 or over

☐ I am under 65

This study is interested in healthy adults who do not have a diagnosis or history of neurological or psychiatric conditions likely to substantially affect cognition (for example, dementia, recent stroke, epilepsy, schizophrenia), sensory deficits or mobility limitations that would prevent or substantially restrict the delivery of the assessment or intervention (for example, uncorrected substantial loss of hearing or vision, severe physical disability).

Have you ever received or have any of the above conditions? *Please tick (x) appropriate box:*

☐ Yes

☐ No

I give consent for Food for the Brain to send you my data to be used for this research study. *Please tick (x) appropriate box:*

☐ Yes

☐

No

Please tick (x) the appropriate box:

☐ Yes, I would like to participate in this study.

☐ No, I do not want to participate in this study.

Debrief page for online survey

Thank you for taking part in this study. The aim of our study is to evaluate the effects of taking a Cognitive Function Test and receiving tailored recommendations for keeping a healthy cognitive function.

The Cognitive Function Test has been developed by the Food for the Brain foundation as part of their 'Plan B: Positive Action against Alzheimer's' Programme', working to inform and raise awareness of the important role that nutrition and lifestyle can have in reducing the risk of Alzheimer's disease and cognitive decline.

If you would like to know more about dementia or Alzheimer's disease prevention, information is available from the Food for the Brain website (http://www.foodforthebrain.org/alzheimers-prevention.aspx), or organisations such as the Alzheimer's Society (www.alzheimers.org.uk) and Dementia UK (www.dementiauk.org).

Appendix B - Full list of questions from the lifestyle behaviour questionnaire embedded in the CFT

Sugar:

1) How many sugar based snacks or drinks (Choc bars, cakes, sweets, fizzy drinks, fruit juices) do you eat each day?
2) How many times a day do you eat white rice, bread, flour or other refined foods?
3) How many times a week do you eat wholegrains e.g. Brown rice, oats, wholegrain bread, wholewheat pasta?
4) How many teaspoons (or equivalent) of sugar do you add to food or drinks each day?

Fish and seeds:

5) How many times a week to you eat fish (of any kind)?
6) How many times a week do you eat fresh oily fish (e.g. salmon, mackerel, sardines, herring)?
7) Do you take a fish oil supplement?
8) How many times a day do you eat fresh, raw nuts and or seeds (not roasted/salted!)?

Antioxidants:

9) How many servings of fruit do you have a day?
10) How many servings of berries, cherries, plums or apples do you have a day?
11) How many servings of fresh (raw or lightly cooked) vegetables/salad do you have a day?
12) How many servings of orange or red vegetables do you have a week eg.carrot/sweet potato/peppers?
13) How many servings of green vegetables do you have a week?
14) How many times a week do you eat fried, deep fried or browned foods including crisps and take away

15) Do you smoke cigarettes & if so how many?

Caffeine:

16) How many cups of tea, coffee and cola or caffeinated drinks do you consume each day in total?
17) How many coffees (excluding decaf) do you have a day (a double expresso counts as two)?
18) How many cups of green tea or herbal tea do you drink a day?
19) How many alcoholic drinks or units of alcohol do you have a week?
20) How much red wine do you drink a week?

B vitamins:

21) How many times a day do you eat vegetable protein (beans, lentils, tofu, quinoa, seed vegetables e.g. peas, corn)?
22) How many times a week do you eat dark green or cruciferous vegetables (eg broccoli, cabbage, cauliflower, Brussels sprouts)?
23) How many times a week do you eat a serving of meat, fish, eggs, cheese or dairy products?
24) Do you take supplements containing B6 most days?
25) Do you take supplements containing B12 most days?
26) Do you take supplements containing folic acid most days?

Activity:

27) How often do you go out? (eg to restaurants, sporting events, day or overnight trips)
28) How often do you participate in groups? (eg church, centres, classes etc)
29) How often do you visit or are visited by friends or relatives?
30) How often do you read, watch TV or youtube, listen to the radio, play games, do the crossword or suduko?
31) How often do you go to museums/art galleries, concerts, theatre or cinema?

32) How much time a week do you spend doing mildly energetic activity such as gardening, light housework or repairing things?

33) How much time a week do you do moderately energetic activity such as dancing, cycling, leisurely swimming, playing tennis, gym or exercise class?

34) How much time a week do you do vigourous exercise such as running, hard swimming/cycling, playing squash, heavy gym or exercise class, competitive sport?

Appendix E – Generalised Anxiety Disorder Questionnaire

GAD-7

Over the last 2 weeks, how often have you been bothered by the following problems?	Not at all	Several days	More than half the days	Nearly every day
1. Feeling nervous, anxious or on edge	0	1	2	3
2. Not being able to stop or control worrying	0	1	2	3
3. Worrying too much about different things	0	1	2	3
4. Trouble relaxing	0	1	2	3
5. Being so restless that it is hard to sit still	0	1	2	3
6. Becoming easily annoyed or irritable	0	1	2	3
7. Feeling afraid as if something awful might happen	0	1	2	3

Total Score ___ = Add Columns ___ + ___ + ___

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all	Somewhat difficult	Very difficult	Extremely difficult
☐	☐	☐	☐

Appendix F - Email confirming ethical approval

Dear Georgina and Elisa,

I am writing to let you know that we have approved your ethics application, "Attitudes towards cognitive health and behaviour change related to an online supported Cognitive Function Test and lifestyle recommendations." Thank you for taking such care to follow up my concerns about reputational risk in relation to the project.

The approval reference number is CEHP/2017/563. I have attached a copy of your application form.

I will keep the approved forms on file, and a copy has been lodged with the UCL Research Ethics Committee (cc'd herein). Please notify us of any amendments, in line with guidance on the PaLS Intranet.

Best Wishes,

John King

Chair of Ethics, CEHP

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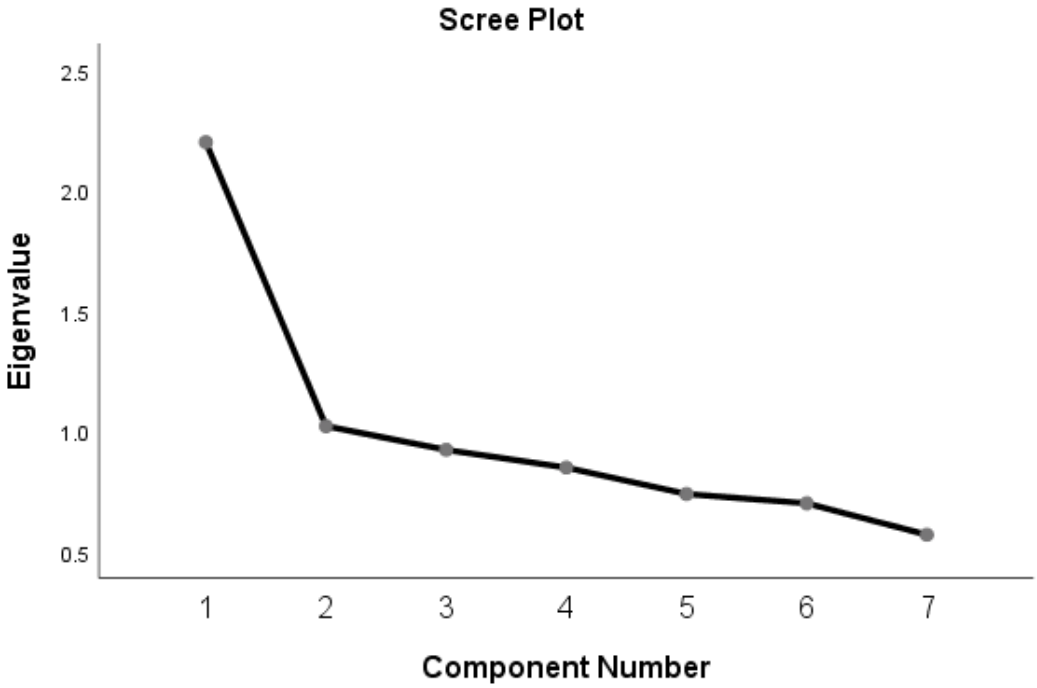
Appendix G – Scree plot diagram and factor loadings for SCC



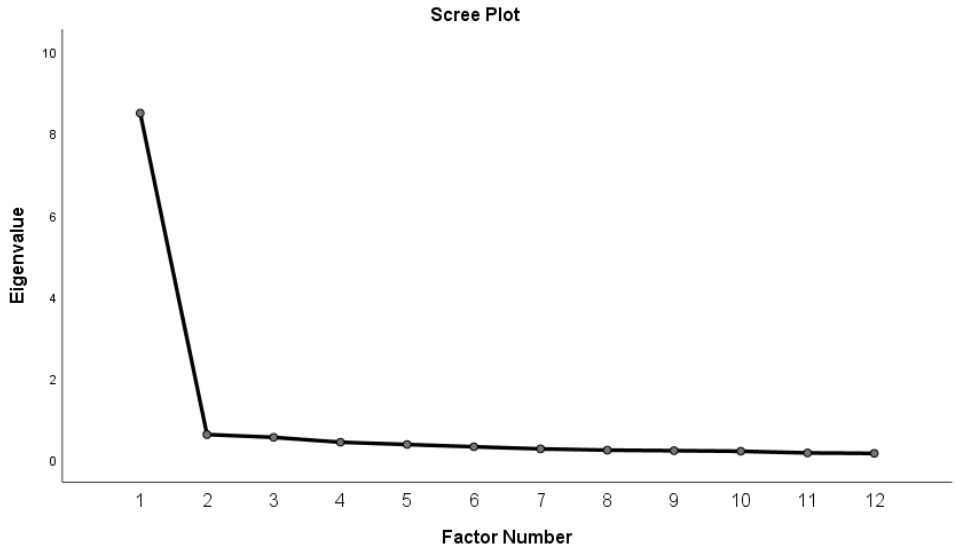
Factor loadings for SCC with two factors

Item	Factor 1	Factor 2
Memory concerns	.666	
Forget friend's names	.402	
Forget where put things	.499	
Forget words	.516	
Lose way		
Friend's report memory is worse than used to be	.544	
Family history of dementia		.359

Factor loadings for SCC with one factor

Item	Factor 1
Memory concerns	.674
Forget friend's names	.398
Forget where put things	.492
Forget words	.519
Friend's report memory is worse than used to be	.530

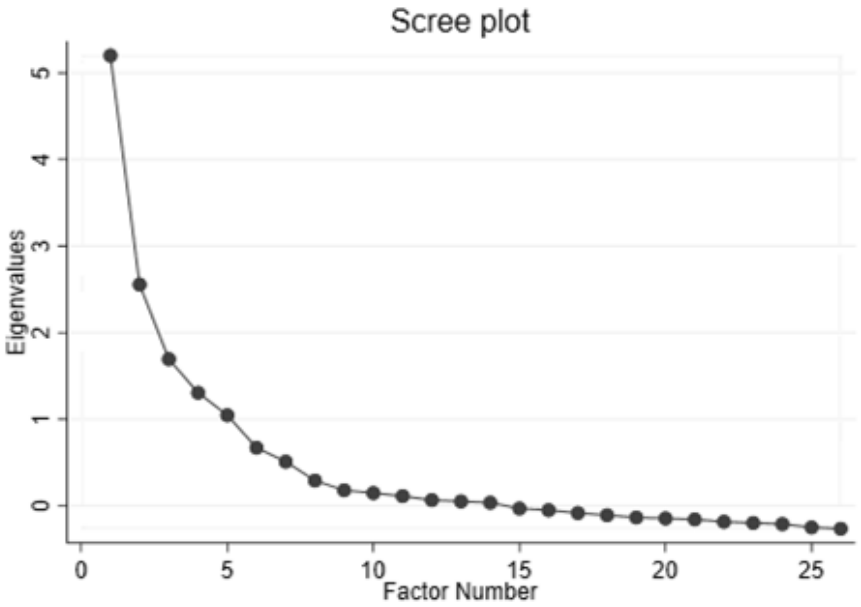
Appendix H- Scree plot diagram and factor loadings for Brief-FoD



Factor loadings for Brief-FoD

Item	Factor 1
The older I get, the more fearful I get I may develop dementia	.872
I am afraid of losing my memories	.818
Even though my memory is good, I am still afraid of developing dementia	.844
When I misplace things, I sometimes think I must have dementia	.762
When I hear of others with dementia, I become fearful I will get it as well	.856
I think I will probably get dementia and it frightens me	.867
Now that dementia is becoming more publicised with the diagnosis of popular TV, movie and political figures, I am more afraid I will develop dementia	.786
I am afraid of getting dementia	.896
Developing dementia frightens me because I would eventually lose all of my independence	.831
I fear not recognising family members	.758
When I think of the possibility of developing dementia, I become nervous or anxious	.797

Appendix I - Scree plot diagram and factor loadings for CHEB



Initial factor loadings for CHEB

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Sugar 1				.665	
Sugar 2				.652	
Sugar 3	.475				
Sugar 4				.387	
Fish 5					.858
Fish 6					.824
Fish 7			.573		
Fish 8	.434				
Antioxidant 9	.577				
Antioxidant 10	.583				
Antioxidant 11	.596				
Antioxidant 12	.790				
Antioxidant 13	.686				
Antioxidant 14				.544	
Antioxidant 15					
Drink 16					
Drink 18	-.348				
Drink 20					

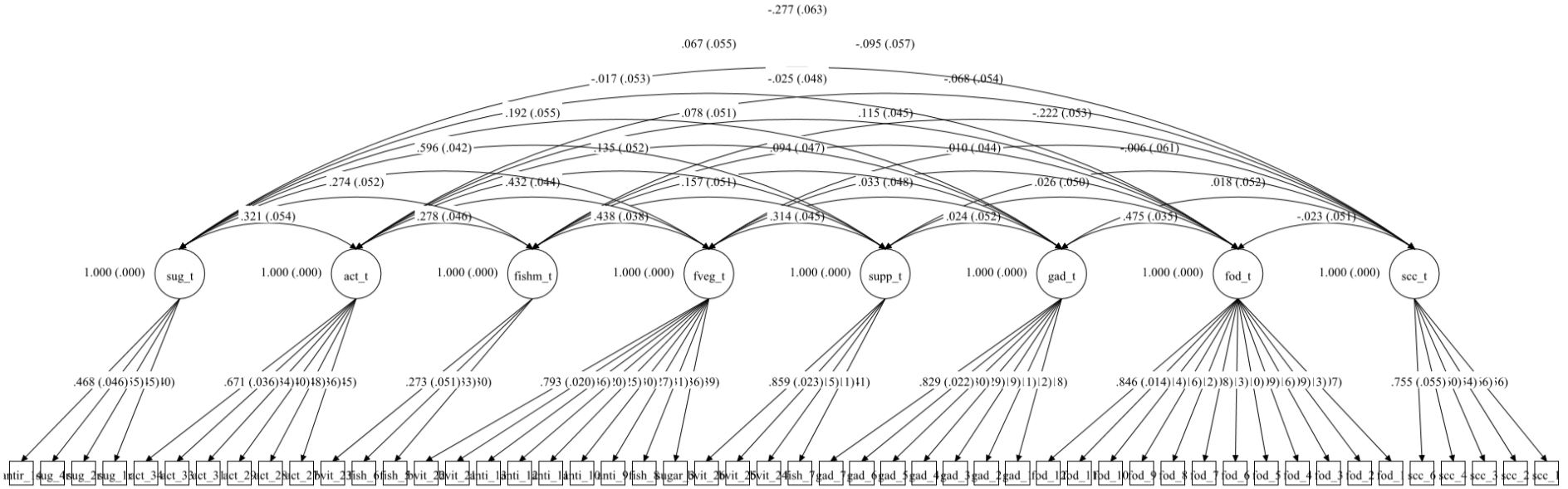
B vitamins 21	.586			
B vitamins 22	.629			
B vitamins 23				.433
B vitamins 24			.932	
B vitamins 25			.891	
B vitamins 26			.900	
Activity 27		.570		
Activity 28		.606		
Activity 29		.417		
Activity 30				
Activity 31		.632		
Activity 33		.724		
Activity 34		.672		

Final factor loadings for CHEB

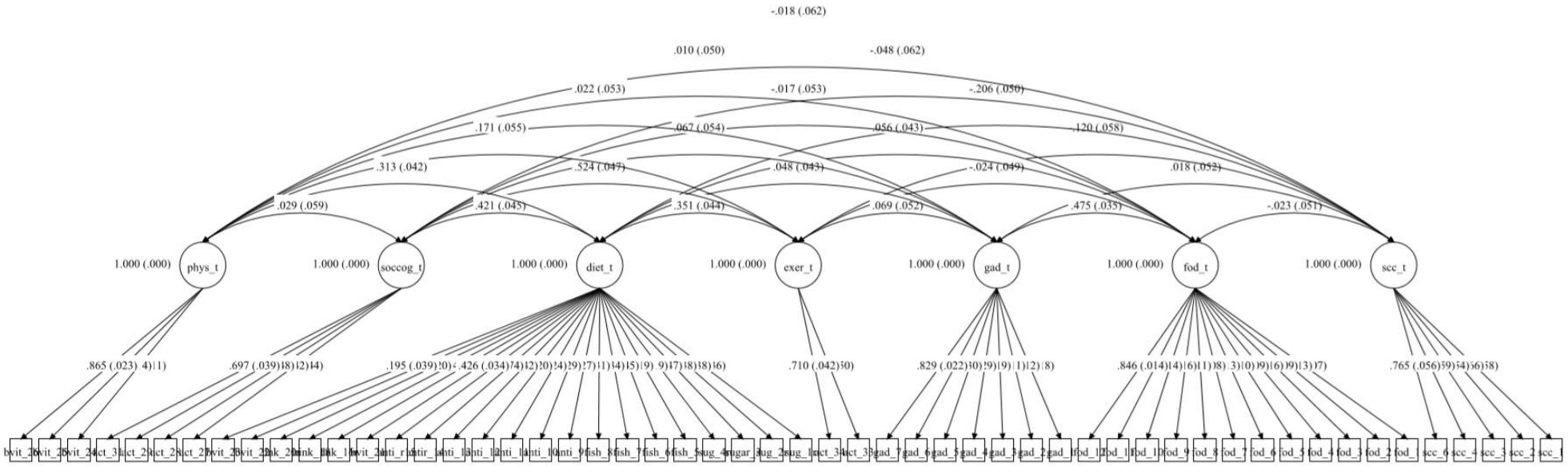
Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Sugar 1				.667	
Sugar 2				.669	
Sugar 3	.476				
Sugar 4				.351	
Fish 5					.860
Fish 6					.834
Fish 7			.563		
Fish 8	.413				
Antioxidant 9	.609				
Antioxidant 10	.619				
Antioxidant 11	.592				
Antioxidant 12	.801				
Antioxidant 13	.651				
Antioxidant 14				.560	
B vitamins 21	.553				
B vitamins 22	.592				
B vitamins 23					.374
B vitamins 24			.933		

B vitamins 25		.892
B vitamins 26		.889
Activity 27	.563	
Activity 28	.608	
Activity 29	.436	
Activity 31	.625	
Activity 33	.707	
Activity 34	.658	

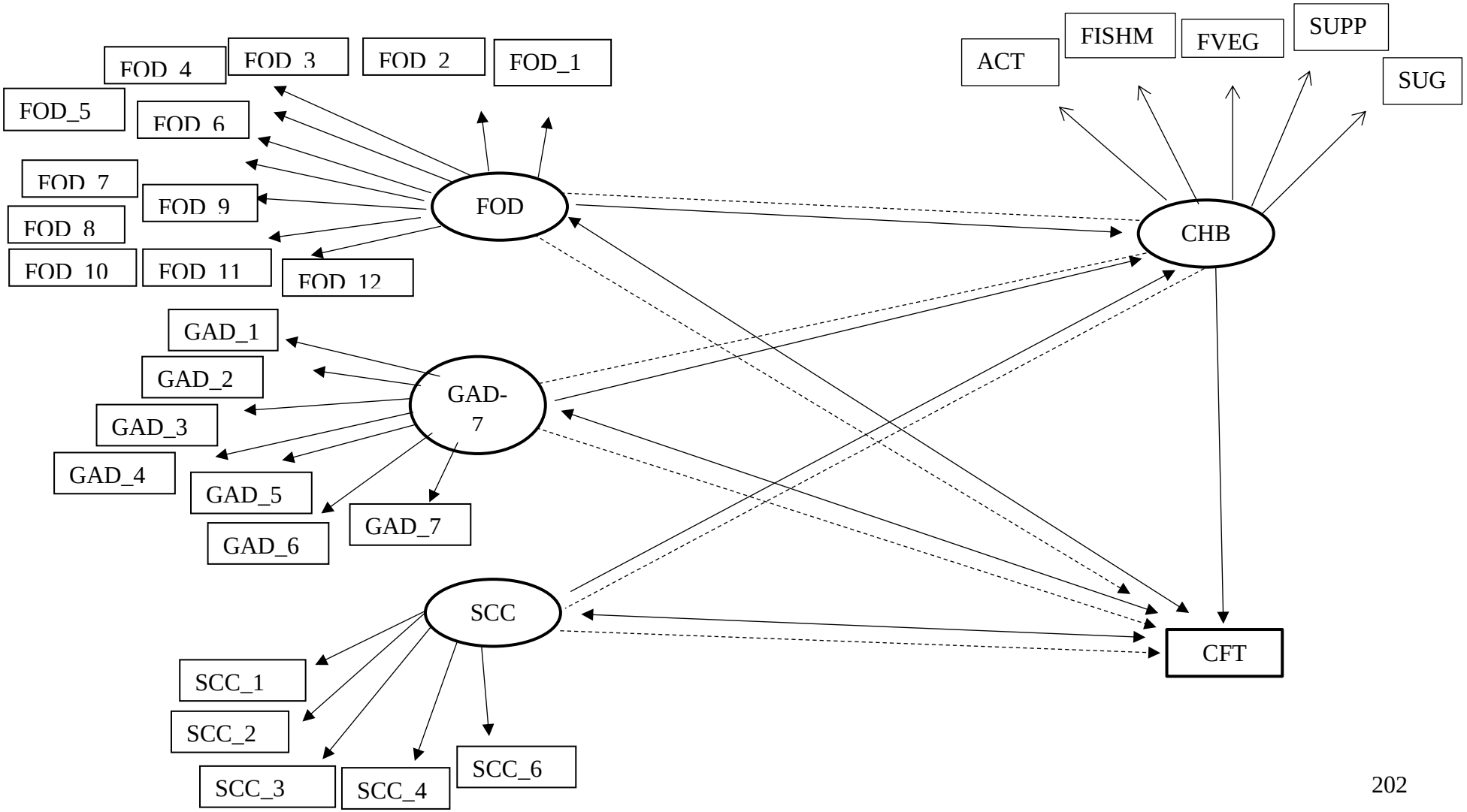
Appendix J - Data-driven measurement model



Appendix K - Theory-driven measurement model



Appendix L – Hypothesised SEM



Hypothesised model (solid black lines= direct effects, hashed lines= indirect effects). CHEB = Cognitive Health Enhancing Behaviours, FOD= Brief- Fear of Dementia, GAD-7 = Generalised Anxiety Disorder scale, SCC= Subjective Cognitive Concern, ACT= Activity total, FISHM= Fish/meat total, FVEG = Fruit/vegetables/wholegrains total, SUPP= supplements total, SUG= Sugar total.