Who uses it and who loses it?
Personality, activity engagement and cognitive health in old age

Calum Marr

Submitted for the degree of Doctor of Philosophy

Department of Psychology

School of Social Sciences

Heriot-Watt University

March 2022

Abstract

Identifying strategies to promote cognitive health in older age is a key research priority as older adults continue to make up a growing proportion of the global population. The ‘use it or lose it’ theory proposes that leading a more active, engaged lifestyle can be cognitively protective. Cross-sectional studies provide support for this, with evidence suggesting that older adults who are mentally, physically, socially and creatively active in their everyday lives may also have higher levels of cognitive ability and experience lower levels of cognitive decline. Intervention studies can provide further insight, going beyond cross-sectional associations to explore causality by testing the effect of increased engagement in an experimental paradigm. It is essential that such interventions consider the importance of individual differences; in particular, evidence suggests that individual differences in personality might predict activity engagement, and in turn cognitive health. It is therefore possible that individual differences in personality might influence engagement level within an intervention, and in turn the degree of benefit received. The PhD research reported in the present thesis examined these possibilities using data collected from a large-scale, activity-based intervention study known as The Intervention Factory. This study tested the cognitive benefits of activity engagement in a more real-world environment by using existing, community-based classes and groups. A sample of 336 adults aged 65 and over without any diagnosed cognitive impairments were recruited and completed baseline assessments. Cross-sectional data at baseline were used to examine whether lifestyle variables such as activity engagement mediated any associations between Big Five personality traits and cognitive ability across several domains. Higher Openness to Experience and lower Neuroticism and Extraversion predicted higher levels of cognitive performance, but there was no evidence to suggest these associations were mediated by activity engagement. The PhD research then examined whether personality might influence activity engagement and cognitive change within the context of an intervention. A systematic review of the literature found ten studies that had previously explored this question; there was some evidence that higher Openness to Experience was linked to greater cognitive gains when studies used novel intervention methods. This theory was then tested within the context of The Intervention Factory specifically. Participants were pseudo-randomly allocated to one of five activity groups (computer classes, dance/exercise/sport classes, social/bingo groups, language classes or handicraft/woodcraft classes) or a no-contact control group and attended their activity for around ten weeks. None of the activity groups showed evidence of significantly greater cognitive improvements compared to the control group over the course of the intervention. There was also no reliable evidence that individual personality traits predicted adherence or moderated intervention-related cognitive change. While these results did not support the efficacy of real-world activities to promote cognitive health, several challenges were identified that will inform and encourage future research in this area. These challenges included issues arising from non-random group allocation, difficulty recruiting an effective control group and variability in intervention delivery when translated to a more real-world setting. Addressing these challenges in future studies will provide further opportunities to explore the potential cognitive benefits of real world activities, and whether any benefits vary at the individual level.

Acknowledgements

To my supervisors, Professor Alan Gow and Dr Michaela Dewar, thank you for keeping me right over the last four years. As a researcher I couldn't have asked for better role models, and your unerring support, encouragement and advice throughout my PhD has been invaluable. In particular, I owe you both a massive debt of gratitude for guiding me through writing this thesis in the middle of a global pandemic (!) - I look forward to thanking you both in person soon.

This thesis would not have been possible without the hard work and support of the other members of The Intervention Factory study team – Malwina Niechcial, Dr Eleftheria Vaportzis and Anna Sim. In particular, I would like to thank Malwina Niechcial, with whom I shared the responsibility of data collection – thank you for all your support and positivity during a very busy few years! Thanks also to other members of the Ageing Lab – Andrew Pearce, for helping out with some very tedious data checking, and Ryan Gray, for bequeathing me his coffee making apparatus.

Mum and Dad – thank you for supporting me through this PhD, even when it seemed like it was never going to end!

The Intervention Factory was coordinated with the support of an international Advisory Panel including Kaarin Anstey (University of New South Wales), Ian Deary (University of Edinburgh), Mike Martin (University of Zurich), Kaisu Pitkälä (University of Helsinki), and Christina Röcke (University of Zurich), and a local Intervention Factory Forum comprising representatives from Age Scotland, NHS Lothian, the City of Edinburgh Council, the Scottish Older People's Assembly, Education Scotland, and Age UK.

Both my PhD studentship and The Intervention Factory study were funded by Velux Stiftung (Project No. 1034 to A.J.G. and Project No. 1034a to A.J.G. and M.D.).

Finally, I would like to thank all the study participants who gave up their time to contribute to this research. Their enthusiasm and good humour during long cognitive testing sessions made my job much easier, and it was a pleasure to meet so many delightful people. The quotes below are from participants reflecting on their experience taking part in the study; I hope these thoughts highlight the value of trying new things.

> "… I don't have an O-level and going in there, a class, having the confidence to go in, knowing you're putting yourself in a position where you may well look absolutely a fool of the class or ridiculous, that's a challenge. But if you do it, you feel better for it! You just got to go and learn."

> "… that for me was a good thing, that's it's just like, just go out and try it. And even if you're no good at it, you know, well, you know, what have you lost by trying new things?"

> "Maybe we're like children again, I think… if given a chance. I remember, I always remember this article… and it was to do with the fact that, you know, when a child arrives at about 12 or 13 or that age, they become, well, more inhibited because if their drawing is not good enough they just say 'I can't draw' instead of trying to improve. And so in a way, you know, we're sort of, back to the point of, 'I can't remember' or 'I can't do something', and then was put into position of being challenged a bit. So I suppose it's maybe made us a little bit

more resilient about going on a course where we don't know too much, so we're back to being the child…”

Research Thesis Submission

Please note this form should be bound into the submitted thesis.

Name:	**Calum Marr**		
School:	**School of Social Sciences**		
Version: *(i.e. First, Resubmission, Final)*	**FINAL**	Degree Sought:	**PHD**

Declaration

In accordance with the appropriate regulations I hereby submit my thesis and I declare that:

1. The thesis embodies the results of my own work and has been composed by myself
2. Where appropriate, I have made acknowledgement of the work of others
3. The thesis is the correct version for submission and is the same version as any electronic versions submitted*.
4. My thesis for the award referred to, deposited in the Heriot-Watt University Library, should be made available for loan or photocopying and be available via the Institutional Repository, subject to such conditions as the Librarian may require
5. I understand that as a student of the University I am required to abide by the Regulations of the University and to conform to its discipline.
6. I confirm that the thesis has been verified against plagiarism via an approved plagiarism detection application e.g. Turnitin.

ONLY for submissions including published works

Please note you are only required to complete the Inclusion of Published Works Form (page 2) if your thesis contains published works)

7. Where the thesis contains published outputs under Regulation 6 (9.1.2) or Regulation 43 (9) these are accompanied by a critical review which accurately describes my contribution to the research and, for multi-author outputs, a signed declaration indicating the contribution of each author (complete)
8. Inclusion of published outputs under Regulation 6 (9.1.2) or Regulation 43 (9) shall not constitute plagiarism.

* *Please note that it is the responsibility of the candidate to ensure that the correct version of the thesis is submitted.*

Signature of Candidate:		Date:	**07/03/2022**

Submission

Submitted By *(name in capitals)*:	CALUM MARR
Signature of Individual Submitting:	
Date Submitted:	**07/03/2022**

For Completion in the Student Service Centre (SSC)

Limited Access	Requested	Yes		No		Approved	Yes		No	
E-thesis Submitted (mandatory for final theses)										
Received in the SSC by *(name in capitals)*:						Date:				

Inclusion of Published Works

Please note you are only required to complete the Inclusion of Published Works Form if your thesis contains published works under Regulation 6 (9.1.2)

Declaration

This thesis contains one or more multi-author published works. In accordance with Regulation 6 (9.1.2) I hereby declare that the contributions of each author to these publications is as follows:

Citation details	Marr, C., Vaportzis, E., Dewar, M., & Gow, A. J. (2020). Investigating associations between personality and the efficacy of interventions for cognitive ageing: A systematic review. Archives of Gerontology and Geriatrics, 87, 103992. https://doi.org/https://doi.org/10.1016/j.archger.2019.103992
Author 1	Study conceptualization; Study planning; Conducting systematic literature review; Writing original manuscript; Review and editing of manuscript
Author 2	Second reviewer for systematic literature review; Review and editing of manuscript
Author 3	Funding acquisition; Supervision; Study planning; Review and editing of manuscript
Author 4	Study conceptualization; Funding acquisition; Supervision; Study planning; Review and editing of manuscript
Signature:	
Date:	07/03/2022

Citation details	Marr, C., Vaportzis, E., Niechcial, M. A., Dewar, M., & Gow, A. J. (2021). Measuring activity engagement in old age: An exploratory factor analysis. PLOS ONE, 16(12), e0260996. https://doi.org/10.1371/journal.pone.0260996
Author 1	Data collection; Data analysis; Study administration; Writing original manuscript; Review and editing of manuscript
Author 2	Study planning; Data collection; Study administration; Review and editing of manuscript
Author 3	Study planning; Data collection; Study administration; Review and editing of manuscript
Author 4	Funding acquisition; Supervision; Review and editing of manuscript
Author 5	Study conceptualization; Funding acquisition; Supervision; Study planning; Study administration; Review and editing of manuscript
Signature:	
Date:	07/03/2022

Please included additional citations as required.

Table of Contents

Preface

The broad objective of the PhD research presented in this thesis was to explore the interplay between personality, activity engagement and cognitive ability in older adults. This was achieved through analysis of data collected from the Intervention Factory, a large-scale intervention study targeted at age-related cognitive decline. The research presented here was conducted under the auspices of this larger study. It is therefore necessary, at the outset, to give a brief overview of how the study came about and how this research fits in to the study as a whole.

The Intervention Factory was conceived to test the potential of real-world, community-based activity programmes to protect against cognitive decline in old age. The project began in July 2016. The project team was led by my primary supervisor, Professor Alan Gow, and consisted of a Research Associate (Dr Eleftheria Vaportzis) and Research Assistant (Miss Malwina Niechcial). Later in the project, Dr Vaportzis took up a post elsewhere, and a Study Administrator (Mrs Anna Sim) joined the team. An Advisory Panel was also convened, which included international experts in the field of cognitive ageing, as well as stakeholders from local government, the NHS and the third sector. Over the course of the initial months, the activities to be used as interventions were selected, and the testing protocol was established. A nationwide survey to examine older adults' attitudes and beliefs about age-related cognitive decline, entitled "What Keeps You Sharp?", was also conducted (survey findings are not relevant to the present thesis but are summarised in Niechcial et al., 2019; Vaportzis & Gow, 2018). The main study planned to recruit a sample of older adults aged 65-74 and sign them up to a new activity in their local community for around 12 weeks. Recruitment and testing commenced in the Summer of 2017.

Around this time, funding was secured for a PhD studentship that would extend the findings of the original study by recruiting an additional sample of adults aged 75 and over and examining whether intervention efficacy was moderated by individual differences in personality. I applied for and successfully secured the studentship; I joined the team as a PhD student in September 2017.

The first two and a half years of my PhD were largely devoted to recruitment and testing of study participants. It is important to acknowledge here that the responsibility for recruiting and testing all participants was shared among the members of the research team. More specifically, responsibility for baseline assessment (i.e., pre-intervention) was shared between myself, Dr Vaportzis and Miss Niechcial, while responsibility for follow-up assessments (i.e., post-intervention) was shared between myself and Miss Niechcial. Between June 2017 and February 2020, over 300 participants were assessed, allocated a new activity to complete and subsequently re-assessed. While the recruitment of adults aged 75 and over was technically under the remit of my PhD studentship, in reality there was no difference in treatment in terms of recruitment, assessment or allocation between these participants and the younger age group that comprised the original sample for the main study. An additional subgroup of participants was also allocated to a second activity and subsequently re-assessed again; their data will not be utilised in the present thesis. Overall, a total of 715 testing sessions were carried out across baseline and follow-up(s), of which I conducted around 350.
All original analyses reported in this thesis use data collected as part of the Intervention Factory study. While, as noted above, I was not directly involved at the design and early implementation stages, I solely planned and conducted all the analyses presented herein. Nevertheless, it is important to explicitly acknowledge that the day-to-day running of the study that made these analyses possible was a collaborative effort.

List of Publications

Marr, C., Vaportzis, E., Dewar, M., & Gow, A. J. (2020). Investigating associations between personality and the efficacy of interventions for cognitive ageing: A systematic review. *Archives of Gerontology and Geriatrics*, *87*, 103992. https://doi.org/https://doi.org/10.1016/j.archger.2019.103992

Marr, C., Vaportzis, E., Niechcial, M. A., Dewar, M., & Gow, A. J. (2021). Measuring activity engagement in old age: An exploratory factor analysis. *PLOS ONE, 16*(12), e0260996. https://doi.org/10.1371/journal.pone.0260996

1. Cognitive Ageing: An Overview

1.1. An Ageing Society

In 1920, the human population was an estimated 1.86 billion (United Nations, 1999). Now, a century later, there are around 7.7 billion people living on planet Earth, a number that is projected to pass over 10 billion by the turn of the next century (United Nations, 2019). While overall population growth is beginning to slow, appearing to have peaked in the late 1960s (United Nations, 2019), the underlying demographic structure of the population has been undergoing a notable transition.

Currently, around nine percent of the global population is aged 65 or over (United Nations, 2019). By 2050 the proportion of over-65s is projected to increase to around 16%, and by the year 2100 almost a quarter of the population is expected to be in this age group (United Nations, 2019). This change is largely driven by a combination of increasing life expectancy and reduced fertility. In other words, people are living longer and fewer babies are being born; 2018 marked the first time in history that adults aged 65 and over outnumbered children under five (United Nations, 2019).

At the national level, ageing trends are largely following global patterns. In England and Wales, 2018 marked the lowest ever recorded birth rate, which has been declining since 2012 (Office for National Statistics, 2019). Concurrent increases in life expectancy have led to 18.3% of the UK population being 65 or over, a number projected to rise to 24.2% by 2038 (Office for National Statistics, 2019). This places the UK around the middle of the ranking of EU countries for proportion of older adults (Office for National Statistics, 2018).

In Scotland, the proportion of over-65s was estimated to be 19% of the population in 2018 (National Records of Scotland, 2019b). More people are living beyond the age of 90 than ever before, with the number of people aged 90-99 estimated to have increased by 45% over the last 10 years, while the number of centenarians has increased by 17% (National Records of Scotland, 2019a). Geographically, the population is older in rural areas; Scotland's three largest cities (Glasgow, Edinburgh and Aberdeen) contain the lowest proportion of over-65s in the country (National Records of Scotland, 2019b).

These population changes have notable implications for society. A recent UK government report acknowledged the intrinsic collective changes that will result from such a significant restructuring of the population: "Growing up and living in a society where younger people are in a majority is fundamentally different to growing up in a society where the majority of people are in older age groups" (Government Office for Science, 2016, p. 4). Adapting to these changes requires an understanding of the central needs of an 'ageing society'.

1.1.1. What does Ageing Mean for Society?

The basic fact that humans are living longer creates new opportunities. Older adults contribute to society in innumerable ways: socially, economically, civically, intellectually, creatively and spiritually. According to the World Health Organisation:

> Longer lives are an incredibly valuable resource, both for each of us as individuals and for society more broadly. Older people participate in, and contribute to, society in many ways, including as mentors, caregivers, artists, consumers, innovators, entrepreneurs and members of the workforce. (World Health Organization, 2017, p. 3)

However, there are also undeniable challenges that can prevent older people from fully realising such potential. Age-related changes in physical health perhaps represent the most prominent issue that older adults face. The incidence of conditions including stroke, hypertension, heart disease and diabetes increases with age (Boehme et al., 2017; Hajjar & Kotchen, 2003; Mozaffarian et al., 2016; Wild et al., 2004). Advanced age is the largest risk factor for neurodegenerative conditions including Alzheimer's

Disease and Parkinson’s Disease (Keller, 2006; Reeve et al., 2014). Walking speed, balance and muscular strength all decline with age, leading to decreased mobility and greater risk of falls (Balogun et al., 1994; Bohannon, 1997; Larsson et al., 1979; Moreland et al., 2004; Muir et al., 2010).

In 2016, it was estimated that 29% of 60-64 year olds in England were living with 2 or more chronic conditions, a figure rising to almost 50% for people over the age of 75 (Office for National Statistics, 2018). As such, older adults rely more on healthcare services; between 2006 and 2016 hospital admissions in England showed a greater increase in those aged 66 and over relative to other age groups (Friebel, 2018). Associated healthcare costs per person also increase with age, particularly from the age of 65 onwards (Office for National Statistics, 2018).

Older adults also experience changes in their social spheres. Social network size tends to shrink with age, with family ties becoming more important than relationships with friends (Lang & Carstensen, 1994; Shaw et al., 2007). Rates of everyday social contact decline and feelings of loneliness tend to increase (Cornwell, 2011; Vozikaki et al., 2018). In England, one in twelve over-50s surveyed reported that they often felt lonely, and this figure is projected to increase over the next 10-15 years (Age UK, 2018). Loneliness and social isolation are in turn linked to increased prevalence of various health issues, including depression, cardiovascular disease and functional impairment (Courtin & Knapp, 2017; Shankar et al., 2017).

It is also important to recognise the economic factors at play in an ageing society. As the proportion of older adults in the UK increases, so too does the old age dependency ratio (i.e., the number of adults of pensionable age per 1000 people of working age; Office for National Statistics, 2018). This means that in the coming years countries including the UK are likely to be met with increasing state-pension costs alongside a simultaneously decreasing workforce. Addressing this discrepancy will have impacts not only at the level of public finance, but also on the individual financial security of older adults.

1.1.2. A Caveat

In recent times, reaction to population ageing has attracted a level of alarmism in popular discourse. Media coverage is abound with terms such as ‘problem’ and ‘crisis’, and metaphorical ‘ticking time bombs’ present the growing number of older adults as inherently destructive (Lundgren & Ljuslinder, 2012). Older adults are commonly framed as burdensome on society, through increased demand for welfare, social care and healthcare (McDaniel, 1987; Rozanova, 2006). This ‘apocalyptic demography’ (Robertson, 1990) can have harmful effects, at once othering and homogenising older adults while ignoring the role of the socioeconomic circumstances that also contribute to the situation (Gee, 2002; McDaniel, 1987).

This is not to say it is false to claim that ageing is having a significant impact in a number of areas. But the tendency to frame such societal problems as inherent and inexorable results of changing demographics implicitly lays the blame on older people. This may well contribute to the stereotypically negative view of ageing as something to be dreaded. Perhaps in response to this, governmental organisations, in planning for how to address these demographic changes, have emphasised that increased life expectancy should be celebrated as an achievement (United Nations, 2002), and that ageing is ultimately a “valuable, if often challenging, process” (World Health Organization, 2017, p. 5).

People who live past the age of 90 are spending about a third of their lives post-retirement. While there are undeniable changes to health and circumstances that come with this, the possibilities for how such an individual could spend this period of their life are vast. A recent report by the World Health Organisation sought to reframe the idea of healthy ageing, focusing not just on the absence of disease, but on the dynamic interplay between an individual’s intrinsic capacity (i.e., physical health, cognitive functioning and psychological wellbeing) and their environment (Beard et al., 2016). Under this new framework, declines in intrinsic capacity can be managed by providing the right care and support, thus allowing older individuals to “be and do what they have reason to value” (Beard et al., 2016, p. 2149). In line with this framework, the research presented within this thesis is driven not merely by the idea of mitigating the costs of ageing, but by maximising its potential.

1.2. Cognitive Ageing

As highlighted above, older people are more likely to experience changes to their physical health and wellbeing, and these are often interconnected. An ageing society is one that will have to adapt to these changes, both socially and economically. There is, however, a change associated with ageing that is yet to be discussed – one that is inherently connected to the issues raised above. As we age, we might also experience changes in our thinking skills, such as memory or reasoning ability. These changes are commonly referred to as cognitive ageing.

Changes to cognitive ability with age have been known and commented on throughout history. As far back as the Greco-Roman period, writings by figures such as Aristotle, Hippocrates and Pythagoras indicate that mental decline in old age was viewed as an inevitable consequence of getting older (Berchtold & Cotman, 1998; Román, 1999). Indeed, years before it came to refer to a loss of mental faculties, the word senile was simply a synonym for ‘old’.

A growing body of scientific research is concerned with characterising and understanding changes in cognition that occur later in the lifespan. As noted by Salthouse (2004b), questions regarding age-related cognitive change can be broadly categorised into questions of what, when, why, where and how. Before considering why and how cognitive change happens, it can be useful to summarise current knowledge regarding *what* cognitive functions change, *when* in the lifespan this change happens and *where* in the brain these changes occur.

1.2.1. Global Cognitive Ageing

To begin with the question of *what*: we know that for the average individual, global cognitive ability develops through childhood, remains relatively stable throughout young-adulthood through to middle-age, then begins to decline in old age (Craik & Bialystok, 2006). In this thesis, 'global cognitive ability' refers to the variance shared among a broad range of individual cognitive abilities, or 'domains' (e.g., memory or visuospatial ability). Sometimes referred to as the *g* factor, this comprehensive measure was originally proposed by Spearman in the early 20th century, upon observation of the positive correlations between school children's performance across different subject areas (Spearman, 1904). Modern consensus in the study of intelligence through psychometric testing generally accepts global cognitive ability as the highest stratum of a hierarchical structure, that accounts for shared variance among measures of performance in several lower order cognitive domains (Carroll, 1993; McGrew, 2009; Salthouse, 2004a).

What global cognitive ability represents beyond a statistical association is beyond the scope of this thesis. What is important is that it has been used by researchers as a marker of global cognitive change; that is, the average change in performance across a range of different cognitive domains in old age. Typically, studies show that as adults age, their performance on measures of global cognitive ability decreases (Izaks et al., 1995; Jacqmin-Gadda et al., 1997; Karlamangla et al., 2009; Lyketsos et al., 1999; Salthouse, 2004a, 2009a; Salthouse & Ferrer-Caja, 2003; Schaie, 2013; Whitley et al., 2016).

However, limiting outcomes to a single overall measure of cognitive ability can mask variations in the pattern of decline that are specific to different cognitive domains.

A growing body of evidence suggests that some individual cognitive abilities are remarkably robust to the effects of age, and that among those that do decline, the onset and rate of change varies considerably.

1.2.2. Domain-Specific Changes

Raymond Cattell was the first proponent of the dichotomous theory of intelligence that divides cognitive ability into ‘fluid’ and ‘crystallised’ ability. According to Cattell (1943), fluid ability “has the character of a purely general ability to discriminate and perceive relations between any fundamentals, new or old” (p. 178), while crystallized ability represents “discriminatory habits long established in a particular field, originally through the operation of fluid ability, but not [*sic*] longer requiring insightful perception for their successful operation” (p. 178). Fluid ability therefore represents the dynamic, inductive processes required to solve novel and complex problems, whereas crystallised ability can be likened to accumulated knowledge or expertise (Nisbett et al., 2012). When it comes to the effects of age, the two appear dissociable, in that performance on measures of fluid ability (e.g., inductive reasoning or figural relations) tends to be higher in younger adults than older adults, whereas performance on measures of crystallised ability (e.g., word knowledge) shows the opposite trend (Horn & Cattell, 1967).

More modern conceptualisations of cognitive ability go beyond this simple two factor structure, and age effects have been found in a variety of specific cognitive domains. For consistency, in this thesis, domain-level findings will typically be summarised under the broad cognitive domains of verbal ability (vocabulary and verbal semantic knowledge), episodic memory (encoding and retrieval of information over long periods of time), executive function (response initiation/inhibition, attentional control and task-switching), reasoning ability (application of logical rules to solve novel and complex problems), working memory (temporary storage and manipulation of information), visuospatial ability (processing and manipulation of complex visual stimuli) and processing speed.

Cross-Sectional Evidence. Cross-sectional studies, in which independent age cohorts are sampled and compared directly, have the benefit of being quicker, less costly and less labour-intensive to run. As such, there is a large evidence base indicating that across many cognitive tests, older adults tend to perform at lower levels than their younger counterparts. Older adults have been found to perform worse on measures of episodic memory (Old & Naveh-Benjamin, 2008), executive function (Verhaeghen et al., 2003), reasoning ability (Verhaeghen & Salthouse, 1997), working memory (Bopp & Verhaeghen, 2005), visuospatial ability (Techentin et al., 2014), and processing speed (Der & Deary, 2006; Hoyer et al., 2004). In their meta-analysis, Verhaeghen and Salthouse (1997) reported negative associations between age and performance across adulthood in five cognitive domains. Age correlations for each domain were as follows (*r*; in order of magnitude): processing speed = -.52; reasoning ability = -.40; visuospatial ability = -.38; episodic memory = -.33; working memory = -.27.

However, it also remains true that performance on certain tasks analogous to crystallised ability remain remarkably robust to the effects of age. In particular, verbal ability actually appears to improve well into late-adulthood; for example, older adults typically outperform younger adults on tests of vocabulary (Verhaeghen, 2003). Across the literature, a pattern emerges in which certain domains such as verbal ability remain fairly age-invariant, whereas others show significant age-related decline, the strongest being in processing speed. Such a pattern is reflected in other cross sectional-studies (e.g., Salthouse, 2004a; Schaie, 2013; Singh-Manoux et al., 2012).

Turning to Salthouse's question of *when* cognitive change happens, this same pattern is also evident. Hartshorne and Germine (2015) used cross-sectional data to estimate at which point in the adult lifespan different abilities reach peak performance.

They found that processing speed tended to peak earliest (around mid-20s), whereas vocabulary peaked in mid-to-late-adulthood (around age 50).

Cross-sectional evidence is, however, liable to certain biases, such as cohort effects, in which effects of cultural or societal differences between generations are misidentified as being due to chronological age (Salthouse, 2009b). Problems like this can be avoided by following individuals over a longer period of time.

Longitudinal Evidence. Longitudinal studies have the benefit of being able to separate the effects of age on cognitive ability from other confounding factors by retesting the same individuals and tracking within-person changes over years or decades. However, the financial and logistical challenges of such an approach mean that such studies are far less common than their cross-sectional counterparts. It should also be noted that longitudinal studies are not immune from their own biases, such as practice effects or attrition bias (Mein et al., 2012; Salthouse, 2009b).

Regarding *what* happens, longitudinal evidence presents a slightly different picture. For example, over 7,000 civil servants in London aged 45-70 underwent cognitive testing as part of the Whitehall II study (Singh-Manoux et al., 2012). They were followed up twice more over a period of around 10 years. Cross-sectional age associations at baseline showed consistent negative relationships with reasoning, memory and verbal fluency, but not vocabulary. However, cross-sectional estimates seemed to overestimate the magnitude of change relative to longitudinal findings, particularly for women. For example, cross-sectional estimates of percentage change in reasoning performance in women showed an 11.4% decline, while longitudinal estimates showed a more modest 3.6% decline. When adjusting for education, the cross-sectional declines were much smaller, suggesting generational and gender differences in level of education may inflate estimates of change cross-sectionally.

Longitudinal studies also provide more insight into exactly *when* (i.e., how early in the lifespan) cognitive change begins. Perhaps the most well-known longitudinal study in the field of cognitive ageing began as a doctoral dissertation project in 1956 (Schaie, 2013). Since then, the Seattle Longitudinal Study followed surviving participants at seven-year intervals (in addition to recruiting new cohorts) until 2005, allowing for the mapping of cognitive abilities from age 25 to 95. In this study, observed longitudinal decline was less precipitous than cross-sectional estimates from the same sample (see Figure 1.1). Cross-sectional estimates indicated significant age-related declines in memory ability at age 39 and reasoning, visuospatial ability and processing speed at 46. Longitudinally, many domains, such as memory, reasoning and visuospatial ability did not show significant decline until the late 60s, while verbal ability appeared to remain stable until the 80s. As in Singh-Manoux et al. (2012), longitudinal estimates of the magnitude of these changes tended to be smaller than cross-sectional estimates. However, the longitudinal estimates of change in processing speed were greater than in other domains, and largely commensurate with cross-sectional estimates.

Evidence therefore appears to suggest that cross-sectional studies over-estimate the change in cognitive ability that comes with age, both in terms of magnitude and age of onset. However, it should be noted that across different domains, the relative pattern of change remains relatively consistent, whether the study is cross-sectional or longitudinal. This pattern is illustrated neatly by results from the Berlin Aging Study. Beginning in the early 1990s, this study has followed adults aged 70 and older for around 20 years. Data from three occasions over a six-year follow-up period were used to track performance in several cognitive domains; results showed the now familiar pattern of age effects, with declining performance across all domains with the exception of verbal ability (Singer et al., 2003).

1.2.3. Where These Changes Happen in the Brain

Turning now, briefly, to the question of *where* cognitive change occurs. Is it possible to connect observed declines in cognitive function to concurrent changes in the structure of the brain? The brain undergoes numerous changes in later life. Convergent evidence from both post-mortem and in-vivo studies reveals declines in gross brain volume, regional declines in both grey matter (neuronal bodies) and white matter (myelinated axons), increased white matter hyperintensities (WMH; i.e., white matter lesions that are visible on MRI brain scans) and diminution in vascular density leading to reduced cerebral blood flow (Raz & Rodrigue, 2006). There is also evidence that these changes may account for the effects of age on cognitive ability. For example, loss of hippocampal volume has been associated with episodic memory decline, loss of whole brain white matter integrity has been shown to predict decline in processing speed and higher levels of WMH in the frontal region have been linked to decline in executive function (Gorbach et al., 2017; Gunning-Dixon & Raz, 2003; Kramer et al., 2007; Kuznetsova et al., 2016; Rabin et al., 2019). A comprehensive account of the neural underpinnings of age-related cognitive change is beyond the scope of the present thesis. However, it is important to note that the associations between lifestyle factors and cognitive ability discussed below can often be attributed to changes in these neurobiological markers.

1.3. What is the Impact of Cognitive Ageing?

1.3.1. Psychological Health

As scientific understanding of cognitive health in old age has increased over recent years, so too has public awareness. One UK survey reported that 52% of adults interviewed reported knowing someone with some form of dementia (Alzheimer's Research UK, 2019). As such, it is perhaps understandable that dementia represents a significant concern for people when it comes to attitudes towards ageing. Dementia, and in particular Alzheimer's Disease, is a notable source of anxiety for older adults (Corner & Bond, 2004; Kessler et al., 2012). Forty-two percent of UK adults in a recent survey agreed that dementia is the health condition they fear getting most in the future (Alzheimer's Research UK, 2019).

Even in the absence of pathological disease, loss of mental capacity is a source of concern (Anderson et al., 2009). One US study conducted focus groups with over-50s regarding their beliefs and attitudes about cognitive health in old age. Their findings give insight into the worries of older adults when it comes to their cognitive abilities: "By far the most common reactions to the question regarding concerns about 'your memory or ability to think' were expressed in terms such as: 'worried', 'afraid', 'scared', 'frightened' and 'terrified'" (Laditka et al., 2011, p. 1212).

Anticipation of cognitive decline, both normal and pathological, is clearly a source of anxiety for many people. The decline itself, however, can also have a major impact on individuals' mental wellbeing. Associations have been found between lower cognitive function and increased symptoms of depression in older adults (Dufouil et al., 1996; Perrino et al., 2008). Results from one study indicated that symptoms of depression and anxiety may be particularly pronounced in the early stages of cognitive decline (Bierman et al., 2007). It has been suggested that this association may be due to negative affective reactions to perceived cognitive decline, and/or fear of loss of independence as a result (Perrino et al., 2008). Such fears may be well-founded; there is consistent empirical evidence of a relationship between cognitive decline and functional independence in old age.

1.3.2. Activities of Daily Living

The idea of old age as a period of increasing dependence is common. Those concerned with the functional ability of older adults (i.e., the ability of an individual to carry out everyday activities without some form of assistance) have developed scales to measure dependence in what are now commonly referred to as Activities of Daily Living (ADL; Katz & Akpom, 1976; Lawton & Brody, 1969). ADLs can be broadly categorised into the more basic ADLs (e.g., personal grooming, walking short distances, using the toilet) that have immediate and direct health implications, and more complex Instrumental Activities of Daily Living (IADL; e.g., preparing meals, cleaning the house, travelling around outside the home, managing finances and taking medication; Spector & Fleishman, 1998; Spector et al., 1987).

Studies have shown that declines in global cognitive ability are associated with functional declines in both ADLs (Black & Rush, 2002; Greiner et al., 1996; Scherr et al., 1988) and IADLs (Fillenbaum et al., 1988). The long-term trajectory of functional decline may in fact be hierarchical in nature, with dependency in the more complex activities occurring earlier in the course of cognitive decline. Njegovan et al. (2001) measured global cognitive status and dependence in both ADL and IADL in a group of community-dwelling older adults, and found that the degree of cognitive decline experienced was reflected in the degree of functional dependence. Increased dependence for IADLs (e.g., housework, shopping, meal preparation) tended to occur when the degree of cognitive impairment was small, whereas increased dependence for basic ADLs (e.g., grooming and feeding) tended to occur in the cases of more severe cognitive impairment. Increased dependence for basic ADLs has in turn been associated with increased institutionalisation (De Buyser et al., 2014), suggesting this could represent a possible outcome for those experiencing a higher degree of cognitive decline.

Broadly speaking, therefore, degree of cognitive change is an important determinant of an individual's ability to function and live independently. However, when it comes to specific activities, different cognitive abilities may play different roles. To illustrate this point, three examples are offered: financial planning, driving and navigation.

The ability to adequately manage finances is linked to financial security in old age (Lusardi & Mitchell, 2007). As such, any decline in this ability could have adverse effects on older adults' security and independence. Executive function generally refers to higher-order processes involved in the planning and execution of goal-directed behaviour (Alvarez & Emory, 2006), skills that may be useful in the management of personal finances. One study found that in a sample of older adults without dementia, a substantial portion of the negative association between age and financial literacy could be explained by the mediating effect of executive function (Boyle et al., 2013). Decline in executive function may therefore represent a risk factor for future financial dependence.

The ability to drive can play a large part in maintaining older adults' independence (Adler & Rottunda, 2006), and driving cessation has been linked to decreased mental wellbeing and life satisfaction (Fonda et al., 2001; Harrison & Ragland, 2003). Evidence suggests that cognitive ageing contributes to declining driving performance independently of visual acuity (Anstey et al., 2012; McKnight & McKnight, 1999). Lower executive function in old age has been linked to increased risk of traffic accidents (Emerson et al., 2012). Another study found that measures of processing speed were the largest predictors of driving performance (Anstey et al., 2012). As noted previously, processing speed is particularly sensitive to age-related decline. Therefore, changes in executive function and processing speed may have a significant impact on independence and life satisfaction through impaired driving ability.

When it comes to getting around, cognitive decline might affect not only driving competency, but also an individual's ability to navigate on foot. The ability to learn routes and travel around novel environments is an important factor in older adults' ability to live independently. However, doing so may rely on memory abilities that are vulnerable to ageing. One study examined the effects of age on ability to learn a route through a novel virtual maze (Moffat et al., 2001). They found that older adults (aged 65+) were significantly slower to navigate the maze. Results also showed that lower visual and verbal memory were associated with slower speed, greater distance travelled and a greater number of errors. These findings imply that age-related memory decline may impair individuals' ability to navigate the world around them.

In summary, declines in different cognitive domains can impact a person's everyday life in different ways. Taken individually, people may be able to adapt to these changes while remaining independent. However, collective declines in ADL and IADL can lead to other less favourable outcomes, including increased depressive symptoms, reduced social participation and lower health-related quality of life (Ormel et al., 2002; Pusswald et al., 2015; Tomioka et al., 2016).

In order to help older people maintain their health and wellbeing for as long as possible, cognitive ability will remain a key factor to consider. The negative outcomes associated with loss of independence in old age are reflected in people's fears about getting older. The costs of functional decline are not just personal either; those who experience the most severe decline may require institutional care, which comes with associated financial implications. All of this supports efforts to ameliorate age-related cognitive decline.

1.4. An Inevitable Process?

1.4.1. Individual Variation

While it is important to recognise the impact that age-related cognitive decline can have on individual lives, this can lead to the impression of inevitability – that old age represents a period of unavoidable impairment. This is problematic not only because it undoubtably contributes towards societal anxiety and antipathy towards ageing, but because it is a broad generalisation. Cognitive decline in old age is certainly prevalent, but it is not necessarily inevitable, and by no means homogenous. The average pattern of cognitive change (i.e., a general decline across most cognitive domains with the exception of verbal ability) has been replicated across samples and cultures (Park & Gutchess, 2006; Salthouse, 2004a; Verhaeghen & Salthouse, 1997). However, longitudinal studies have afforded the opportunity to compare rates of change across individuals and there is evidence for considerable between-person variability in the trajectory of cognitive ability (Christensen et al., 1999; Schaie, 1989).

The Religious Orders Study (Wilson et al., 2002) recruited a sample of adults aged 65 and over and tested them annually over six years. While, on average, performance declined in all seven cognitive domains tested, some individuals demonstrated a steep decline while others showed relatively stable performance, and some even showed an improvement (Figure 1.2). As the authors noted, “The observed heterogeneity in rates of change is not easily reconciled with the idea that cognitive ability declines inevitably or uniformly in old age as part of some developmental process” (p. 190).

So why might some individuals show steep declines, while others show no decline? In fact, direct age effects may account for only a small fraction of the total variance in cognitive ability; based on a previous cross-sectional meta-analysis, Salthouse estimated somewhere between 4 and 36% of variation in cognitive ability could be attributed to age alone (Salthouse, 2010). This suggests there are other factors that predict cognitive ability throughout the lifespan. If age alone explains, at most, 36% of the variance, then it becomes necessary to ask what other determinants account for the remaining 64%.

1.4.2. Influencing Factors

In recent years, research has explored what factors might influence differences in the path of cognitive ability in old age. Studies have examined influences on both baseline level of cognitive ability and rate of change over time. A full and detailed account of each individual contributing factor is beyond the scope of this thesis, but a brief summary of the major factors is offered.

Genes. Genetic influences represent one of the largest contributors to individual differences in cognitive ability level in old age. Various estimates suggest that anywhere from 30 to 80% of the variance in global cognitive ability may be heritable (Deary, Johnson, et al., 2009). Understanding of which specific genes contribute to this heritability is in its relative infancy. However, one specific gene has demonstrated relatively consistent links to cognitive function. The gene coding for a plasma protein known as apolipoprotein E (APOE) has three allelic variations (ε2, ε3 and ε4); an estimated 14% of people possess the ε4 variant. This ε4 allele has been consistently linked to an increased risk of Alzheimer's Disease (Farrer et al., 1997). Among individuals without any neurodegenerative condition, those with this gene variant perform significantly poorer in global cognitive ability, episodic memory and executive function (Small et al., 2004; Wisdom et al., 2011). Estimates of the heritability of cognitive *change* are notably smaller than those of cross-sectional measures of cognitive ability (Zhang & Pierce, 2014). However, the APOE4 gene variant has been linked to increased cognitive decline, particularly for memory and reasoning ability (Plassman et al., 2010; Schiepers et al., 2012). Genes may also influence cognitive health indirectly; there are many diseases and health conditions known to be heritable that have an effect on cognitive ability (Deary, Wright, et al., 2004).

Disease. Evidence suggests that diseases and health conditions affecting the circulatory system may affect cognitive ability. Cardiovascular disease (CVD; e.g., peripheral arterial disease, hypertension or atherosclerosis) has been linked both to lower cognitive performance and to increased rate of decline (Birns & Kalra, 2009; Okonkwo et al., 2010; Rafnsson et al., 2007; Vinkers et al., 2005). Experiencing a stroke is a notable risk factor for decline in processing speed and episodic memory (Hochstenbach et al., 1998; Rafnsson et al., 2007). The brain is particularly dependent on blood flow to function properly. Any sudden reductions in blood supply (as in the case of stroke) or even slight reductions over a long period due to chronic CVD, can therefore have negative consequences on brain function, and thus cognitive ability (Deary, Corley, et al., 2009; Waldstein et al., 2001).

Health-Related Behaviour. Given the links between CVD and cognitive outcomes, it is unsurprising that well-known risk factors for CVD are also risk factors for cognitive decline. Smokers typically exhibit poorer cognitive ability and increased rate of decline at the global level and in executive function and episodic memory (Anstey et al., 2007; Nooyens et al., 2008). Smoking a greater number of cigarettes has also been linked to greater decline in executive function, memory and processing speed, indicating a dose-response relationship (Nooyens et al., 2008).

A dietary pattern typically associated with better cognitive health outcomes in old age is the ‘Mediterranean diet’ (i.e., high intake of vegetables, legumes, fruit, nuts, cereal and fish); diets high in trans and saturated fats tend to be linked to poorer outcomes (Corley et al., 2013; Lee et al., 2010; Parrott & Greenwood, 2007; Van Dyk & Sano, 2007). In particular, omega-3 fatty acids have been highlighted for their potential benefits to synaptic plasticity (Gómez-Pinilla, 2008).

The relationship between alcohol intake and cognition is less straightforward. Evidence suggests a curvilinear relationship, with both abstainers and heavy drinkers experiencing poorer cognitive outcomes relative to moderate drinkers (Lee et al., 2010). One study found that minimal to moderate alcohol intake was linked to reduced declines in global cognitive ability as well as memory and executive function (Ganguli et al., 2005).

Collectively, these findings suggest that living a stereotypically ‘healthy’ lifestyle (i.e., not smoking, avoiding fatty foods, not drinking to excess) tends to lead to more favourable cognitive outcomes in old age. However, these are not the only lifestyle factors that may have an influence.

1.5. Benefits of an Active Lifestyle

Investigating the cognitive impact of how we spend our leisure time is of increasing interest. How do the everyday activities we engage in affect our cognitive health in old age? The ‘use it or lose it’ theory argues that, just as muscles become weaker if not exercised regularly, so does the brain (Hertzog et al., 2008; Kramer et al., 2004; Salthouse, 2006). In other words, maintaining an active, engaged lifestyle, as opposed to a sedentary, unoccupied one can help maintain healthy cognitive ability. Testing the validity of this theory involves investigating the vast spectrum of possible human activities. For the sake of brevity, activities will be summarised under four broad categories: mental, physical, social and creative.

1.5.1. Mental Activity

Exact definitions of mentally stimulating leisure activity vary across studies, but typically tend to cover engagement in activities deemed to stimulate cognitive faculties, such as reading, puzzles, visiting libraries, galleries or museums and attending educational classes. Cross-sectional studies have generally demonstrated positive associations between engagement in mental activities and global cognitive ability (Kåreholt et al., 2011; Vemuri et al., 2014). At the domain level, increased mental engagement has been linked to higher verbal ability, episodic memory, executive function, working memory, visuospatial ability and processing speed, (Bielak et al., 2012; Opdebeeck et al., 2016; Parslow et al., 2006; Wilson et al., 2003). Opdebeeck et al.'s (2016) meta-analysis reported significant positive associations between mental activity and cognitive abilities, although effect sizes were generally small to moderate.

Evidence from longitudinal studies is more mixed. Some studies have found that those who are more mentally active tend to experience less global cognitive decline over time (Vemuri et al., 2014; Wang et al., 2013). Conversely, Bielak et al. (2012) found no evidence of a link between mental engagement and decline.

1.5.2. Physical Activity

Self-reported level of physical activity (e.g., frequency of engagement in a variety of exercise, sport or movement-based activities like yoga) has been positively associated with global cognitive ability, memory, verbal fluency and working memory, and with less decline in the same domains (Wang et al., 2013; Weuve et al., 2004). More objective measures of fitness level (e.g., oxygen consumption or grip strength) have also been associated with higher performance on measures of global ability, memory and executive function, as well as reduced global cognitive decline (Barnes et al., 2003; Blondell et al., 2014; Deary et al., 2006; Sofi et al., 2011).

The benefits of physical activity for cognitive function are typically attributed to the neuroprotective effects of increased cardiovascular fitness (Kramer et al., 2005; Sofi et al., 2011). However, it has also been suggested that some physical activity may enhance cognition by directly engaging specific cognitive abilities (i.e., complex strategic thought in competitive sport or memorising dance routines; Bielak, 2010).

1.5.3. Social Activity

Individuals who engage in more social activities (e.g., attending social events, going out with friends or attending meetings of organised groups or clubs) have been shown to perform significantly better on measures of global cognitive ability, episodic memory and processing speed (James et al., 2011). Social activity has also been linked to less global cognitive decline and less decline in processing speed over time (Lövdén et al., 2005; Wang et al., 2013). Smaller social network size, poor social support and increased loneliness have also been linked to greater cognitive decline (Kuiper et al., 2016). In line with the ‘use it or lose it’ hypothesis, it has been suggested that navigating complex interpersonal exchanges may provide cognitive stimulation that in turn improves cognitive ability (James et al., 2011).

1.5.4. Creative Activity

While relatively few studies have examined the potential relationship between creative engagement and cognition in old age, there is some evidence of potential beneficial effects. Parslow et al. (2006) found that engagement in artistic activities (including sketching, painting, creative writing and drama) was positively associated with verbal ability and processing speed. Roberts et al. (2015) found that engagement in artistic and craft activities was associated with reduced risk of incident Mild Cognitive Impairment (MCI). A small body of literature has also found that individuals who have played musical instruments for a substantial part of their lives outperform non-musicians in measures of episodic memory, executive function, visuospatial ability, working memory and processing speed (Gray & Gow, 2020; Hanna-Pladdy & Gajewski, 2012; Hanna-Pladdy & MacKay, 2011). Research into the potential mechanisms through which creativity might influence cognitive ability in old age is relatively scarce, although some have suggested that creative activity requires the recruitment of cognitive abilities including executive function, processing speed and working memory (Bink & Marsh, 2000). As such, creative pursuits may stimulate the brain in much the same way that more typically ‘mental’ activities do.

1.5.5. Reverse Causation

Evidence is consistent with the suggestion that leading a more engaged lifestyle is protective against cognitive decline in later life. However, before accepting such conclusions it is important to rule out alternative explanations. Static associations do not provide any clarity on the causality of the observed relationship. In other words, there is no way to say definitively whether engagement influences cognition or cognition influences engagement. This problem of reverse causation is a pervasive and oft-ignored aspect of cognitive ageing research (Deary, Corley, et al., 2009).

Competing Theories. The question of causality in this instance is often dichotomised into two competing hypotheses (Salthouse et al., 1990). The 'differential preservation' account argues that the protective effect of activity engagement is real; in line with the 'use it or lose it' hypothesis, individuals who engage in more activities throughout their lives experience more favourable cognitive outcomes as an older adult. Conversely, the argument for 'preserved differentiation' is that individuals who show higher levels of cognitive function in old age were high functioning to begin with, and such individuals are inherently more likely to adopt more active lifestyles. Therefore, cognitive performance in old age and activity engagement are related because they are both a function of lifetime cognitive ability.

Resolving the tension between these two explanations is difficult within observational studies; other approaches are necessary. Tracking and analysing the concurrent longitudinal paths of activity engagement and cognitive ability with structural equation models has proved fruitful in elucidating the time course of the relationship between the two variables. For example, Ghisletta et al. (2006) used Dual Change Score Modelling to track the effect of activity engagement on changes to cognitive ability (and vice versa) over several years. Their results showed that engaging in more activities typically thought of as mentally stimulating predicted significantly less decline in processing speed, but processing speed did not influence changes in activity engagement. Similarly, other studies found that baseline social engagement predicted less subsequent cognitive decline, but that the opposite pattern was non-significant (James et al., 2011; Lövdén et al., 2005). These findings are in line with the differential preservation hypothesis.

Conversely, another study found essentially the opposite pattern of results. Aartsen et al. (2002) reported no evidence that engagement in socially or mentally stimulating activities predicted change in any cognitive abilities over a six-year period. However, processing speed did significantly predict engagement in mentally stimulating activity, providing support for the preserved differentiation hypothesis.

Hultsch et al. (1999) tested the two hypotheses using data from the Victoria Longitudinal Study. In one structural model, engagement in mental activities was associated with change in working memory scores over a period of six years: more active individuals showed less decline. However, an alternative model with comparatively good fit showed that change in both activity engagement and working memory could be accounted for by change in a global cognitive ability factor; in other words, general cognitive decline predicted decline in mental activity. Thus, the data provided compelling evidence for both hypotheses.

In response to such conflicting results, others have rejected the binary nature of the competing hypotheses, instead proposing a more dynamic, mutual interplay between activity engagement and cognition. One study reported reciprocal effects between a measure of cognitive ability and engagement in mentally demanding activities (Schooler & Mulatu, 2001). In this case, those who scored higher in cognitive ability tended to engage in more mentally complex leisure activities, and, simultaneously, engaging in more complex activities was associated with higher cognitive functioning. The authors posited that, rather than one causing the other, activity engagement and cognitive ability were involved in a more complex relationship of mutual reinforcement. Those with initially high levels of cognitive ability may tend to seek out more mentally stimulating environments and engage in more mentally stimulating behaviour, which then further enhances their cognitive ability (and vice versa).

There is other evidence in support of this theory. One study recruited and re-tested a group of Canadian WWII veterans who had undergone cognitive testing in young adulthood when they enlisted (Pushkar Gold et al., 1995). Using structural equation modelling, the authors found that verbal ability in young adulthood significantly predicted a more complex lifestyle in later life (partly measured through engagement in mentally stimulating activities), which in turn predicted verbal ability in old age. This was taken as evidence for an interactive, reciprocal relationship in which activity engagement and cognition reinforced each other throughout the life span. It should be noted that this relationship was not evident for non-verbal measures of cognitive function such as visuospatial ability.

However, the preserved differentiation hypothesis argues for the primacy of cognitive ability *throughout the lifespan* – i.e., differences in activity engagement are due to cognitive differences established in early life, prior to initial engagement in those activities. Therefore, to test this theory completely, it is necessary to examine the effects of cognitive ability from childhood through to old age. Practically, this is difficult; if longitudinal studies are comparatively rare, longitudinal studies that follow people from childhood to old age are even more so. Nonetheless, one study has been able to take advantage of pre-existing data collected over eighty years ago in order to map out cognition across the life course.

The Lothian Birth Cohorts. In 1932, the educational authorities of Scotland tested the mental ability of almost all children born in 1921 using an assessment known as the Moray House Test (MHT). The entire process, using the same age-group and the same test, was repeated fifteen years later, in 1947 (testing all children born in 1936). The result of these efforts was comprehensive data about the cognitive ability at age 11 of two entire Scottish birth cohorts. Over 60 years later, a group of researchers traced and contacted people from both cohorts and retested them. Now known as the Lothian Birth Cohorts (LBC; Deary et al., 2012), participants have been re-tested numerous times in the ensuing years. Initial cognitive testing involved re-administration of the MHT, as well as various other cognitive measures. This has allowed researchers to track the development of cognitive ability over the lifespan. It has also provided the opportunity to test the preserved differentiation hypothesis of cognitive ageing directly.

To reiterate: the hypothesis of preserved differentiation argues that (a) differences in cognitive ability in old age reflect differences in cognitive ability throughout the lifespan, and that (b) increased activity engagement is a consequence rather than a driver of these differences. Evidence from the LBC studies supports the first of these suppositions. Correlations between MHT performance at age-11 and age-80 in the 1921 cohort were found to be .66, indicating that premorbid cognitive ability accounts for around 43% of cognitive ability in old age (Deary, Whiteman, et al., 2004).

The ability to control for the effects of premorbid ability also allowed the testing of the second supposition. Using data from the 1936 cohort, Gow et al. (2012), examined the relationship between 'socio-intellectual'/physical activity and performance in a range of cognitive domains at age 70. Initial results showed that both socio-intellectual and physical activity were positively associated with all cognitive outcomes. However, when models were adjusted to include the predictive effect of cognitive ability at age-11, almost all of these associations became non-significant (all except for positive associations between socio-intellectual activity and vocabulary score, and physical activity and global cognitive ability and processing speed). These results suggest that almost any predictive effect that activity engagement had for cognitive ability in old age were confounded by the lifelong stability of cognitive ability. In other words, as proposed by the preserved differentiation hypothesis, those who have always been high functioning remain so in old age, and their engaged lifestyle is a by-product of this.

Additional findings from the 1921 cohort revealed that even when adjusting for premorbid ability, socio-intellectual activity during midlife specifically (i.e., age 40-55) was positively associated with global cognitive ability at age 80 (Gow et al., 2017). These findings suggest that activity engagement, specifically earlier in the life course, may exert a beneficial effect in old age. However, while physical ability in later life was related to less global decline over a ten-year period, there was no evidence of an association between socio-intellectual activity at any point in the life course and cognitive change. The effects of social or mental stimulation (unlike physical activity) may therefore be enhancing, but may not reduce any changes experienced in the long-term.

1.5.6. Intervention Studies

The scarcity of available data covering the whole life-course as well as the prohibitive cost of longitudinal studies mean that resolving the issue of reverse causation is difficult using observational data alone. Intervention trials allow us to test causation more directly by deliberately increasing engagement in a behaviour in a group of individuals and examining any resulting change in cognitive ability relative to those who did not engage in that behaviour. Given that mental, physical, social and creative activity are each inherently modifiable, these activities lend themselves well to such interventions. Indeed, there is evidence to suggest that increasing levels of engagement in all these areas can lead to cognitive improvements in older adults (Kelly et al., 2014a, 2014b; Noice et al., 2014; Pitkala et al., 2011). The efficacy of interventions to improve cognitive ability or reduce cognitive decline will be returned to in Chapter 3 of this thesis.

1.6. The Role of Personality

When considering the wide variability in cognitive health among older adults, it can be useful to acknowledge that individuals might age differently from each other because they are just that: individuals. People differ in their attitudes, beliefs, feelings, motivations and behaviour. The study of personality is concerned with characterising these differences and how they might manifest in real life outcomes.

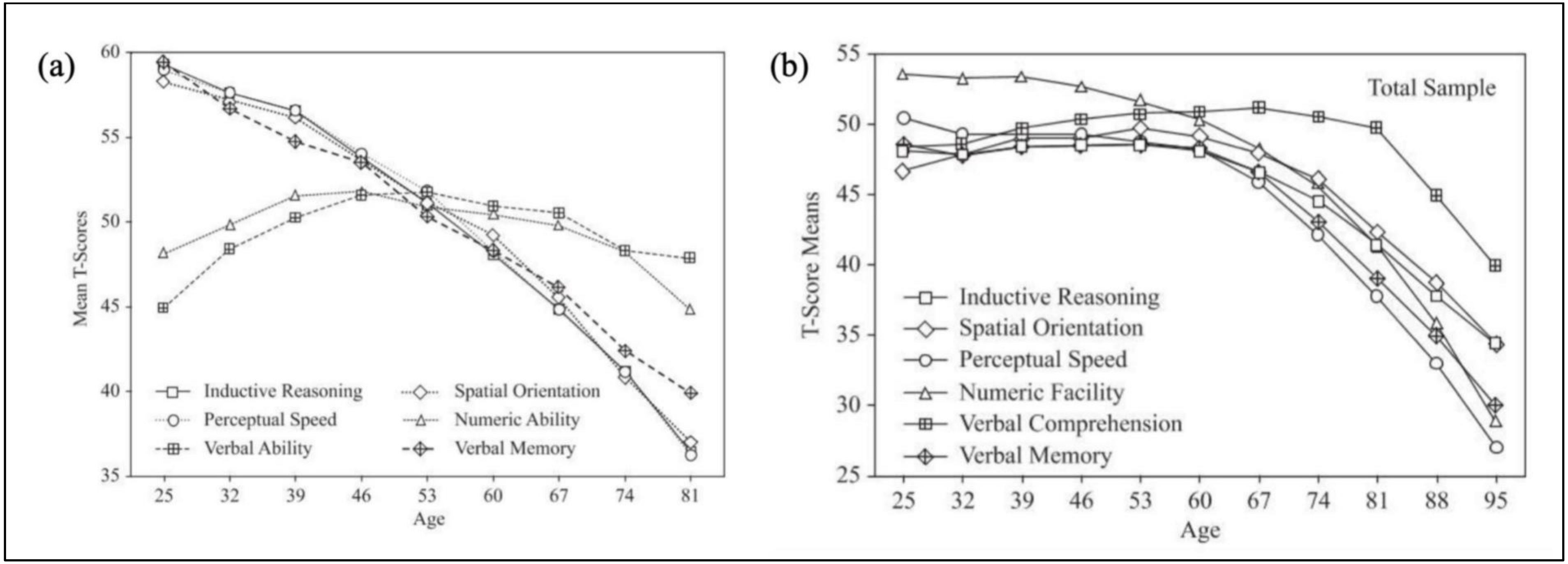
For example, personality appears to predict cognitive ability in old age (Curtis et al., 2015). Personality has also been associated with many of the lifestyle variables that, as noted above, are predictive of cognitive ability (e.g., health-related behaviours or activity engagment; Bogg & Roberts, 2004; Stephan et al., 2014). Given these findings, one might consider the possibility of a causal chain, in which personality exerts an influence on cognition via lifestyle determinants. As will be discussed in the next chapter, there is evidence to suggest that this may be the case.

1.7. Summary

As the proportion of older adults in the population continues to increase, so too does the need for effective strategies to help people maintain their health in old age. Cognitive health generally seems to deteriorate with age, and this can in turn impact older adults' independence and quality of life. However, the actual change experienced varies between individuals. One factor that may account for some of this variation is activity engagement. There is compelling evidence for the existence of an association between an active, engaged lifestyle and more favourable cognitive outcomes in later life. However, evidence regarding the relationship between activity engagement and longitudinal change in cognitive ability is mixed. Furthermore, characterising the direction of any association remains contentious. Does activity engagement drive cognition or does cognition drive engagement? Evidence exists for both hypotheses. There is also evidence to suggest that both are partly true, and that engagement and cognition mutually reinforce each other throughout the lifespan. Longitudinal studies and interventions are helping address these questions. Furthermore, it may be the case that important lifestyle factors such as activity engagement are influenced by personality traits, to which this thesis now turns.

Figure 1.1

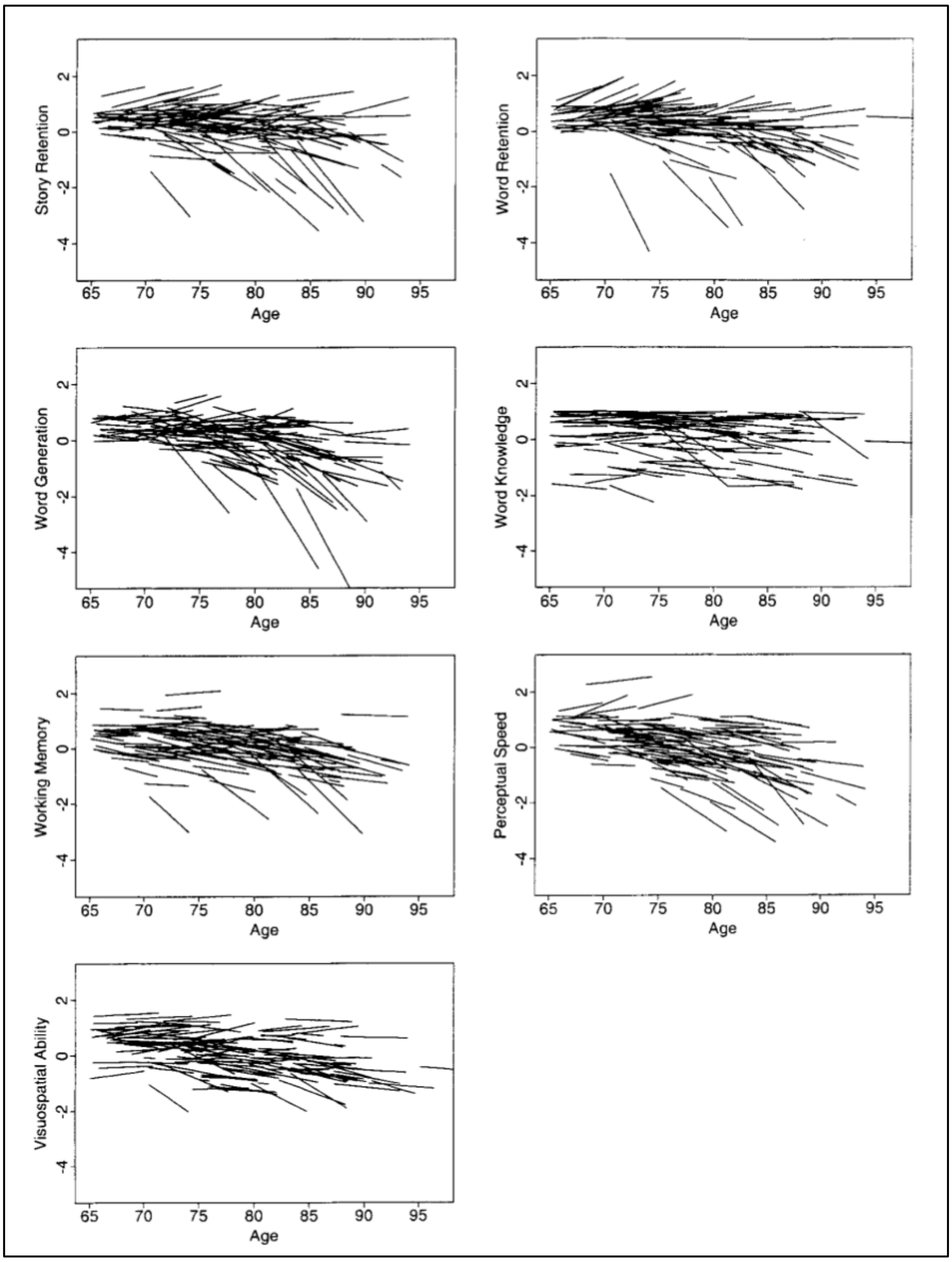
Cross-Sectional and Longitudinal Associations Between Age and Performance Across Six Cognitive Domains in the Seattle Longitudinal Study



Note. Data are (a) cross-sectional and (b) longitudinal. Figures are taken from *Developmental Influences on Adult Intelligence: The Seattle Longitudinal Study (2nd Edition)* by K. Warner Schaie (2013). © Oxford University Press 2013. Reproduced with permission of the Licensor through PLSclear.

Figure 1.2

Individual Paths of Performance on Different Cognitive Measures in the Religious Order Study



Note. Lines represent individual participants' changes in performance over time. Copyright © 2002 by American Psychological Association. Reproduced with permission. Wilson, R. S., Beckett, L. A., Barnes, L. L., Schneider, J. A., Bach, J., Evans, D. A., & Bennett, D. A. (2002). Individual differences in rates of change in cognitive abilities of older persons. Psychology and Aging, 17(2), 179-193. https://doi.org/10.1037/0882-7974.17.2.179

2. Personality and Cognitive Ability in Old Age: Investigating the Mediating Role of Active and Healthy Lifestyles

Note. Part of this chapter was published as 'Measuring activity engagement in old age: An exploratory factor analysis' by Marr et al. (2021). The published version can be found at: https://doi.org/10.1371/journal.pone.0260996

2.1. Introduction

Individual differences in personality have been linked to various health outcomes, both physical and mental (Friedman, 2000; Friedman & Kern, 2014; Smith & Spiro III, 2002). Personality refers to individual tendencies to think, feel and behave in certain, relatively consistent, ways. Typically, individual differences in personality are measured as scores on specific dimensions, or 'traits'. Personality traits have been shown to predict the incidence of various diseases and overall risk of mortality (Graham et al., 2017; Weston et al., 2014). In particular, certain personality traits have been associated with a greater risk of developing neurodegenerative diseases such as Alzheimer's (Terracciano et al., 2014).

There has been growing interest in the association between personality and cognitive ability among healthy older adults. A clear understanding of this association can be beneficial in several ways. Understanding whether certain personality traits represent a risk or protective factor for cognitive health can help to identify and target support towards those who need it most. Furthermore, knowledge of the underlying mechanisms that explain why certain personality traits are associated with better cognitive health could illuminate new intervention strategies.

Theories of personality have evolved through the years, but the most commonly used today is the Five-Factor Model (McCrae & John, 1992), which characterises individuals across five traits (often referred to as the 'Big Five'): Neuroticism, Extraversion, Openness to Experience, Agreeableness and Conscientiousness.

2.1.1. The Five-Factor Model

The Five-Factor Model developed over the course of the late twentieth century via two main approaches: the lexical approach, in which meaningful personality descriptors were obtained from analysis of natural language, and the questionnaire approach, in which latent dimensions of personality were extracted from questionnaire data (John et al., 1988; McCrae & John, 1992). The Five-Factor Model has been validated across instruments, observers and cultures (Jolijn Hendriks et al., 2003; McCrae & Costa, 1987; McCrae & Terracciano, 2005). Although a full consideration of the measurement of personality is beyond the scope of this thesis, it should be noted that several other personality models have been offered over the years, including Cattell's sixteen factors (Cattell & Mead, 2008), Eyesenck's three factors (Eysenck, 1990) and the HEXACO six-factor model (Ashton & Lee, 2007). However, the five traits identified under the Five-Factor Model represent the most widely accepted taxonomy of personality in the field today:

- Neuroticism measures individuals' tendency to experience stress, anxiety and negative affect; it is occasionally conceptually reversed and referred to as Emotional Stability.
- Extraversion measures sociability, assertiveness and self-confidence.
- Openness to Experience measures the extent to which individuals exhibit intellectual curiosity, adventurousness and a need for novelty and variety in their lives.
- Agreeableness measures tendencies towards altruism and prosocial behaviour.
- Conscientiousness measures levels of organisation, diligence and self-control (McCrae et al., 2015; McCrae & John, 1992).

One of the most commonly used personality questionnaires, the NEO Personality Inventory, conceptualises these five traits as higher order factors, each accounting for six lower order factors, or 'facets' (McCrae et al., 2015). Figure 2.1 depicts the Big Five traits and their respective facets within this hierarchical structure.

2.1.2. Associations Between Big Five Traits and Cognitive Ability in Older Adults

The literature regarding personality-cognition associations in older adults is highly heterogeneous, in terms of sample size, personality questionnaires, cognitive assessments and analytic approach. However, broadly speaking, three of the Big Five traits show consistent associations with cognitive ability: Openness to Experience, Conscientiousness and Neuroticism. Positive associations between Openness and global cognitive ability have been found in a number of studies (Austin et al., 2002; Booth et al., 2006; Chapman et al., 2012; Mortensen et al., 2014; Simon et al., 2020). Openness has also been linked to higher performance in a broad range of cognitive domains, including verbal ability (Ihle et al., 2016), memory (Allen et al., 2019; Luchetti et al., 2016), executive function (Sutin, Stephan, Luchetti, et al., 2019; Williams et al., 2010), visuospatial ability (Baker & Bichsel, 2006; Sutin, Stephan, Luchetti, et al., 2019) and processing speed (Soubelet & Salthouse, 2010; Sutin, Stephan, Luchetti, et al., 2019).

There is some evidence suggesting a link between higher Conscientiousness and higher level of global cognitive ability (Luchetti et al., 2016; Martin et al., 2009). At the domain level, there are consistent positive relationships between Conscientiousness and memory performance (Allen et al., 2019; Luchetti et al., 2016; Sutin, Stephan, Luchetti, et al., 2019) and executive function (Booth et al., 2006; Sutin, Stephan, Luchetti, et al., 2019). Conversely, Neuroticism tends to be inversely associated with cognitive ability, with individuals who score higher on this trait showing poorer global ability (Austin et al., 2002; Chapman et al., 2012; Gow et al., 2005b; Luchetti et al., 2016; Simon et al., 2020; Waggel et al., 2015), episodic memory (Aiken-Morgan et al., 2012; Klaming et al., 2017), working memory (Weinstein et al., 2019), executive function (Williams et al., 2010) and processing speed (Booth et al., 2006).

Findings regarding the remaining Big Five traits are more variable. Higher Extraversion has been linked to both higher (Martin et al., 2009) and lower global cognitive ability (Luchetti et al., 2016; Simon et al., 2020). There is little evidence for consistent links between Extraversion and performance in any cognitive domain, although two studies have demonstrated positive associations between Extraversion and performance on tests of verbal fluency (Sutin, Stephan, Damian, et al., 2019; Sutin, Stephan, Luchetti, et al., 2019). Agreeableness, for the most part, demonstrates no significant associations with global cognitive ability (Booth et al., 2006; Chapman et al., 2012; Gow et al., 2005b; Simon et al., 2020). At the domain level results are dominated by null findings; the only somewhat consistent association is a positive one with executive function (Sutin, Stephan, Luchetti, et al., 2019; Williams et al., 2010).

Few studies have examined whether these associations are consistent across the lifespan, and those that have present mixed findings. Baker and Bichsel (2006), found that domain-specific associations varied between age groups. For example, while Openness was significantly positively associated with auditory processing and visuospatial ability in older adults, it was not associated with these domains in younger adults; instead, Openness was positively associated with verbal ability and working memory. It should be noted that sample size in this study was comparatively small (total N = 381). Soubelet and Salthouse (2011) employed a much larger sample (N > 2000) to examine associations between the Big Five traits and cognition in three age groups (18-39, 40-59 and 60-96), and found associations to be broadly consistent across groups, especially the positive associations between Openness and cognitive ability in multiple domains.

In summary, the traits of Openness and Conscientiousness demonstrate relatively robust positive relationships with a range of cognitive abilities in old age, while Neuroticism tends to show the opposite association. Extraversion and

Agreeableness do not demonstrate consistent relationships with cognition. Establishing these links is, however, only the first step in understanding the relationship between personality and cognition. Additional research has attempted to elucidate the mechanisms that underlie these associations.

2.1.3. Potential Lifestyle Mechanisms

The suggestion that more open individuals tend to have higher levels of cognitive ability tracks intuitively from what we know about people who score highly on this trait. Older adults who are more open are more likely to habitually engage in activities typically thought to be mentally stimulating (e.g., learning a language; Hultsch et al., 1999). This type of mental engagement has in turn been linked to higher cognitive ability in old age, suggesting it may exert a protective effect (Kåreholt et al., 2011; Opdebeeck et al., 2016; Vemuri et al., 2014). It has therefore been suggested that mental engagement may offer a mechanism through which Openness exerts a positive effect on cognition. Under this 'investment theory', older adults who are more open engage in more mentally stimulating activity in their everyday life, which then has an enhancing effect on their cognitive ability (Chamorro-Prezumic & Furnham, 2004).

Previous studies have tested this theory by examining whether activity engagement mediates the association between Openness and cognitive ability. Soubelet and Salthouse (2010) found that Openness predicted performance across several cognitive domains. They also measured the number of hours participants spent engaging in a range of mentally demanding activities (including reading, writing and puzzles); there was no evidence that this measure of engagement mediated the Openness-cognition relationship. It should be noted that the sample in this study included adults of all ages. Conversely, Hogan et al. (2012) found that the tendency to engage in mental activities (e.g., reading, problem solving) mediated the positive relationship between Openness and verbal ability in a sample of adults aged 60-64.

Other studies of older adults have also found evidence of a mediating effect. Ihle et al. (2016) employed a broader measure of activity engagement that went beyond purely mental pursuits (including exercise, travel and socialising). Results showed that the positive association between Openness and performance in measures of verbal ability and processing speed was mediated by retrospective ratings of activity engagement during midlife. A further study using the same activity questionnaire found that activity engagement significantly mediated the relationship between Openness and change in cognition over time; those who scored higher on Openness demonstrated higher activity engagement, and this engagement in turn predicted smaller declines in executive function over six years (Ihle et al., 2019).

Another study found that level of engagement in mentally stimulating activities such as reading, writing and puzzles significantly mediated the association between Openness and attention/executive function, but not verbal memory (i.e., learning and recall of lists and stories) in adults aged 65 and over (Mercuri & Holtzer, 2020). The authors suggested that the mediating role of activity engagement may be domain specific; in other words, the self-directed, motivated behaviour of engaging in mentally demanding activities in old age may specifically enhance executive function. However, Jackson et al. (2020) also found that engagement in mentally demanding activities significantly mediated the positive association between Openness and both visuospatial ability and processing speed in adults aged 60 and over.

The current weight of evidence thus supports the possibility of an indirect effect of Openness on cognitive ability via mental activity engagement. However, it should be noted that measures of activity engagement varied across the aforementioned studies and tended to quantify engagement across several activities using a single metric. It may be that different types of mentally stimulating activity have different relationships with both personality and cognitive ability. For example, Park et al. (2007) differentiate between ‘productive’ engagement (i.e., activities that involve acquiring new knowledge or skills such as learning a language) and ‘receptive’ engagement (i.e., activities that involve no new learning such as watching films). Similarly, Jopp and Hertzog (2007) differentiate between ‘developmental’ activities (e.g., attending lectures or courses) and ‘experiential’ activities (e.g., reading). While there is currently no widely agreed upon way to categorise activities, research using more nuanced measures of activity engagement would help to provide more insight into exactly what kind of activities might explain the Openness-cognition relationship.

Behavioural factors may also explain any positive effects of Conscientiousness on cognitive ability. There is evidence to support the theory that more conscientious individuals tend to engage in more positive health-related behaviours (e.g., higher physical activity, lower tobacco exposure and alcohol consumption; Bogg & Roberts, 2004), which might in turn offer protection from age-related cognitive changes via increased cardiovascular and neuronal health (Lee et al., 2010; Nooyens et al., 2008; Weuve et al., 2004). For example, positive health-related behaviour has been found to mediate the negative association between Conscientiousness and brain tissue loss in healthy older adults (Booth et al., 2014). Another study found that health-related behaviour mediated the association between Conscientiousness and memory in older adults (Allen et al., 2019). Specifically, more conscientious individuals exhibited less sedentary behaviour and were more physically active, which in turn predicted better memory performance. To date, no other studies have examined whether this effect holds across other cognitive domains.

Explanations for the negative association between Neuroticism and cognitive function tend to focus on the tendency of individuals higher in Neuroticism to experience stress and anxiety. This may have both short-term deleterious effects on their performance in a test-taking situation, and long-term effects on the brain through neuronal damage as a result of stress-related elevated glucocorticoid levels (Chamorro-Prezumic & Furnham, 2004; Curtis et al., 2015; Lupien et al., 2007). However, there is evidence that Neuroticism may also influence activity engagement and health-related behaviour, and therefore cognition. Unlike Openness, evidence suggests Neuroticism is linked to *lower* engagement in mentally engaging activities in older adults (Hultsch et al., 1999). Higher Neuroticism has also been linked to lower levels of social activity in old age (Krueger et al., 2009). Lower levels of social engagement have also been associated with lower cognitive ability in old age (James et al., 2011). Furthermore, Neuroticism has been linked to poorer health-related behaviour (e.g., diet, smoking, exercise, etc.; Booth-Kewley & Vickers Jr, 1994; Mõttus et al., 2013; Rhodes & Smith, 2006; Terracciano & Costa Jr, 2004). As noted previously, these factors are all linked to cognitive outcomes, and thus may offer other possible mechanisms through which Neuroticism might influence cognitive function. In other words, it may be that individuals higher in Neuroticism are less mentally and socially active, and engage in more unhealthy behaviours, and this in turn has a negative effect on their cognitive function in old age. This suggestion has yet to be empirically examined.

As noted, the current literature provides mixed results when it comes to the relationship between Extraversion and cognitive function in older adults. Where a positive association has been found, one suggestion is that this may be due these individuals being more confident and assertive in a testing situation (Chamorro-Prezumic & Furnham, 2004). Another theory is that more extraverted individuals seek out more social stimulation in old age, and that this in turn provides a protective effect on cognition (Meier et al., 2002). Indeed, there is evidence to suggest that social activity in old age is associated with both Extraversion and cognitive function (Krueger et al., 2009). Exploring whether social engagement mediates any relationship between

Extraversion and cognitive function has been highlighted as a potentially useful approach (Curtis et al., 2015). To date, no study has tested this hypothesis.

In terms of Agreeableness, there is no clear pattern of findings to suggest a consistent relationship with cognitive function. Critically, there is also no clear rationale to explain any significant relationship beyond that of chance (Curtis et al., 2015). Agreeableness does not seem to be consistently related to either physical, social or mental activity (Rhodes & Smith, 2006; Stephan et al., 2014). Examination of any associations with this trait are therefore entirely exploratory.

2.1.4. The Present Study

The present study was designed to investigate the potential mechanisms through which personality traits might be associated with ability across a range of cognitive domains in older age, and therefore address several gaps in the current literature. Using baseline data collected as part of a large-scale intervention study, the present study examined the association between the Big Five traits and performance on measures of verbal ability, visuospatial ability, working memory, processing speed, visual memory and auditory memory. Furthermore, where significant personality-cognitive ability associations were found, the present study explored potential lifestyle mechanisms by examining the mediating effects of activity engagement and health-related behaviours. In line with the current evidence, it was predicted that a) Openness to Experience would be positively associated with ability in one or more cognitive domains, b) Conscientiousness would be positively associated with ability in one or more cognitive domains and c) Neuroticism would be negatively associated with ability in one or more cognitive domains. Furthermore, based on the findings discussed in Section 2.1.3, it was predicted that d) any positive association between Openness and cognitive ability would be mediated by higher levels of engagement in mentally demanding activities, e) any positive association between Conscientiousness and cognitive ability would be mediated by engagement in more positive health-related behaviours and f) any negative association between Neuroticism and cognitive ability would be mediated by lower levels of engagement in mentally demanding activities and/or lower levels of social engagement and/or engagement in less positive health-related behaviours. Due to the lack of consistent findings in the current literature, no predictions were made for Extraversion or Agreeableness, and all analyses regarding these traits were exploratory. However, where exploratory analyses revealed any associations between Extraversion and cognitive ability, further analyses were planned to test the hypothesis that this association would be mediated by higher levels of social engagement.

2.2. Methods

2.2.1. Participants

Participants were recruited as part of the Intervention Factory, a large-scale activity-based intervention study (to be described fully in Chapter 5). Eligible participants had to be aged 65 or over and fluent in English. Participants were excluded if they a) had been diagnosed with a neurodegenerative condition (e.g., Alzheimer's disease or Parkinson's disease) or a brain tumour; b) had previously experienced a stroke; c) had previously experienced a head injury; d) had a significant manual impairment that prevented writing with a pen or pressing keyboard buttons; e) were already engaged in all the activities offered as part of the intervention study; f) lived outside Edinburgh and the Lothians and were unable to travel to the area regularly for the duration of the intervention.

Participants were recruited via local newspaper adverts, flyers in community centres and GP surgeries, contact with local community groups and social media posts. Existing volunteer databases (Join Dementia Research [www.joindementiaresearch.nihr.ac.uk] and NHS Share [https://www.registerforshare.org]) were also utilised. A total of 416 individuals were screened for eligibility over the phone. Forty-four did not meet the eligibility criteria and were excluded. A further 36 individuals eligible individuals chose to withdraw from the study after completing the phone screening. The remaining 336 volunteers were enrolled on the study (102 males, 234 females; for sample characteristics see Table 2.1). All participants lived in Scotland, predominantly around Edinburgh and the Lothians. Participants were asked how they would describe their ethnic group; 330 (98.2%) identified as White (British/Irish/European/Other White Background).

All data reported here were collected as part of participants' baseline assessment, prior to their being allocated to an intervention group. Baseline assessments were carried out at the Edinburgh campus of Heriot-Watt University between June 2017 and December 2019. All participants provided written informed consent at the start of their assessment. The study received ethical approval from the Heriot-Watt University School of Social Sciences Ethics Committee (Ref: 2017-453) and the NHS South East Scotland Research Ethics Committee 02 (REC Ref: 17/SS/0153; SSA Ref: 17/SS/0157).

2.2.2. Materials and Measures

Cognitive Battery. Cognitive ability was assessed using the ten core subtests from the 4th (UK) edition of the Wechsler Adult Intelligence Scale (WAIS-IV; Wechsler, 2010a) and three subtests from the 4th (UK) edition of the Wechsler Memory Scale (WMS-IV [Older Adult Battery]; Wechsler, 2010b). Scores on the WAIS-IV and WMS-IV subtests were used to derive six domain-level composite measures: Verbal Comprehension (i.e., vocabulary and verbal semantic knowledge); Perceptual Reasoning (i.e., visuospatial ability and abstract reasoning); Working Memory (i.e., the ability to retain and manipulate information over short periods of time); Processing Speed (i.e., the ability to process visual information quickly); Auditory Memory (i.e., the ability to learn and recall verbal stimuli); and Visual Memory (i.e., the ability to learn and recall visual stimuli). Details of the specific subtests used to derive each composite measure are presented in Table 2.2.

Alternative composite measures can be derived from the WMS-IV by combining raw subtest scores in a different way: Immediate Memory (obtained by summing scaled scores on Logical Memory I, Verbal Paired Associates I and Visual Reproduction I) and Delayed Memory (obtained by summing scaled scores on Logical Memory II, Verbal Paired Associates II and Visual Reproduction II; see Table 2.2). Immediate and Delayed subtests were administered around 20-30 minutes apart. Immediate Memory measures the ability to remember both verbal and visual stimuli immediately following presentation. Delayed Memory measures the ability to remember the same stimuli after a delay. To avoid inflating Type I error by analysing the same data twice (i.e., by deriving both Auditory/Visual Memory scores and Immediate/Delayed Memory scores), analyses in this chapter did not examine the association between personality and Immediate Memory or Delayed Memory scores.

All WAIS-IV and WMS-IV subtests were administered and scored using tablet computers installed with the Q-interactive application (Pearson, n.d.). Both the test administrator and the participant were provided with a tablet. The administrator recorded the participant’s responses on their own tablet. For subtests involving visual stimuli (Block Design, Matrix Reasoning, Vocabulary, Arithmetic, Visual Puzzles and Visual Reproduction), this was presented on the participant’s tablet screen. For Matrix Reasoning and Visual Puzzles participants recorded their response by tapping on the screen. Raw scores for each subtest were automatically calculated by the application.

The standard procedure according to the WAIS-IV/WMS-IV manual for deriving composite scores is to first convert the relevant raw subtest scores to scaled scores, then sum the scaled scores and convert them into composite scores. Under standard procedure, raw sores are converted to scaled scores according to age-based norms (norms are grouped into five-year age groups; i.e., 65-69, 70-74 etc. up to the age of 90). This meant that the composite scores of a 65-year-old and an 85-year-old would be calculated differently, such that they were comparable within their respective age-groups, but not with each other. In order to ensure that all participants' scores were standardised in the same way, all raw subtest scores were scaled according to the norms for 65–69-year-olds. Composite scores were then calculated as normal according to the WAIS-IV/WMS-IV manual. In this way, composite scores were directly comparable between all participants and (importantly for analyses of intervention effects to be discussed later) across time points.

Where WAIS-IV composite scores were derived from three subtests and participants were missing scores on one of these subtests, the composite score in question was prorated according to instructions in the WAIS-IV manual. In the case that more than one relevant subtest score was missing, the resulting composite score could not be determined and this data point was treated as missing. The WMS-IV does not include a protocol for prorating composite scores, meaning that composite scores could not be determined when a relevant subtest score was missing.

Personality. Participants completed the UK edition of the NEO-Personality Inventory 3 (NEO-PI-3; McCrae et al., 2015). The 240-item questionnaire provides scores on each of the Big Five traits (with internal consistency estimates as follows: Neuroticism, α = .94; Extraversion, α = .90; Openness to Experience, α = .88; Agreeableness, α = .89; Conscientiousness, α = .91; McCrae et al., 2015). Each item consists of a statement, to which individuals respond on a five-point scale from Strongly Disagree to Strongly Agree. Responses are coded 0-4; trait scores are derived by summing responses across the 48 items measuring each trait.

Activity Engagement. The Victoria Longitudinal Study-Activity Lifestyle Questionnaire (VLS-ALQ) activity questionnaire (Hultsch et al., 1993) assesses engagement across a broad range of everyday leisure activities. Each item comprises a statement (e.g., "I read newspapers") with nine response options to indicate current frequency of engagement in the activity. Response options are coded as follows: 0 = Never, 1 = Less than once a year, 2 = About once a year, 3 = Two or three times a year, 4 = About once a month, 5 = Two or three times a month, 6 = About once a week, 7 = Two or three times a week, 8 = Daily.

An abbreviated 57-item version of this questionnaire measuring activity engagement across eleven domains was validated by Jopp and Hertzog (2010). The present study adapted this version in two ways. First, the wording of some of the items was amended from North American English to UK English. Second, three items from the original 70-item version that had been removed by Jopp and Hertzog (2010) were re-instated (listen to radio, attend concert/play, attend sports events), along with two new items covering activities not included in the original VLS-ALQ (go to galleries/museums, go to pubs/social clubs), leading to a total of 62 items.

Health-Related Behaviours. Smoking history was assessed by asking if participants had ever smoked a cigarette, cigar or pipe; if they were currently a smoker; the total number of years they had smoked regularly; and the average number of cigarettes they smoked per day (retrospectively if they were no longer smokers). Lifelong smoking behaviour was measured as Pack Years (average number of cigarettes smoked per day multiplied by years as a smoker, then divided by twenty; as used in Corley et al., 2012). One pack year is the equivalent of smoking twenty cigarettes per day for one year. Alcohol intake was measured by asking how often participants had drunk alcohol on average over the preceding year, and how much they typically drank (i.e., number of pints of beer/glasses of wine, etc.) in an average week/month/year (as appropriate). This was then converted into an average number of units per week. Diet was assessed by asking participants if they typically ate any of the following to excess:

a) sugar; b) salt; c) animal fats; d) junk food and snacks. Scores ranged from 0 (none of the above) to 4 (all of the above).

The short version of the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003) assessed current physical activity. The questionnaire asks individuals to consider the preceding week and record the number of days in which they engaged in at least ten minutes of vigorous activity, moderate activity and walking respectively. Individuals also record how many minutes per day they typically spent engaging in these activities. This information was used to calculate an overall measure of metabolic equivalent of task (MET) minutes-per-week (i.e., overall energy expenditure; test-retest reliability = .76; Craig et al., 2003), according to formulae specified in the IPAQ scoring guidelines. Craig et al. (2003) also examined the validity of a version of the questionnaire that asked participants to indicate activity over a 'usual week' rather than the last seven days (which theoretically may not be representative). They found that reliability of the two versions was comparable, and qualitative feedback indicated that some participants found it difficult to define a 'usual week' and deferred to the preceding week for their answers.

Demographics. Years of education was recorded as the total number of years in primary, secondary and further/higher education. The Scottish Index of Multiple Deprivation 2016 (SIMD16; Scottish Government, 2016) was used as a proxy measure of socioeconomic status. Geographical areas are ranked according to overall level of deprivation using a combination of multiple indicators (e.g., income, education, housing) and rankings are split into vigintiles (1 = most deprived to 20 = least deprived). Vigintile rankings for each participant were obtained based on their postcodes.

As an indicator of perceived health-status, participants were asked to rate their general health on a five-point scale (1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 =

Excellent). The Mini-Mental State Examination (MMSE; Folstein et al., 1975) was used as an indicator of global cognitive status. The MMSE is a standardised instrument that is widely used to detect possible cognitive impairment in both clinical and research settings. The test takes around five minutes to administer, with questions covering orientation (time and place), memory (registration and recall of three objects), concentration (spelling 'world' backwards), language (naming objects, sentence repetition and reading comprehension) and praxis (ideational [folding a piece of paper in half], copying/drawing and spontaneous writing). Scores range from 0-30; test-retest reliability estimates typically range from .80 -.95 (Tombaugh & McIntyre, 1992). MMSE scores ≤ 23 are often taken to indicate potential cognitive impairment. One participant scored below this cut-off. However, MMSE was not used as an exclusion criterion in the present study to avoid excluding individuals with low education (MMSE score has been shown to be sensitive to level of education; Crum et al., 1993).

2.2.3. Procedure

The assessment was conducted in person by a member of the research team (either the PhD student, Research Assistant or Research Associate) and normally lasted 3 to 3.5 hours. Participants first provided demographic information and information regarding their smoking, alcohol and dietary habits, then completed the MMSE, followed by the cognitive battery and the NEO-PI-3. During the session participants completed several other tests, including a physical battery, that will be described in later chapters. Given the length of the assessment, participants were offered a short break halfway through the session and were also allowed to take a break at any other point they wished. At the end of the session, participants were also given a booklet of lifestyle/wellbeing questionnaires, including the VLS-ALQ and the IPAQ, to complete at home and return by post. In the case that a questionnaire was returned with missing responses, attempts were made to contact the participant via phone or email to request their answers.

2.2.4. Statistical Analysis

Missing Data. All analyses were conducted using R (version 4.0.1; R Core Team, 2020). Across all participants and variables, 2.4% of the data was missing (2572 missing cells from 106,848 [318 variables across 336 participants]). Data were complete for 228 individuals (67.9%); the remaining 108 (32.1%) had at least some missing data. Table 2.3 provides a summary of missing data for all demographic variables, health-related behaviours and cognitive domain scores.

Seventeen participants did not return the VLS-ALQ; a further 23 returned the questionnaire with missing responses and did not respond to requests to complete these (18 participants missed one item, four participants missed two items and one participant missed five items).

Two participants did not initiate the NEO Personality Inventory, and four participants stopped before completing it (missing 120, 123, 180 and 232 items respectively). A further 28 participants completed the questionnaire with some items missing (sixteen participants missed one item, seven participants missed two items, three participants missed three items, one participant missed four items and one participant missed five items). One participant's questionnaire was deemed invalid according to the protocol in the NEO-PI-3 manual: the participant selected the neutral response for more than 10 consecutive items.

To examine possible systematic patterns of missingness, responders and non-responders were compared on all variables. For the sake of brevity, all individuals missing at least one item in one of the multi-item questionnaires (VLS-ALQ or NEO-PI-3) were grouped together and compared to those who responded to all items. Results of the comparisons are presented in Appendix A. Briefly, participants with missing values tended to have fewer years of education and lower average scores on the measures of cognitive ability. As such, conducting analysis using listwise deletion would risk the systematic exclusion of individuals with lower cognitive ability.

Missing data were dealt with via multiple imputation. Schafer (1999) provides an accessible overview of the multiple imputation approach. Multiple imputation involves the replacement of missing values with a set of $m > 1$ plausible values, resulting in m complete sets of data containing varying estimates of the missing values. Standard statistical methods are then applied to each of these datasets, and parameter estimates and standard errors are pooled into a single set of results according to formulae suggested by Rubin (2004). In comparison to more conventional approaches to missing data (e.g., listwise deletion, single imputation), multiple imputation yields unbiased parameter estimates provided data are missing at random (MAR; i.e., missingness in a given variable does not depend on the variable itself, but may depend on other variables; Enders, 2010; Sinharay et al., 2001).

Multiple imputation by chained equations was carried out using the mice package in R (version 3.12.0; van Buuren & Groothuis-Oudshoorn, 2011). Predictive mean matching (PMM) was the selected imputation method for all variables. Briefly, predictive mean matching works by estimating a regression model that predicts values of the outcome variable with missing data using other observed variables as predictors. Predicted values for missing data are then compared to predicted values for complete cases. A subset of the complete cases for which the predicted value most closely matches the predicted value of a given missing datapoint are selected. A value is randomly selected from this subset, and the corresponding observed value is substituted in for the given missing data point. This is done for all missing data points. The process is repeated over multiple iterations for each imputed dataset. Based on White, Royston and Wood’s (2011) rule of thumb (the number of imputations should at least be equal to the percentage of missing data), five datasets were imputed, each over 20 iterations. The imputation model included all variables used in any subsequent analyses, along with two additional auxiliary variables, discussed below. Analyses were conducted on each dataset and pooled results are reported.

For the multi-item questionnaires (VLS-ALQ and NEO-PI-3), multiple imputation was conducted on the item responses rather than domain-level scores (i.e., trait scores on the NEO-PI-3). Studies have shown that applying MI using PMM to questionnaire data at the item level results in less biased estimates (Eekhout et al., 2014). For the NEO-PI-3, after item-level scores were imputed, they were summed as normal to provide trait scores which were subsequently used in analyses.

Mean comparisons indicated that participants with missing data on some variables scored significantly lower on the MMSE and had significantly lower self-rated health (see Appendix A). These variables were therefore included as auxiliary variables in the imputation model, as evidence suggests that an inclusive strategy that incorporates potential causes of missingness can reduce bias and make the MAR assumption more plausible (Collins et al., 2001; Enders, 2010).

Exploratory Factor Analysis. Exploratory factor analysis (EFA) was used to establish the underlying factor structure of the adapted version of the VLS-ALQ. Analyses were conducted using the fa() function in the psych package (version 1.9.12; Revelle, 2019) in R. In line with the approach suggested by Nassiri et al. (2018), the EFA was conducted on the pooled Pearson correlation matrix of all imputed datasets (Pearson correlations have been recommended as appropriate for use when ordinal variables have five or more response categories and are approximately normally distributed; Lloret-Segura et al., 2014). Correlations were computed using the micombine.cor() function in the miceadds package (version 3.9-14; Robitzsch & Grund, 2020).

A combination of parallel analysis (Horn, 1965) and Velicer's Minimum Average Partial (MAP; 1976) test was used to establish the possible number of factors. Parallel analysis compares the eigenvalues of the observed data to those obtained from simulated random data of the same size; only the observed eigenvalues that are greater than those in the random data are retained. Evidence suggests that parallel analysis on the pooled correlation matrix performs well in determining the correct number of factors when multiple imputation is used (Goretzko et al., 2019). Velicer's MAP test calculates the necessary number of factors to extract in order to minimise the average squared partial correlation of the correlation matrix. The number of factors suggested by parallel analysis was used as a maximum estimate, while MAP was used to indicate a minimum; all possibilities in between were investigated.

The fa() function in the psych package (version 1.9.12; Revelle, 2019) was used to estimate models. All models were estimated using maximum likelihood with oblique (oblimin) rotation to allow for correlations between factors. Given the distributional assumptions of maximum likelihood estimation, any items that were substantially non-normal (absolute univariate skew > 2 and/or absolute univariate kurtosis > 7; Curran et al., 1996) across all imputations were excluded prior to conducting the analysis. Any item that did not correlate at a magnitude of at least .3 with one or more other items was also excluded (Tabachnick & Fidell, 2001). Finally, any item with a Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy value of less than 0.5 (the bare mimimum proposed by Kaiser, 1974) was excluded. Models were then estimated on the remaining pool of items. Bartlett's test was conducted to ensure that correlations between these items were of sufficient size for EFA. The determinant of the item correlation matrix was calculated to assess multicollinearity among the items (a value > .00001 can be taken as indicating an absence of multicollinearity; Yong & Pearce, 2013).

For each possible number of factors, models were estimated, then moderated in an iterative fashion by removing items with no pattern coefficients (i.e., loadings) of at least .3 on any factor, and items loading on multiple factors (according to Hofmann's index of complexity; Hofmann, 1978). Models were deemed viable once all items primarily loaded on one factor and each factor had at least three items loading on it (a minimum that has been suggested as more items per factor improves factor stability; Floyd & Widaman, 1995; Lloret-Segura et al., 2014). The most appropriate number of factors was decided by examining and comparing each model's root mean square error of approximation (RMSEA; values < .05 indicating good fit, values .05 - .08 indicating adequate fit; Browne & Cudeck, 1992), Tucker-Lewis Index (TLI; values ≥ .95 indicating good fit; Hu & Bentler, 1999) and conceptual interpretability. Once the appropriate factor model was selected, activity domain scores were calculated by summing responses to the relevant items for each factor.

Regressions and Mediation Model. Bivariate correlations between personality traits, activity domain scores, health-related behaviours and cognitive domain scores were computed. To investigate the unique associations between personality and each cognitive domain, a series of multiple regression analyses were then conducted, including all five traits as predictors while also controlling for demographic covariates (age, gender, deprivation and education). Pooled regression estimates were calculated using the pool() function in the mice package.

Path analysis was employed to investigate possible indirect effects of personality on cognitive ability via activity engagement/health-related behaviour. The runMI() function in the semTools package (version 0.5-3; Jorgensen et al., 2020) was used to fit the path model in each imputed dataset and pool the parameter estimates. Only those personality-cognition associations that were significant in the regressions were modelled. Potential mediators were included in the model on the basis of prior hypothesised relationships and observed correlations. Variables that were theorised to act as mediators were included in the model only if they were significantly correlated with both the relevant personality trait(s) and one or more cognitive outcome in the expected direction. For example, it was hypothesised that any negative association between Neuroticism and cognitive ability would be mediated by health-related behaviour. Therefore, any health-related behaviour variable that was significantly correlated with both Neuroticism and a cognitive outcome would be included as a mediating variable, provided that Neuroticism was a significant predictor of that same cognitive outcome. As correlations were used to suggest associations to be tested in the full model rather than directly to draw conclusions, uncorrected *p*-values were used for this purpose (Bonferroni-corrected *p*-values were also calculated and are reported below). Model fit was assessed based on χ^2 test (non-significance indicating good fit; Bowen & Guo, 2011), comparative fit index (CFI; values > .95 indicating good fit; Hu & Bentler, 1999) and RMSEA.

2.3. Results

2.3.1. Exploratory Factor Analysis

Initial Examination of Items. An initial examination of the distribution of the 62 activity items across imputations revealed several items with non-normal distributions. Eight items consistently had an absolute skew value greater than 2. Four items were extremely positively skewed (i.e., individuals tended to rarely engage in the activity) and four items were extremely negatively skewed (i.e., individuals tended to engage in the activity every day). Two of these items (‘Watch TV news’ and ‘Use computer’) also had kurtosis values greater than 7. These items were excluded from further analysis. A further 23 items were excluded due to consistently low correlations (< .3) with other variables. Item-level KMO was then checked; one item (‘Watch TV comedy/adventure’) had a KMO < .5 and was excluded. Following this, another item

(‘Watch TV game shows’) no longer had any correlations > .3, and was also excluded. Details of the specific items excluded are listed in Table 2.4. EFA was conducted on the remaining 29 items.

The overall KMO indicated the suitability of the data for factor analysis was adequate (KMO = .69). Item-level KMO values ranged from .55 to .79 (see Table 2.5). Bartlett’s test of sphericity, χ^2 (406) = 2020.58, $p < .001$, indicated that item correlations were of an acceptable magnitude for EFA. The determinant of the correlation matrix did not indicate any problem with multicollinearity among the items (determinant = .002).

Factor Extraction. The MAP test suggested that a minimum average squared partial correlation of 0.01 was achieved after extracting three factors. Parallel analysis suggested that eight factors had eigenvalues greater than would be expected by chance (see Figure 2.2). Thus, all possibilities within the range of three to eight factors were explored.

The eight and seven-factor models failed to meet the outlined criteria for viability (exclusion of problematic items led to some factors being defined by only one or two primary loadings). The six-factor model met the specified criteria after seven items were excluded, the five-factor model did so after ten items were excluded, the four-factor model did so after nine items were excluded, and the three-factor model did so after twelve items were excluded.

The six-factor model was found to have the lowest RMSEA value (0.036), indicating good fit (see Table 2.6). The five and six factor models had the joint highest TLI value (.918; see Table 2.6), although both were below the cut-off threshold for good model fit of .95 recommended by Hu and Bentler (1999). Therefore, given that the six-factor model had the lowest RMSEA value, and the factors identified in the six-factor model were conceptually sound, this model was selected as the optimal factor structure for the activity items. The pattern matrix and structure matrix for the six-factor model are presented in Tables 2.7 and 2.8. Pattern/structure matrices for the three, four, five, seven and eight factor solutions are presented in Appendix B.

Bolded pattern coefficients presented in Table 2.7 indicate primary loadings. The items that loaded primarily on the first factor were all related to manual, practical skills (e.g., 'Do household repairs [for example, painting or leaky faucets]', 'Repair a mechanical device [for example, a car or lawn mower]'); this factor was named Manual. The items that loaded primarily on the second factor indicated an interest in learning and culture (e.g., 'Engage in creative writing, writing poems, writing newspaper articles, etc.', 'Read books or magazines as part of my job, career, or formal education'); this factor was named Intellectual. Items such as 'Play card games (for example, Bridge)' and 'Play word games (for example, Scrabble)' loaded primarily on the third factor; this factor was named Games.

The fourth factor was primarily explained by loadings from items associated with religion (e.g., 'Attend church or other religious services', 'Attend organised social events [for example, activities at the community centre or church social groups]'); this factor was named Religious. Items related to physical activity loaded primarily on the fifth factor (e.g., 'Do aerobics [for example, cardiovascular, fitness training, or workout]', 'Do weight lifting, strength training or calisthenics'); this factor was named Exercise. The sixth factor was primarily explained by a very large loading of 'Visit relatives, friends or neighbours' and two less substantial loadings of 'Talk on the phone to friends or relatives' and 'Go out with friends'; this factor was named Social.

The structure coefficients presented in Table 2.8 can be interpreted as the correlations between the items and the factors (Graham et al., 2003). The structure coefficients mirrored the pattern coefficients, indicating that no items were highly correlated with more than one factor. Of note was the near-perfect correlation (rounded up from 0.997) between the item ‘Visit relatives, friends or neighbours’ and the Social Activity factor. Correlations between factors were generally low (Table 2.7). The largest correlation (albeit considered a small effect size) was a positive one between Intellectual and Exercise (r = .26).

For comparison, a complete-case analysis was also conducted on only those participants who had no missing responses for the 22 items included in the six-factor solution reported above (N = 311). The six factors extracted were conceptually identical to those reported above, and the pattern of loadings was the same (see Appendix C). Collectively, the factors explained 43.7% of the variance, and fit indices were largely comparable (RMSEA = 0.048 [90% CI = 0.037, 0.060], TLI = .880).

For descriptive purposes, omega reliability coefficients were calculated for each factor using the complete cases (omega being recommended as a more appropriate measure than Cronbach’s alpha when factor loadings are unequal; McNeish, 2018). Estimates were computed using the ci.reliability() function in the MBESS package (version 4.7.0; Kelley, 2020). Reliability coefficients were as follows: Manual (ω = 0.85), Intellectual (ω = 0.69), Games (ω = 0.69), Religious (ω = 0.72), Exercise (ω = 0.66), Social (ω = 0.65).

The items that primarily loaded on each factor were summed to provide activity domain scores. Scores in the Social domain were taken as the primary indicator of social engagement frequency. Scores in the Exercise domain were taken as the primary indicator of physical engagement frequency. An additional physical activity questionnaire (the IPAQ) was also administered; scores from this measure (MET-minutes per week) were also included in analyses as an indicator of normal level of weekly physical exertion. While the VLS-ALQ does not measure mental engagement directly, there was a notable overlap among items measuring three of the activity domains from the VLS-ALQ (Manual, Intellectual and Games) and items used to measure mental engagement in previous studies; these domains were thus taken as indicators of different ‘types’ of mental engagement frequency.

Mean comparisons between males and females on activity domain scores are presented in Table 2.9. On average, men scored significantly higher than women in the Manual domain, while women scored significantly higher in the Religious and Social domains. There were no significant correlations between any of the activity domain scores and either age, deprivation, self-rated health or MMSE score (see Table 2.9). Years of education demonstrated small but significant positive correlations with scores in the Manual (r = .14, p < .05), Intellectual (r = .30, p < .001) and Exercise (r = .12, p < .05) domains. Scores in the Exercise domain were significantly positively correlated with total MET-minutes per week from the IPAQ (r = .26, p < .001), as were scores in the Intellectual domain (r = 0.14, p < .05).

2.3.2. Correlations

Table 2.10 shows correlations between cognitive domain scores, personality traits, activity domains and health-related behaviours. As Pack Years consistently demonstrated a notably skewed distribution (univariate skew > 2.5 across all imputations), Spearman’s rank correlation coefficients were computed for all associations involving this variable.

Personality-cognition correlations were generally small to moderate in size. Openness to Experience demonstrated the largest correlations with cognitive outcomes, all of which were significant except for Working Memory (rs = .14 - .31, ps < .05). Neuroticism was negatively correlated with Perceptual Reasoning (r = -.12, p < .05) and Visual Memory (r = -.13, p < .05). Agreeableness was positively correlated with Auditory Memory (r = .16, p < .05) and Visual Memory (r = .12, p < .05). Neither Extraversion nor Conscientiousness were significantly correlated with any of the cognitive outcomes.

Neuroticism was positively correlated with Diet ($r = .29$, $p < .001$) and Pack Years ($\rho = .17$, $p < .01$), suggesting that individuals higher in Neuroticism tended to eat more unhealthy foods and smoke more over their lifetime. Neuroticism was also negatively correlated with scores in the Social activity domain ($r = -.14$, $p < .05$). Extraversion was positively correlated with MET-minutes per week ($r = .19$, $p < .01$), as well as scores in several activity domains (Games: $r = .15$, $p < .01$; Intellectual: $r = .17$, $p < .01$; Social: $r = .32$, $p < .001$). Openness was negatively correlated with Pack Years ($\rho = -.11$, $p < .05$), and positively correlated with scores in the Games ($r = .16$, $p < .05$), Intellectual ($r = .30$, $p < .001$), Exercise ($r = .14$, $p < .01$) and Social ($r = .12$, $p < .05$) activity domains. Higher Agreeableness was correlated with healthier diet ($r = -.12$, $p < .05$), fewer Pack Years ($\rho = -.18$, $p < .001$), lower scores in the Manual domain ($r = -.23$, $p < .001$) and higher scores in the Religious ($r = .13$, $p < .05$) and Social ($r = .13$, $p < .05$) domains. Conscientiousness was correlated with Diet and Pack Years, such that more conscientious individuals had a healthier diet ($r = -.26$, $p < .001$) and smoked less ($\rho = -.16$, $p < .01$). Conscientiousness was not significantly related with scores in any of the activity domains.

Alcohol consumption was positively correlated with scores in Perceptual Reasoning ($r = .15$, $p < .01$) and Working Memory ($r = .19$, $p < .001$). Pack Years was negatively correlated with Perceptual Reasoning ($\rho = -.13$, $p < .05$), Processing Speed ($\rho = -.20$, $p < .001$), Auditory Memory ($\rho = -.13$, $p < .05$) and Visual Memory ($\rho = -.17$, $p < .01$). MET-minutes per week and Diet were not significantly related to any of the cognitive outcomes.

Scores in the Manual activity domain were positively correlated with Verbal Comprehension ($r = .19$, $p < .01$), Perceptual Reasoning ($r = .28$, $p < .001$), and Visual Memory ($r = .13$, $p < .05$). Intellectual domain scores were positively correlated with Verbal Comprehension ($r = .19$, $p < .001$). There were also significant negative correlations between scores in the Religious domain and both Perceptual Reasoning (r = -.13, $p < .05$) and Working Memory (r = -.12, $p < .05$). There were no significant correlations between Games or Social domain scores and any cognitive outcomes.

2.3.3. Regressions

Multiple regression models predicting each cognitive domain score are presented in Table 2.11. Adjusted R^2 estimates for each model were as follows: Verbal Comprehension, adjusted R^2 = 0.32 (95% CI = 0.24, 0.41); Perceptual Reasoning, adjusted R^2 = 0.26 (95% CI = 0.18, 0.34); Working Memory, adjusted R^2 = 0.14 (95% CI = 0.08, 0.22); Processing Speed, adjusted R^2 = 0.22 (95% CI = 0.15, 0.31); Auditory Memory, adjusted R^2 = 0.14 (95% CI = 0.07, 0.23); Visual Memory, adjusted R^2 = 0.17 (95% CI = 0.10, 0.25).

When controlling for other personality traits and demographic covariates, Openness to Experience significantly predicted Verbal Comprehension and Perceptual Reasoning; those who scored higher on Openness showed higher scores in these domains. Conversely, higher Neuroticism was a significant predictor of lower scores in Verbal Comprehension, Perceptual Reasoning and Visual Memory. The only cognitive domain for which Conscientiousness was a significant predictor was Working Memory; contrary to what was hypothesised, higher Conscientiousness predicted lower scores. Extraversion demonstrated the same patterns of association as Neuroticism, significantly negatively predicting Verbal Comprehension, Perceptual Reasoning and Visual Memory. Agreeableness did not significantly predict any of the cognitive outcomes.

Age was a significant predictor of scores in all cognitive domains except Verbal Comprehension, with older adults scoring lower. This association was largest for Processing Speed. Women scored significantly lower than men in Verbal Comprehension, Perceptual Reasoning and Working Memory, but scored significantly higher in Processing Speed. There were no significant gender differences in memory scores. Having more years of education significantly predicted higher scores in all cognitive domains except Processing Speed. Living in a less deprived area significantly predicted higher scores in Perceptual Reasoning, Working Memory and Processing Speed.

Analyses were repeated on only those participants who had complete data for all study variables (N = 240; see Appendix D). The relative contribution of the predictors was consistent with those reported above, and the hypothesised associations (i.e., the positive relationships between Openness and Verbal Comprehension/Perceptual Reasoning and the negative relationships between Neuroticism and Verbal Comprehension/Perceptual Reasoning/Visual Memory) remained significant.

2.3.4. Path Analysis

In examining the potential mechanisms underpinning the observed personality-cognitive ability associations, several conditional hypotheses were offered. Two of these were ruled out immediately. First, where a significant positive association between Conscientiousness and cognitive ability was found, it was hypothesised that this association would be mediated by positive health-related behaviour. While Conscientiousness was correlated with some healthier behaviours, the only significant unique association between Conscientiousness and cognitive ability was negative. Second, it was hypothesised that any positive association between Extraversion and cognitive ability would be mediated by increased social engagement. Although there was a positive correlation between Extraversion and the Social activity domain, this prediction was not supported as the observed associations between Extraversion and cognitive ability are all either non-significant or significantly negative.

It was hypothesised that positive associations between Openness and cognitive ability would be mediated by increased mental engagement. Openness was positively associated with Verbal Comprehension; the Intellectual activity domain score was also positively correlated with both Openness and Verbal Comprehension, which suggested it could potentially mediate the relationship between the two. It was also hypothesised that any negative associations between Neuroticism and cognitive ability would be mediated by lower mental activity and/or lower social activity and/or poorer health-related behaviour. Neuroticism significantly predicted lower scores in Verbal Comprehension, Perceptual Reasoning and Visual Memory. The only hypothesised mediator that was significantly correlated with both Neuroticism and any of these cognitive outcomes was Pack Years; those who smoked more tended to have higher levels of Neuroticism and also scored lower on both Perceptual Reasoning and Visual Memory.

As such, the full mediation model included the indirect effect of Openness on Verbal Comprehension via the Intellectual activity domain score, and the indirect effects of Neuroticism on both Perceptual Reasoning and Visual Memory via Pack Years, as well as any other significant personality and covariate direct effects identified in the regression models[1]. Due to the skewed distribution of Pack Years, the model was estimated using maximum likelihood with Satorra-Bentler rescaling of test statistics and robust standard error estimates, as recommended by Finney and DiStefano (2006). For estimates of indirect effects, the monteCarloMed() function in the semTools package was used to calculate Monte Carlo confidence intervals (Preacher & Selig, 2012).

Fit indices indicated that model fit was poor to adequate: $\chi^2(21) = 57.53$, $p < .001$; CFI = 0.91; RMSEA = 0.074 (90% CI = 0.052, 0.098). Parameter estimates are presented in Table 2.12. None of the hypothesised indirect effects were significant, with confidence intervals crossing zero for all three. As can be seen in Figure 2.3, the

[1] The terms 'indirect effect' and 'direct effect' are commonly used in path modelling to differentiate between patterns of association that include or do not include a mediating variable. It is important to emphasise that, while the word 'effect' implies causality, causal relationships among variables cannot be definitely ascribed using cross-sectional data like those reported here.

association between Intellectual activity domain score and Verbal Comprehension score was non-significant. Neuroticism was not significantly associated with Pack Years, nor was Pack Years significantly associated with Perceptual Reasoning or Verbal Memory.

The path analysis was also repeated with complete cases; estimates of indirect effects were comparably small and remained non-significant (see Appendix D).

2.4. Discussion

A growing body of research shows that individual differences in personality are associated with cognitive outcomes in old age. The present study built on these findings by examining whether these associations are mediated by lifestyle variables such as activity engagement or health-related behaviour. Results provided support for several of the hypothesised direct associations. However, there was no evidence that these associations were mediated by any of the proposed lifestyle variables.

2.4.1. Openness to Experience

It was predicted that higher scores in Openness to Experience would be associated with higher scores in one or more cognitive domains. Results supported this hypothesis. Higher scores on the trait of Openness to Experience were found to predict higher scores in Verbal Comprehension and Perceptual Reasoning. This is in line with previous studies that have shown Openness to predict both verbal ability (DeYoung et al., 2014; Ihle et al., 2016; Jackson et al., 2020; Sharp et al., 2010) and visuospatial/reasoning ability (Baker & Bichsel, 2006; Jackson et al., 2020; Sharp et al., 2010; Soubelet & Salthouse, 2010; Sutin, Stephan, Luchetti, et al., 2019). Unlike in some studies (e.g., Sutin, Stephan, Luchetti, et al., 2019), Openness did not significantly predict scores in Working Memory, Processing Speed, Auditory Memory or Visual Memory.

Chamorro-Premuzic and Furnham’s (2004) model of the relationship between personality and cognitive ability suggested that Openness may exert a particular effect on verbal ability via increased mental engagement, as such engagement leads to greater acquisition of knowledge. Findings regarding this domain-specific theory are mixed; two studies have found that activity engagement mediated the relationship between Openness and verbal ability (Hogan et al., 2012; Ihle et al., 2016) while another found no such effect (Soubelet & Salthouse, 2010). In the present study, the indirect association between Openness and Verbal Comprehension via engagement in the Intellectual domain was not significant. In other words, there was no evidence to support the hypothesis that the relationship between Openness and verbal ability can be accounted for by activity engagement. This is particularly notable as the activities that comprise the Intellectual domain may well stimulate the kind of new learning and knowledge acquisition that could enhance verbal ability (e.g., reading, attending public talks, visiting galleries or museums).

One alternative explanation for the observed associations is that higher cognitive ability may actually influence Openness to Experience. There is some evidence in support of this theory. Gow et al. (2005b) found that significant positive associations between global cognitive ability in old age and both Openness and mental engagement became non-significant when controlling for premorbid (age 11) global ability. These findings, contrary to the investment theory, suggest that Openness, mental engagement and higher levels of cognitive ability in old age are related because they are all the result of higher levels of cognitive ability throughout the lifespan. In other words, rather than higher ability being a result of more open individuals investing in their cognitive ability, it may be the case that those with initially higher levels of cognitive ability become more open and choose to live a more mentally engaged lifestyle. However, another study found that mental engagement significantly mediated the association between Openness and verbal ability, even when controlling for premorbid ability (Hogan et al., 2012). In this case, regardless of how high functioning an individual was to begin with, higher Openness still predicted higher mental engagement, which in turn predicted higher verbal ability. Future studies should continue to investigate the possibility of reverse causation, to better understand the exact nature of the relationship between Openness to Experience and cognition in old age.

2.4.2. Neuroticism

As predicted, Neuroticism was negatively associated with performance in three cognitive domains (Verbal Comprehension, Perceptual Reasoning and Visual Memory). The observed negative association between Neuroticism and verbal ability is in line with previous findings (Chamorro-Premuzic et al., 2006; Hogan et al., 2012). Neuroticism was not associated with memory for verbal stimuli in the present study, in contrast to previous findings of a negative association (Aiken-Morgan et al., 2012; Klaming et al., 2017). Neuroticism did, however, predict lower memory for visual stimuli. The fact that Neuroticism was associated with both Perceptual Reasoning and Visual Memory suggests that this trait may be particularly relevant when it comes to the processing of visual stimuli. Previous findings support this; Sutin, Stephan, Lucetti et al. (2019) found that higher Neuroticism predicted lower scores on tests of visuospatial ability and visual memory. Chapman et al. (2017) also found evidence of a negative association between Neuroticism and visuospatial ability.

It was hypothesised that less positive health related behaviours would mediate the association between Neuroticism and cognitive ability. There was some evidence to support the suggestion that Neuroticism would predict less healthy behaviour. Neuroticism scores were significantly correlated with diet, such that more individuals scoring higher on this trait tended to eat more unhealthy foods. Mõttus et al. (2013) previously reported similar findings; in their study, older adults who scored higher in Neuroticism were more likely to maintain a convenience diet (i.e., higher intake of meat and processed foods) and less likely to maintain a healthier, Mediterranean-style diet.

The current results showed that Neuroticism was also positively correlated with pack years (although this correlation was not significant when adjusted for multiple tests, so should be interpreted with caution). Neuroticism has previously been linked to smoking behaviour; a study including adults of all ages found that current smokers scored significantly higher in Neuroticism (Terracciano & Costa Jr, 2004) and another study of older adults reported a significant positive correlation between Neuroticism and pack years (Booth et al., 2014). A previous meta-analysis found evidence of a small negative correlation between Neuroticism and physical activity (r = -.11; Rhodes & Smith, 2006). The present study found no such association, although the study may have lacked the power to detect so small an effect. Few studies of older adults have examined the relationship between Neuroticism and alcohol consumption. The present study found no evidence that the two variables were correlated, unlike Booth et al. (2014) who reported a small negative correlation.

Results indicated that smoking history (pack years) was negatively correlated with scores in several cognitive domains. Several previous studies have reported associations between smoking and poorer cognitive outcomes in old age (Collins et al., 2009; Corley et al., 2012; Starr et al., 2007). Of particular interest here was the fact that pack years was, like Neuroticism, negatively correlated with performance in Perceptual Reasoning and Visual Memory. Analysis therefore examined whether the association between Neuroticism and performance in these domains was mediated by pack years. The hypothesised indirect effects were both non-significant in the specified model. In other words, we found no evidence that the negative association between Neuroticism and visuospatial ability or visual memory could be accounted for by lifetime smoking behaviour. Given that correlations between pack years and Neuroticism, Perceptual Reasoning and Visual Memory all became non-significant when adjusted for multiple tests, it cannot be ruled out that these associations are simply due to chance.

2.4.3. Conscientiousness

It was also hypothesised that higher Conscientiousness would be associated with higher cognitive ability in one or more domain. No evidence was found to support this hypothesis. In contrast, the only significant association between Conscientiousness and cognitive ability was a negative one with Working Memory. This finding was unexpected; Conscientiousness measures individual levels of self-control and organisation (McCrae & John, 1992; Roberts et al., 2005), dispositions that would seem to be useful in performing tasks measuring working memory (e.g., digit span). Few studies have examined the relationship between Conscientiousness and Working Memory; those including younger adults have typically reported no association (Fleming et al., 2016; Unsworth et al., 2009). The only other study to examine the association in a sample of older adults reported a significant positive association between Conscientiousness and a measure of working memory (Baker & Bichsel, 2006). One study (including younger adults) did report a negative association between Conscientiousness and performance on an *n*-back task (Waris et al., 2018), while another (also including younger adults) reported a negative association between Conscientiousness and performance on a letter-number sequencing test (Soubelet, 2011). It has been theorised that this negative association may be compensatory; older adults with lower working memory capacity may behave more conscientiously to offset difficulties with processing complex information (Chamorro-Prezumic & Furnham, 2004; Soubelet, 2011). However, when Soubelet (2011) tested whether working memory mediated the association between age and Conscientiousness, they found the indirect effect to be non-significant, suggesting that working memory ability does not account for any age differences in this trait. Given these inconsistencies, further evidence is needed to support this theory.

2.4.4. Extraversion and Agreeableness

No hypotheses were offered regarding the traits of Extraversion and Agreeableness. As is common in most studies, no significant associations were found between Agreeableness and performance in any of the cognitive domains. Extraversion, however, was found to be significantly negatively associated with Verbal Comprehension, Perceptual Reasoning and Visual Memory. In the context of previous studies, these results are relatively novel. Unlike the present findings, Sutin, Stephan, Luchetti et al. (2019) reported no evidence of an association between Extraversion and visuospatial ability or visual memory. Another study found positive associations between Extraversion and performance on tests of verbal fluency (which require the integration of multiple cognitive domains, including word knowledge; Sutin, Stephan, Damian, et al., 2019). A meta-analysis including participants of all ages also reported a small but positive overall association between Extraversion and verbal ability (Wolf & Ackerman, 2005).

It has been suggested that more extraverted individuals may be less comfortable in a formal, restricted testing environment and that this may interfere with their performance (Costa et al., 1976), although there is little empirical evidence to support this. It is also possible that performance among more extraverted individuals may be affected by the level of social interaction or dialogue within a specific cognitive test. While the testing environment for the present study was somewhat formal, participants were allowed breaks and were generally interacting with a member of the research team at all times, suggesting that social stifling may not adequately explain these findings. Furthermore, the tests that comprise the Verbal Comprehension domain involve more interaction with the researcher than others, yet more extraverted individuals still performed worse. The vast heterogeneity in findings regarding Extraversion would seem to suggest that study-specific factors may be influencing associations. Further research on the domain specific associations between cognition and Extraversion, with greater consideration of the influence of testing environment, is clearly necessary.

2.4.5. Measuring Activity Engagement

One of the benefits of this study was the more nuanced measure of activity engagement provided by the adapted VLS-ALQ. The items that loaded on the Manual, Games, Religious, Exercise and Social factors also loaded on conceptually similar factors in a previous analysis conducted on the VLS-ALQ (termed Crafts, Games, Religious, Physical and Social-Private respectively; Jopp & Hertzog, 2010). The Manual activity domain reported here is similar to the Realistic activity domain in the questionnaire described in Parslow et al. (2006), and Ghisletta et al. (2006) also reported domains similar to the Games and Religious domains (termed Leisure and Religious respectively). The fact that the activity domains identified in the present study reflect those of other questionnaires provides more confidence that they reflect meaningful distinctions in the types of activities people engage in.

The VLS-ALQ measures frequency of engagement and does not assume relative level of mental demand of the activities themselves. However, there were clear similarities between several of the activity domains identified here and measures of mental engagement reported elsewhere. Items that loaded on the Intellectual domain (e.g., writing, reading) and the Games domain (e.g., word games, card games) are commonly used to measure mental engagement in other studies (e.g., Carlson et al., 2012; Verghese et al., 2006; Wilson et al., 2003). Another measure of mental engagement also includes items similar to those that load on the Manual domain (e.g., household repairs; Schinka et al., 2005). Engagement in these different domains was not consistently associated with cognitive ability. Scores in the Manual domain were significantly positively correlated with Verbal Comprehension, Perceptual Reasoning and Visual Memory. Scores in the Intellectual domain were only correlated with Verbal

Comprehension. Scores in the Games domain were not correlated with performance in any of the cognitive domains. These findings should be interpreted with caution as only the correlation between engagement in the Manual domain and Perceptual Reasoning remained significant after adjusting for multiple tests. Further research is necessary to establish exactly how mentally engaging these different types of activity are, but the current findings suggest that different types of mental engagement might be related (or indeed unrelated) to cognition in different ways.

Adopting a more nuanced measure of activity engagement that focused on several specific types of engagement may also explain why we found no mediation of the Openness-cognition association. It may be the case that there is no one specific type of activity that accounts for the association between Openness and cognition, but rather it is the overall range of activities that is important. Jackson et al. (2020) reported that a measure of activity diversity (i.e., the raw number of activities engaged in over a typical week) had a stronger relationship with Openness to Experience than time spent engaging in a subset of mentally engaging activities. This measure of activity diversity significantly mediated the positive associations between Openness and performance in several cognitive domains. The authors suggested that more open individuals may have to manage a busier repertoire of activities in their day-to-day life, which may place demands on higher level cognitive functions and in turn confer a protective effect.

2.4.6. Limitations and Future Directions

It is important to note that the cross-sectional nature of this study precludes any definitive conclusions regarding the causal direction of any observed relationships. Ihle et al. (2019) instead adopted a longitudinal approach and found that higher baseline Openness to Experience was associated with smaller cognitive decline over time, and that this association was mediated by higher initial levels of activity engagement. Such results provide stronger evidence of a protective effect of Openness via activity engagement on cognition over time. Future studies could adopt this approach to further examine whether associations between personality traits and change in cognition over time are mediated by lifestyle factors.

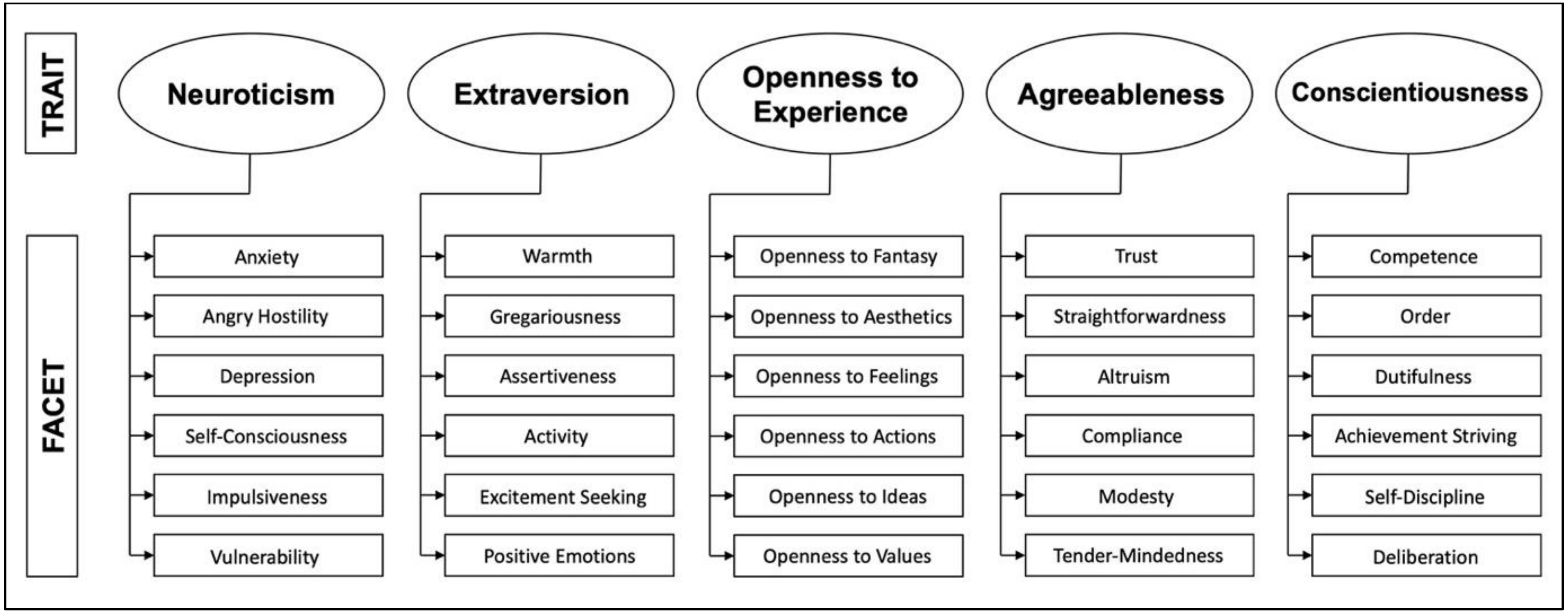
It is also likely that the present results were influenced by the self-selecting nature of the volunteer sample of participants. The sample was generally well educated and from less deprived areas, and it is possible that such individuals show similar patterns of activity engagement. The highly skewed distribution of pack years in the current sample is indicative of the fact that most led healthy lives and tended to avoid unhealthy behaviours. It is therefore likely that lack of variability within the sample could have biased results. Future studies using larger, more diverse and representative samples are strongly encouraged.

2.4.7. Conclusion

Understanding how personality might be related to cognition in old age is important to identify not only which individuals represent a model approach to healthy ageing, but which individuals might be at risk of cognitive decline in old age. The results presented here support previous findings indicating that those who score lower on the trait of Openness to Experience and higher on the trait of Neuroticism may be at greater risk of poor cognitive health in old age. In contrast to previous findings, mental engagement was not found to mediate observed associations between Openness and cognitive ability. This study is also the first to examine whether poorer health-related behaviours mediate the relationship between Neuroticism and cognitive ability; no such effect was observed. Further research is needed to investigate the exact nature of the causal relationship between personality traits, lifestyle factors and cognitive ability in old age.

Figure 2.1

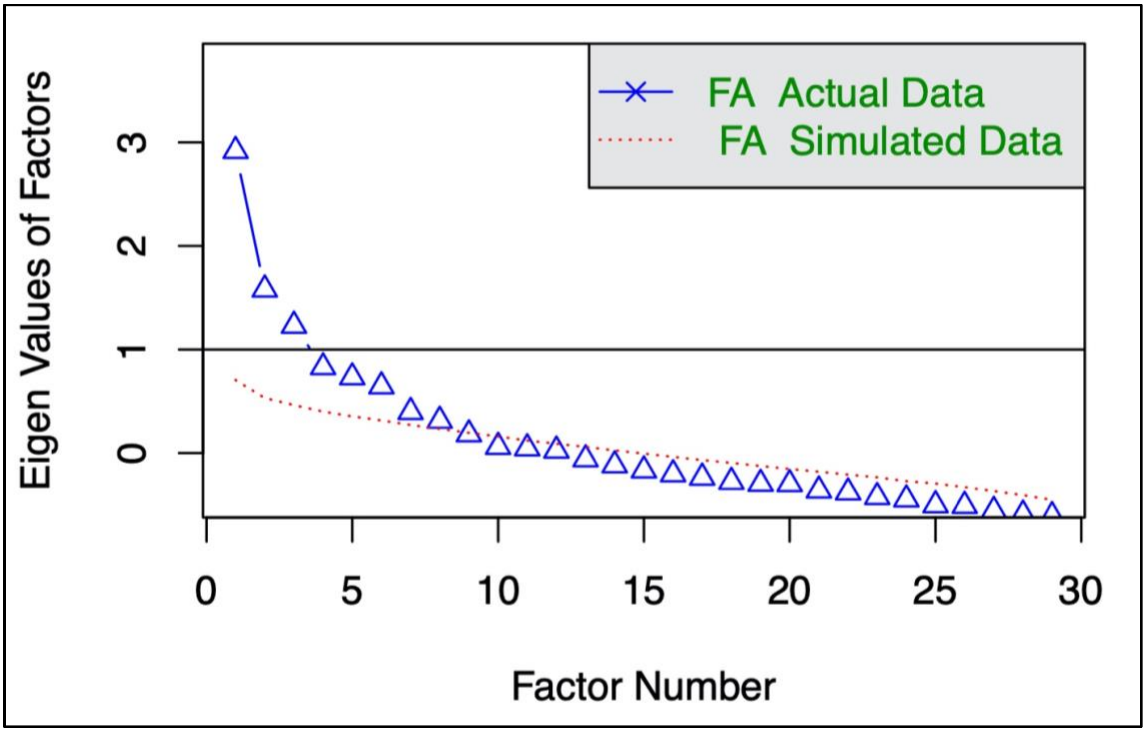
NEO Personality Inventory Five Factor Model Hierarchical Structure



Note. Lower order facets measured by the NEO Personality Inventory 3rd UK Edition (McCrae, Costa and Lord, 2015).

Figure 2.2

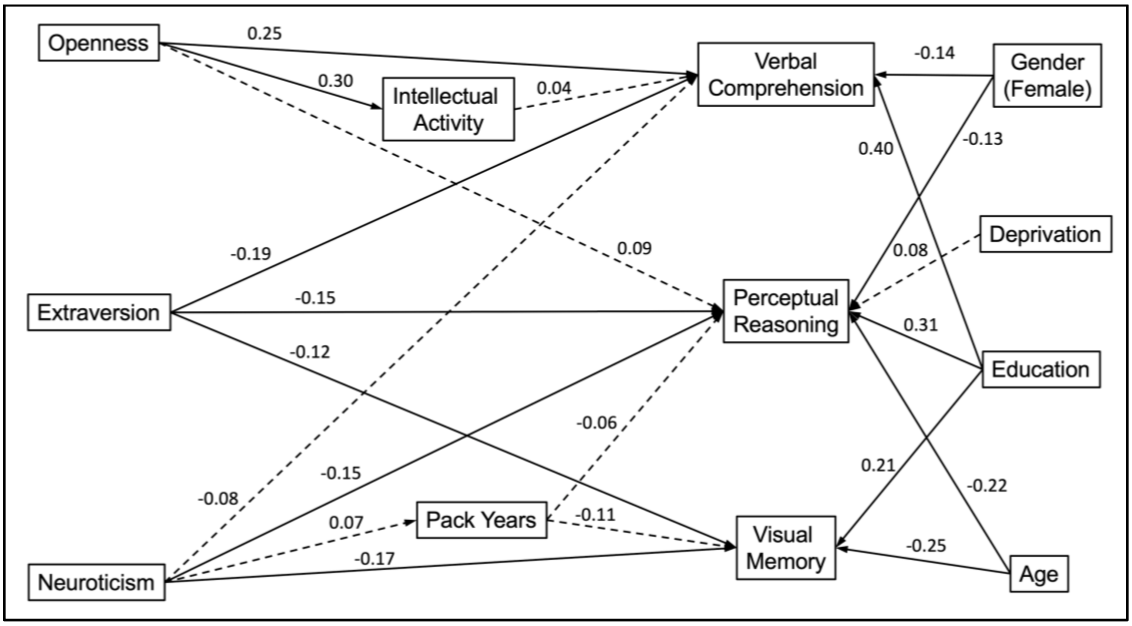
Parallel Analysis Scree Plot



Note. Parallel analysis compares the eigenvalues of the observed data (blue triangles) to those obtained from simulated random data of the same size (red dashed line) – only the observed eigenvalues that are greater than those in the random data are retained.

Figure 2.3

Standardised Path Estimates of the Mediation Model



Note. Continuous lines indicate significant paths and dashed lines indicate non-significant paths.

Table 2.1

Sample Characteristics

Variable	Mean	SD	Min	Max	Skew	Kurtosis
Age	71.4	5.4	65	92	1.00	0.67
Years of Education	15.9	3.5	9	26	0.03	-0.51
Deprivation	16.2	4.6	2	20	-1.23	0.53
Self-Rated Health[a]	3.7	0.9	1	5	-0.47	-0.13
MMSE Total Score	28.9	1.2	23	30	-1.62	3.55

Note. Deprivation = Scottish Index of Multiple Deprivation (vigintile ranking [i.e. 1-20] based on postcode where lower values indicate higher deprivation). MMSE = Mini-Mental State Examination; scores range from 0 to 30 where lower values indicate cognitive problems.

[a] 1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent.

Table 2.2

Composite Cognitive Ability Measures and their Respective Subtests from the WAIS-IV and the WMS-IV

Composite	Reliability Estimate	Subtest
		WAIS-IV
Verbal Comprehension	.96	Similarities Participants are orally presented with pairs of words and asked to explain how the two words are alike. Responses are scored 0, 1 or 2 points; more abstract responses are awarded higher scores than those describing concrete features. Total raw scores range from 0-36. Vocabulary Participants are presented with a list of words (visually and orally) and asked to provide a verbal definition. Responses are scored 0, 1 or 2 points based on the quality of the definition provided; responses are penalised for vagueness, lack of content, or for being incorrect. Total raw scores range from 0-57. Information Participants are asked a series of general knowledge questions. Responses are scored as correct (1) or incorrect (0). Total raw scores range from 0-26.
Perceptual Reasoning	.95	Block Design Participants are presented with a series of 2D patterns and asked to recreate these patterns using 3D coloured blocks within a specific time limit. Higher scores are awarded for faster completion. Total raw scores range from 0-66. Matrix Reasoning Participants are presented with a series of incomplete matrices of shapes and asked to select from five possible options the shape that logically completes the pattern of each matrix. Responses are scored as correct (1) or incorrect (0). Total raw scores range from 0-26. Visual Puzzles Participants are presented with a series of completed puzzles and must select three shapes from six possible options to reconstruct the puzzle within a specific time limit. Responses are scored as correct (1) or incorrect (0). Total raw scores range from 0-26.

Composite	Reliability Estimate	Subtest
Working Memory	.94	<u>Digit Span</u> Digit Span Forwards: Participants hear a series of numbers (progressively ranging from 2-9 digits in length) and must repeat those numbers back in the same order. Digit Span Backwards: Participants hear a series of numbers (progressively ranging from 2-9 digits in length) and must repeat those numbers back in reverse order. Digit Span Sequencing: Participants hear a series of numbers (progressively ranging from 2-9 digits in length) and must repeat those numbers back in numerical order. Responses are scored as correct (1) or incorrect (0). Total raw scores range from 0-48. <u>Arithmetic</u> Participants are orally presented with a series of arithmetic problems and allowed 30 seconds to mentally solve each one. Responses are scored as correct (1) or incorrect (0). Total raw scores range from 0-22.
Processing Speed	.90	<u>Symbol Search</u> Participants are presented with a pencil and response booklet. The booklet contains rows of symbols divided into target symbols and search groups. For each row, participants must scan and indicate whether the search group contains one of the target symbols by marking it with their pencil. Participants are scored according to the number of correct responses they record within two minutes. Total raw scores range from 0-60. <u>Coding</u> Participants are presented with a pencil and response booklet. The booklet presents a key, in which the numbers 1-9 are coded with a specific symbol. Underneath are a series of numbers – underneath each number participants must draw the corresponding symbol. Participants are scored according to the number of correct responses they record within two minutes. Total raw scores range from 0-135.

Composite	Reliability Estimate	Subtest
		WMS-IV
Auditory Memory	.95	Logical Memory I (Immediate) Participants are read two stories. Immediately after hearing each story, participants must recite as much as they can remember, in as close to the same words as possible. Responses are scored according to the number of details correctly remembered. Total raw scores range from 0-53. Logical Memory II (Delayed) After a period of 20-30 minutes, participants must recite the same two stories from memory. Responses are scored according to the number of details correctly remembered. Total raw scores range from 0-39. Verbal Paired Associates I (Immediate) Participants are orally presented with a series of ten word-pairs. After hearing all ten pairs, the participant is immediately presented with the first word from each pair and asked to name the word that went with it. There are four trials consisting of the same pairs presented in different orders. Responses are scored as correct (1) or incorrect (0). Total raw scores range from 0-40. Verbal Paired Associates II (Delayed) After a period of 20-30 minutes, participants are again presented with the first word from each pair and asked to name the word that went with it. Responses are scored as correct (1) or incorrect (0). Total raw scores range from 0-10.
Visual Memory	.97	Visual Reproduction I (Immediate) Participants are presented with five 2D designs and allowed ten seconds to study each one. Participants are also provided with a paper and pencil; after studying each design, they must immediately reproduce it on the paper. Responses are scored according to the number of design features adequately reproduced. Total raw scores range from 0-43. Visual Reproduction II (Delayed) After a period of 20-30 minutes, participants must reproduce the same five designs, from memory and in any order. Responses are scored according to the number of design features adequately reproduced. Total raw scores range from 0-43.

Note. Reliability estimates taken from WAIS-IV-UK and WMS-IV-UK manuals (Wechsler, 2010a, 2010b).

Table 2.3

Missing Values for Demographic, Cognitive and Health-related Behaviour Variables

Variable	N missing	Percent missing
Age	0	0
Gender	0	0
Years of Education	0	0
Deprivation	0	0
Self-Rated Health	0	0
MMSE Total Score	0	0
Verbal Comprehension	0	0
Perceptual Reasoning	0	0
Working Memory	7	2.1
Processing Speed	1	0.3
Auditory Memory	15	4.5
Visual Memory	4	1.2
Alcohol	0	0
Diet	0	0
Pack Years	9	2.7
Total MET-minutes per week	28	8.3

Note. Deprivation = Scottish Index of Multiple Deprivation (vigintile ranking [i.e. 1-20] based on postcode where lower values indicate higher deprivation). MMSE = Mini-Mental State Examination; scores range from 0 to 30 where lower values indicate cognitive problems. MET = metabolic equivalent of task; total MET-minutes per week measured using the International Physical Activity Questionnaire.

Table 2.4

Items Excluded Prior to Exploratory Factor Analysis

Item	Reason(s) for exclusion
Woodwork/carpentry	Highly skewed (skew values ranged from 2.27 to 2.51 across five imputed datasets)
Collect stamps etc.	Highly skewed (skew values ranged from 2.70 to 3.02 across five imputed datasets)
Read for leisure	Highly skewed (skew values ranged from -2.17 to -2.34 across five imputed datasets)
Watch TV news	Highly skewed (skew values ranged from -2.98 to -3.39 across five imputed datasets); High kurtosis (kurtosis values ranged from 8.15 to 11.25 across five imputed datasets)
Watch TV documentary	Highly skewed (skew values ranged from -2.06 to -2.19 across five imputed datasets)
Use computer	Highly skewed (skew values ranged from -3.32 to -3.96 across five imputed datasets); High kurtosis (kurtosis values ranged from 9.86 to 15.03 across five imputed datasets)
On-the-job training	Highly skewed (skew values ranged from 2.67 to 2.91 across five imputed datasets)
Course at college/university	Highly skewed (skew values ranged from 2.09 to 2.37 across five imputed datasets)
Play musical instrument	Did not correlate highly with other items
Photography	Did not correlate highly with other items
Sewing/knitting/needlework	Did not correlate highly with other items
Gardening	Did not correlate highly with other items
Exercise (jogging, swimming etc.)	Did not correlate highly with other items
Outdoor activities (sailing, fishing etc.)	Did not correlate highly with other items
Crossword puzzles etc.	Did not correlate highly with other items
Jigsaw puzzles	Did not correlate highly with other items
Read newspapers	Did not correlate highly with other items
Go to library	Did not correlate highly with other items
Listen to radio[a]	Did not correlate highly with other items
Write letters	Did not correlate highly with other items

Item	Reason(s) for exclusion
Use electronic calculator	Did not correlate highly with other items
Prepare taxes/finances	Did not correlate highly with other items
Do mathematical calculations	Did not correlate highly with other items
Attend films	Did not correlate highly with other items
Attend concert/play[a]	Did not correlate highly with other items
Eat at restaurant	Did not correlate highly with other items
Go to pubs/social clubs[b]	Did not correlate highly with other items
Volunteer work	Did not correlate highly with other items
Business activities not related to career	Did not correlate highly with other items
Study foreign language	Did not correlate highly with other items
Travel in foreign country	Did not correlate highly with other items
Watch TV comedy/adventure	KMO < .5
Watch TV game shows	Did not correlate highly with other items[c]

Note. KMO = Kaiser-Meyer-Olkin measure of sampling adequacy. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

[a] Item reincluded from original 70-item VLS-ALQ. [b] New item. [c] Item no longer had any correlations > .3 after 'Watch TV comedy/adventure' was removed.

Table 2.5

Summary Statistics for 29 Items Included in Exploratory Factor Analysis

Item	Mean	*SD*	KMO
Household repairs	2.37	2.06	0.70
Repair mechanical device	1.17	1.69	0.72
Purchase new item requiring set-up	1.75	1.33	0.72
Creative writing	1.38	2.18	0.68
Recreational sports (tennis, golf etc.)	1.81	2.77	0.61
Aerobics (cardiovascular, fitness training etc.)	2.35	2.92	0.71
Flexibility training (stretching, yoga etc.)	3.24	3.19	0.72
Weight lifting, strength training etc.	1.28	2.47	0.62
Card games	1.95	2.65	0.73
Board games	1.35	1.83	0.74
Knowledge games	1.45	1.73	0.69
Word games	2.08	2.24	0.67
Read for career/education	2.13	3.09	0.79
Go to galleries/museums[b]	3.33	1.42	0.71
Attend public talk	2.48	1.70	0.79
Attend sports events[a]	1.09	1.75	0.59
Talk on phone to friends/relatives	6.32	1.61	0.62
Visit relatives/friends	5.39	1.53	0.58
Go out with friends	4.99	1.68	0.70
Attend parties	2.73	1.23	0.76
Give dinner/party	2.51	1.59	0.71
Attend religious services	2.09	2.43	0.58
Engage in prayer/meditation	2.99	3.13	0.66
Attend club meetings	2.71	2.53	0.76
Attend organised social events	2.15	2.18	0.69
Engage in political activities	1.22	1.93	0.70
Give public talk	0.78	1.44	0.71
Travel outside region	3.41	1.26	0.55
Travel outside town	4.62	1.49	0.58

Note. Responses range from 0-8; KMO = Kaiser-Meyer-Olkin measure of sampling adequacy. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

[a] Item reincluded from original 70-item VLS-ALQ. [b] New item.

Table 2.6

Model Comparisons

Number of factors	Proportion of variance explained (%)	RMSEA (90% CI)	TLI
3	31.0	0.082 (0.072, 0.093)	.700
4	33.1	0.070 (0.061, 0.080)	.742
5	39.3	0.040 (0.026, 0.053)	.918
6	40.0	0.036 (0.023, 0.048)	.918

Note. RMSEA = root mean square error of approximation. TLI = Tucker-Lewis Index.

Table 2.7

Six-Factor Model Pattern Matrix and Factor Correlations

Item	Factor 1.	2.	3.	4.	5.	6.	h^2
Do household repairs (for example, painting or leaky faucets)	**0.86**	-0.02	0.00	0.01	0.02	0.02	0.741
Repair a mechanical device (for example, a car or lawn mower)	**0.71**	0.08	0.00	0.00	0.00	0.02	0.537
Purchase a new item requiring some set-up or assembly	**0.61**	-0.01	0.07	0.00	0.00	-0.06	0.388
Engage in creative writing, writing poems, writing newspaper articles, etc.	0.13	**0.57**	-0.06	0.04	-0.08	0.02	0.354
Read books or magazines as part of my job, career, or formal education	0.02	**0.55**	0.03	-0.11	-0.01	0.00	0.297
Go to galleries or museums	-0.12	**0.43**	0.11	-0.04	0.10	0.10	0.258
Attend a public lecture or talk	-0.11	**0.54**	0.09	0.09	0.07	-0.01	0.357
Engage in political activities (for example, neighbourhood organisation)	0.08	**0.46**	0.00	-0.02	0.03	-0.01	0.233
Give a public talk or lecture (for example, to a club, service organisation, etc.)	0.05	**0.50**	-0.09	0.05	0.01	-0.08	0.269
Do aerobics (for example, cardiovascular, fitness training, or workout)	0.04	-0.01	0.03	0.06	**0.65**	-0.02	0.429
Do flexibility training (for example, stretching, yoga, or tai chi)	-0.09	0.07	0.11	0.05	**0.49**	0.02	0.289
Do weight lifting, strength training, or calisthenics	0.03	-0.01	-0.06	-0.05	**0.77**	0.00	0.592
Play card games (for example, Bridge)	-0.02	-0.05	**0.46**	0.05	0.06	0.01	0.221
Play board games (for example, chess or checkers)	0.08	0.03	**0.63**	-0.01	0.01	-0.05	0.412
Play knowledge games (for example, Trivial Pursuit)	0.03	0.03	**0.65**	0.00	-0.03	0.00	0.426
Play word games (for example, Scrabble)	-0.03	-0.04	**0.64**	-0.01	-0.03	0.04	0.403
Talk on the phone to friends, or relatives	-0.10	-0.03	0.08	0.13	0.04	**0.35**	0.177
Visit relatives, friends, or neighbours	0.02	-0.01	0.00	-0.01	0.00	**1.00**	0.995
Go out with friends	-0.15	0.09	0.01	-0.01	-0.05	**0.34**	0.160
Attend church or other religious services	0.01	-0.03	-0.02	**0.91**	-0.04	-0.02	0.810
Engage in prayer, meditation, or philosophical contemplation	-0.01	0.08	0.06	**0.54**	0.11	0.00	0.343
Attend organised social events (for example, activities at the community centre or church social groups)	-0.05	0.13	0.02	**0.47**	0.05	0.13	0.297
Sum of Squared Loadings	1.73	1.61	1.50	1.39	1.30	1.28	
Variance Explained (%)	7.9	7.3	6.8	6.3	5.9	5.8	
Factor Correlations							
1. Manual	-	-	-	-	-	-	
2. Intellectual	.19	-	-	-	-	-	
3. Games	.09	.20	-	-	-	-	
4. Religious	-.03	.19	.09	-	-	-	
5. Exercise	.15	.26	.11	.00	-	-	
6. Social	-.10	.09	.14	.05	.01	-	

Note. **Bold** = primary loadings (pattern coefficient > .3); h^2 = communality. VLS-ALQ items are included with permission to support the analyses; permission to use the VLS-ALQ in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table 2.8

Six-Factor Model Structure Matrix

Item	Factor					
	1. Man	2. Int	3. Gam	4. Rel	5. Exe	6. Soc
Do household repairs (for example, painting or leaky faucets)	**0.86**	0.15	0.08	-0.03	0.14	-0.06
Repair a mechanical device (for example, a car or lawn mower)	**0.73**	0.22	0.08	-0.01	0.13	-0.05
Purchase a new item requiring some set-up or assembly	**0.62**	0.11	0.12	-0.01	0.09	-0.11
Engage in creative writing, writing poems, writing newspaper articles, etc.	0.22	**0.57**	0.06	0.14	0.08	0.05
Read books or magazines as part of my job, career, or formal education	0.13	**0.53**	0.13	0.00	0.14	0.05
Go to galleries or museums	-0.02	**0.46**	0.21	0.06	0.21	0.16
Attend a public lecture or talk	0.01	**0.57**	0.21	0.20	0.21	0.06
Engage in political activities (for example, neighbourhood organisation)	0.17	**0.47**	0.10	0.06	0.16	0.02
Give a public talk or lecture (for example, to a club, service organisation, etc.)	0.15	**0.50**	0.01	0.14	0.13	-0.05
Do aerobics (for example, cardiovascular, fitness training, or workout)	0.14	0.18	0.11	0.05	**0.65**	-0.01
Do flexibility training (for example, stretching, yoga, or tai chi)	0.01	0.21	0.18	0.07	**0.51**	0.06
Do weight lifting, strength training, or calisthenics	0.14	0.17	0.02	-0.06	**0.76**	0.00
Play card games (for example, Bridge)	0.02	0.06	**0.46**	0.08	0.10	0.07
Play board games (for example, chess or checkers)	0.14	0.17	**0.63**	0.05	0.10	0.03
Play knowledge games (for example, Trivial Pursuit)	0.09	0.16	**0.65**	0.06	0.06	0.09
Play word games (for example, Scrabble)	0.00	0.07	**0.63**	0.04	0.02	0.13
Talk on the phone to friends, or relatives	-0.14	0.03	0.14	0.15	0.03	**0.37**
Visit relatives, friends, or neighbours	-0.08	0.08	0.14	0.04	0.01	**1.00**
Go out with friends	-0.18	0.08	0.06	0.03	-0.05	**0.36**
Attend church or other religious services	-0.03	0.13	0.06	**0.90**	-0.05	0.02
Engage in prayer, meditation, or philosophical contemplation	0.01	0.22	0.14	**0.56**	0.13	0.04
Attend organised social events (for example, activities at the community centre or church social groups)	-0.04	0.23	0.11	**0.50**	0.08	0.17

Note. Man = Manual, Int = Intellectual, Gam = Games, Rel = Religious, Exe = Exercise, Soc = Social. **Bold** = coefficient > .3. VLS-ALQ items are included with permission to support the analyses; permission to use the VLS-ALQ in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table 2.9

Activity Domain Scores: Gender Comparisons and Correlations with Demographic Variables, MMSE Scores and Total MET-minutes per week

Activity Domain	Mean (SD) Male	Mean (SD) Female	*t*	df	*p*	Correlations					
						Age	Years of Education	Deprivation	Self-Rated Health[a]	MMSE	Total MET-minutes per week
Manual	**8.49 (4.97)**	**3.89 (3.83)**	**8.94**	**107.09**	**<0.001**	-0.08	0.14*	-0.10	-0.01	-0.11	0.12
Intellectual	11.81 (8.25)	11.11 (7.91)	0.73	125.20	0.469	-0.08	0.30***	0.00	0.05	0.00	0.14*
Games	5.96 (6.90)	7.23 (6.73)	-1.72	95.61	0.089	-0.06	0.02	-0.05	-0.01	-0.05	0.12
Religious	**5.78 (6.06)**	**7.86 (6.28)**	**-2.95**	**175.60**	**0.004**	0.10	-0.04	0.03	-0.02	-0.05	0.02
Exercise	6.69 (7.72)	6.93 (6.72)	-0.28	129.84	0.780	-0.01	0.12*	0.01	0.04	-0.13	0.26***
Social	**15.24 (4.12)**	**17.33 (3.82)**	**-4.49**	**71.61**	**<0.001**	0.06	-0.01	0.10	0.11	0.08	0.05

Note. Deprivation = Scottish Index of Multiple Deprivation (vigintile ranking [i.e. 1-20] based on postcode where lower values indicate higher deprivation). MMSE = Mini-Mental State Examination (scores range from 0 to 30 where lower values indicate cognitive problems). MET = metabolic equivalent of task; total MET-minutes per week measured using the International Physical Activity Questionnaire (higher scores indicate higher levels of overall physical activity). Significant gender differences (indicated by boldface) remained so after Bonferroni correction.

[a]1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent.

*p < .05, **p < .01, ***p < .001

Table 2.10

Bivariate Correlations Between Personality Traits, Activity Domains, Health-related Behaviours and Cognitive Outcomes

			Correlations														
Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. VC	108.40	11.78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. PR	104.18	13.51	**.53*****	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. WM	110.73	14.19	**.51*****	**.51*****	-	-	-	-	-	-	-	-	-	-	-	-	-
4. PS	104.78	12.71	**.26*****	**.46*****	**.38*****	-	-	-	-	-	-	-	-	-	-	-	-
5. AM	116.94	15.91	**.41*****	**.38*****	**.36*****	**.31*****	-	-	-	-	-	-	-	-	-	-	-
6. VM	98.60	14.44	**.33*****	**.51*****	**.33*****	**.34*****	**.47*****	-	-	-	-	-	-	-	-	-	-
7. Alcohol	11.02	13.64	.10	.15**	.19***	.08	.04	.07	-	-	-	-	-	-	-	-	-
8. Diet	0.58	0.86	.06	.05	.04	.03	.04	-.04	-.01	-	-	-	-	-	-	-	-
9. PY	8.84	17.22	*-.05*	*-.13**	*.08*	***-.20******	*-.13**	*-.17***	*.18****	*.11*	-	-	-	-	-	-	-
10. MET	2811.38	2757.90	-.10	-.12	-.12	-.08	-.11	-.06	.03	-.07	*.01*	-	-	-	-	-	-
11. N	82.31	22.24	-.05	-.12*	.03	.05	-.02	-.13*	.06	**.29*****	*.17***	-.07	-	-	-	-	-
12. E	102.06	17.56	-.10	-.09	-.10	.06	.02	-.07	.06	-.10	*.00*	.19**	**-.25*****	-	-	-	-
13. O	120.10	16.91	**.31*****	.18**	.03	.18**	**.23*****	.14*	.01	.03	*-.11**	.08	.01	**.35*****	-	-	-
14. A	130.55	15.91	.00	.08	-.09	.09	.16*	.12*	-.08	-.12*	*-.18****	.01	**-.30*****	.02	.17**	-	-
15. C	112.48	18.68	-.04	.02	-.07	-.02	-.06	.03	-.08	**-.26*****	*-.16***	.11	**-.52*****	**.26*****	.00	.16**	-
16. Man	5.29	4.26	.19**	**.28*****	.13	-.02	-.09	.13*	.12	.00	*.09*	.12	-.02	-.05	.06	**-.23*****	.05
17. Gam	6.84	6.03	.07	.02	.06	.05	.07	.03	.06	-.07	*-.02*	.12	-.06	.15**	.16*	-.05	-.04
18. Int	11.32	7.45	.19***	.07	.02	.01	.07	.07	.13*	-.07	*-.04*	.14*	.02	.17**	**.30*****	-.08	.00
19. Rel	7.23	6.07	-.09	-.13*	-.12*	-.08	-.03	-.05	-.10	.00	*-.03*	.02	.04	.05	.02	.13*	-.02
20. Soc	16.69	3.54	-.09	-.11	-.10	.03	.05	-.05	.07	-.05	*-.08*	.05	-.14*	**.32*****	.12*	.13*	.04
21. Exe	6.86	6.65	.03	.00	-.02	-.03	.01	-.02	-.03	-.13*	*-.03*	**.26*****	.01	.08	.14**	-.05	.03

Note. VC = Verbal Comprehension; PR = Perceptual Reasoning; WM = Working Memory; PS = Processing Speed; AM = Auditory Memory; VM = Visual Memory; PY = Pack Years; MET = total metabolic equivalent of task-minutes per week; N = Neuroticism; E = Extraversion; O = Openness to Experience; A = Agreeableness; C = Conscientiousness; Man = Manual; Gam = Games; Int = Intellectual; Rel = Religious; Soc = Social; Exe = Exercise. Plain text denotes Pearson's *r*, *italics* denotes Spearman's ρ. For descriptive purposes, correlations that remain significant after Bonferroni correction are presented in **bold**.

*p < 0.05, **p < 0.01, ***p < 0.001

Table 2.11

Multiple Regression Models

Predictor	Estimate (95% CI)	*SE*	*t*	*df*	*p*
	Verbal Comprehension				
(Intercept)	91.62 (67.41, 115.82)	12.30	7.45	308.57	<0.001
Age	0.04 (-0.16, 0.24)	0.10	0.37	320.42	0.715
Gender (Female)	**-3.93 (-6.39, -1.48)**	**1.25**	**-3.15**	**321.57**	**0.002**
Education	**1.37 (1.04, 1.70)**	**0.17**	**8.10**	**295.34**	**<0.001**
Deprivation	0.20 (-0.04, 0.43)	0.12	1.67	321.62	0.096
Neuroticism	**-0.08 (-0.13, -0.02)**	**0.03**	**-2.50**	**315.19**	**0.013**
Extraversion	**-0.12 (-0.19, -0.05)**	**0.04**	**-3.28**	**185.29**	**0.001**
Openness	**0.19 (0.12, 0.27)**	**0.04**	**4.96**	**169.75**	**<0.001**
Agreeableness	-0.04 (-0.12, 0.04)	0.04	-1.05	268.83	0.296
Conscientiousness	-0.07 (-0.14, 0.00)	0.04	-1.91	175.27	0.057
	Perceptual Reasoning				
(Intercept)	130.72 (101.78, 159.66)	14.71	8.89	319.66	<0.001
Age	**-0.53 (-0.77, -0.29)**	**0.12**	**-4.31**	**323.23**	**<0.001**
Gender (Female)	**-5.06 (-8.02, -2.11)**	**1.50**	**-3.37**	**321.82**	**<0.001**
Education	**1.18 (0.79, 1.58)**	**0.20**	**5.88**	**318.10**	**<0.001**
Deprivation	**0.39 (0.11, 0.67)**	**0.14**	**2.76**	**323.43**	**0.006**
Neuroticism	**-0.11 (-0.18, -0.04)**	**0.04**	**-2.97**	**323.74**	**0.003**
Extraversion	**-0.11 (-0.20, -0.03)**	**0.04**	**-2.58**	**251.55**	**0.011**
Openness	**0.10 (0.01, 0.19)**	**0.05**	**2.13**	**275.77**	**0.034**
Agreeableness	0.04 (-0.05, 0.13)	0.05	0.98	310.98	0.329
Conscientiousness	-0.07 (-0.15, 0.02)	0.04	-1.61	274.68	0.109
	Working Memory				
(Intercept)	154.02 (116.83, 191.22)	18.63	8.27	65.66	<0.001
Age	**-0.48 (-0.80, -0.16)**	**0.16**	**-3.00**	**52.94**	**0.004**
Gender (Female)	**-6.55 (-9.88, -3.21)**	**1.70**	**-3.86**	**321.18**	**<0.001**
Education	**0.84 (0.34, 1.34)**	**0.25**	**3.35**	**79.68**	**0.001**
Deprivation	**0.41 (0.09, 0.73)**	**0.16**	**2.55**	**322.57**	**0.011**
Neuroticism	-0.04 (-0.13, 0.06)	0.05	-0.78	62.36	0.441
Extraversion	-0.06 (-0.15, 0.04)	0.05	-1.15	221.35	0.253
Openness	0.00 (-0.10, 0.11)	0.05	0.05	164.12	0.958
Agreeableness	-0.04 (-0.14, 0.07)	0.05	-0.70	312.81	0.483
Conscientiousness	**-0.10 (-0.20, -0.01)**	**0.05**	**-2.12**	**249.14**	**0.035**
	Processing Speed				
(Intercept)	151.35 (123.60, 179.11)	14.11	10.73	323.01	<0.001
Age	**-0.98 (-1.21, -0.75)**	**0.12**	**-8.28**	**322.67**	**<0.001**
Gender (Female)	**2.97 (0.12, 5.82)**	**1.45**	**2.05**	**318.49**	**0.041**
Education	0.10 (-0.30, 0.50)	0.20	0.48	160.83	0.630
Deprivation	**0.42 (0.15, 0.69)**	**0.14**	**3.09**	**322.19**	**0.002**
Neuroticism	0.01 (-0.06, 0.08)	0.03	0.31	323.08	0.754
Extraversion	0.01 (-0.07, 0.09)	0.04	0.30	260.75	0.761
Openness	0.06 (-0.03, 0.15)	0.04	1.34	253.19	0.180
Agreeableness	0.05 (-0.04, 0.13)	0.04	1.04	320.17	0.298
Conscientiousness	-0.02 (-0.10, 0.06)	0.04	-0.50	281.49	0.615

Predictor	Estimate (95% CI)	*SE*	*t*	*df*	*p*
		Auditory Memory			
(Intercept)	106.49 (67.96, 145.02)	19.52	5.46	169.91	<0.001
Age	**-0.33 (-0.67, 0.00)**	**0.17**	**-1.99**	**119.85**	**0.048**
Gender (Female)	3.11 (-0.88, 7.10)	2.02	1.54	141.68	0.126
Education	**1.11 (0.60, 1.63)**	**0.26**	**4.26**	**239.35**	**<0.001**
Deprivation	0.21 (-0.18, 0.61)	0.20	1.07	82.86	0.286
Neuroticism	-0.04 (-0.13, 0.05)	0.05	-0.88	217.23	0.378
Extraversion	0.00 (-0.11, 0.11)	0.06	0.00	107.22	0.998
Openness	0.09 (-0.03, 0.22)	0.06	1.45	76.99	0.151
Agreeableness	0.11 (-0.03, 0.24)	0.07	1.62	50.26	0.111
Conscientiousness	-0.09 (-0.20, 0.01)	0.05	-1.70	173.29	0.090
		Visual Memory			
(Intercept)	142.13 (109.42, 174.83)	16.62	8.55	317.76	<0.001
Age	**-0.69 (-0.96, -0.41)**	**0.14**	**-4.90**	**310.95**	**<0.001**
Gender (Female)	-2.30 (-5.74, 1.14)	1.75	-1.32	236.58	0.189
Education	**0.81 (0.35, 1.26)**	**0.23**	**3.50**	**287.03**	**<0.001**
Deprivation	0.20 (-0.12, 0.53)	0.16	1.22	264.62	0.222
Neuroticism	**-0.12 (-0.20, -0.04)**	**0.04**	**-2.93**	**317.59**	**0.004**
Extraversion	**-0.12 (-0.21, -0.02)**	**0.05**	**-2.38**	**252.72**	**0.018**
Openness	0.09 (-0.02, 0.19)	0.05	1.67	263.38	0.096
Agreeableness	0.06 (-0.04, 0.16)	0.05	1.12	273.60	0.265
Conscientiousness	-0.05 (-0.14, 0.05)	0.05	-0.96	179.99	0.341

Note. Deprivation = Scottish Index of Multiple Deprivation (vigintile ranking [i.e. 1-20] based on postcode where lower values indicate higher deprivation). **Bold** = significant at $p < .05$.

Table 2.12

Parameter Estimates of the Path Model

Parameter			Estimate (95% CI)	SE	Standardised Estimate	p
			Direct Effects			
VCI	←	Neuroticism	-0.04 (-0.09, 0.01)	0.03	-0.08	0.093
VCI	←	Extraversion	-0.13 (-0.20, -0.05)	0.04	-0.19	<0.001
VCI	←	Openness	0.17 (0.09, 0.25)	0.04	0.25	<0.001
VCI	←	Intellectual Activity	0.07 (-0.07, 0.21)	0.07	0.04	0.338
VCI	←	Gender	-3.51 (-5.91, -1.10)	1.23	-0.14	0.004
VCI	←	Education	1.34 (0.99, 1.69)	0.18	0.40	<0.001
PRI	←	Neuroticism	-0.09 (-0.16, -0.03)	0.03	-0.15	0.006
PRI	←	Extraversion	-0.12 (-0.20, -0.03)	0.04	-0.15	0.006
PRI	←	Openness	0.07 (-0.01, 0.16)	0.04	0.09	0.086
PRI	←	Pack Years	-0.05 (-0.10, 0.01)	0.03	-0.06	0.087
PRI	←	Gender	-3.87 (-6.58, -1.16)	1.38	-0.13	0.005
PRI	←	Education	1.17 (0.76, 1.59)	0.21	0.31	<0.001
PRI	←	Age	-0.54 (-0.77, -0.31)	0.12	-0.22	<0.001
PRI	←	Deprivation	0.23 (-0.01, 0.48)	0.12	0.08	0.057
VMI	←	Neuroticism	-0.11 (-0.18, -0.04)	0.04	-0.17	0.003
VMI	←	Extraversion	-0.10 (-0.18, -0.02)	0.04	-0.12	0.016
VMI	←	Pack Years	-0.09 (-0.19, 0.01)	0.05	-0.11	0.086
VMI	←	Education	0.87 (0.47, 1.27)	0.20	0.21	<0.001
VMI	←	Age	-0.68 (-0.99, -0.37)	0.16	-0.25	<0.001
Intellectual Activity	←	Openness	0.13 (0.09, 0.18)	0.02	0.30	<0.001
Pack Years	←	Neuroticism	0.06 (-0.02, 0.13)	0.04	0.07	0.160

Parameter					Estimate (95% CI)	SE	Standardised Estimate	p
					Indirect Effects			
VCI	←	Intellectual Activity	←	Openness	0.01 (-0.01, 0.03)[a]	0.01	0.01	0.312
PRI	←	Pack Years	←	Neuroticism	0.00 (-0.01, 0.00)[a]	0.00	0.00	0.227
VMI	←	Pack Years	←	Neuroticism	0.00 (-0.02, 0.00)[a]	0.00	-0.01	0.308
					Total Effects			
VCI	←	Openness			0.18 (0.11, 0.26)	0.04	0.26	<0.001
PRI	←	Neuroticism			-0.09 (-0.16, -0.03)	0.03	-0.15	0.005
VMI	←	Neuroticism			-0.12 (-0.19, -0.04)	0.04	-0.18	0.002

Note. VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index; AMI = Auditory Memory Index; VMI = Visual Memory Index.

[a] Monte Carlo confidence intervals

3. Cognitive Ageing Interventions: An Overview

As discussed in Chapter 1, evidence from cross-sectional studies supports the existence of associations between activity engagement and cognitive ability in older age. Based on these studies, one could argue that increased engagement – whether mental, physical, social, creative or some combination thereof – appears to be a promising approach to enhance cognitive ability or delay cognitive decline. Equally, one could argue that increased cognitive ability could enhance engagement, or delay disengagement. As noted previously, cross-sectional data cannot provide conclusive evidence about the *direction* of any association, and findings from longitudinal studies can be cited to support both arguments (recall the conflicting accounts of 'differential preservation' and 'preserved differentiation' described in Section 1.5.5). Clearly, establishing cause and effect requires an alternative approach.

Intervention trials can be useful in addressing causality by examining the potential cognitive benefits of directly manipulating a given behaviour within a (theoretically) controlled experimental environment (Hertzog et al., 2008). As engagement in mental, social, physical and creative activities are innately modifiable, these activities lend themselves to intervention. In recent years a growing body of research has begun to examine the direct benefits of increasing individuals' engagement levels using an array of intervention strategies.

3.1. Cognitive Training Interventions

The most common approach to increasing mental engagement within an experimental paradigm is cognitive training. In simple terms, cognitive training can be viewed as analogous to physical exercise; the brain is 'strengthened' through repeated exposure to basic cognitive tasks, or through the learning and practice of cognitive strategies, over a period of weeks or months. Such approaches are typically tested within the structure of a randomised controlled trial (RCT) design, in which change in cognitive performance in an experimental (training) group is compared to that of a control group and/or other active comparison group. Training protocols are often designed to enhance performance in a specific cognitive domain.

The benefits of cognitive training can be measured in several ways. If training involves repetitive practice on a specific task, then performance on this task can be used as an index of improvement. Take, for example, the domain of working memory. A researcher may be interested in testing whether training individuals to perform the *n*-back task could enhance ability in this domain. The *n*-back task involves presenting a subject with a sequence of stimuli (e.g., letters or numbers), and asking the subject to indicate when a particular stimulus matches that which was presented *n* steps previously in the sequence. Working memory must be employed to continuously update and hold a representation of the previously presented stimuli in order to identify a match. The researcher could recruit a group of participants and instruct them to spend twenty minutes per day practicing the *n*-back task for two weeks. The researcher could then measure the change in *n*-back scores over this period and compare them to a control group who did not practice the *n*-back task. If the experimental group shows a significantly larger improvement, the researcher might conclude that practice on this task had successfully improved the ability of working memory.

However, such an improvement may be the result of habituation and familiarity with the specific task rather than a reflection of any generalisable changes to the latent ability of working memory. Observing improvement in performance on a separate, untrained task designed to measure the same construct, such as digit span (which involves immediate recall of progressively longer sequences of numbers), would therefore provide more solid evidence that ability, and not task-specific performance, is being enhanced (Noack et al., 2014). Such improvements are typically referred to as ‘near-transfer’ effects.

Near-transfer has been demonstrated in a range of cognitive training studies with older adult participants, including those targeted at episodic memory (Bottiroli & Cavallini, 2009; Cavallini et al., 2010; Craik et al., 2007; Vranic et al., 2013; Zimmermann et al., 2016), reasoning (Cheng et al., 2012; McArdle & Prindle, 2008; Payne et al., 2012), executive function (Mozolic et al., 2011), working memory (Borella et al., 2010; Carretti et al., 2013; Payne & Stine-Morrow, 2017; Richmond et al., 2011) and processing speed (Edwards et al., 2005; Edwards et al., 2002). Meta-analyses have reported convincing evidence of near-transfer from cognitive training studies, although effect sizes tend to be smaller compared to improvements on trained tasks (Nguyen et al., 2019; Verhaeghen et al., 1992). For example, Sala et al. (2019) examined the effects of working memory training in older adults; the overall estimated effect size for improvements on trained tasks was 0.88, compared to 0.27 for near-transfer tasks.

However, near-transfer effects are not universally observed. For example, Goghari and Lawlor-Savage (2017) trained older participants' logical reasoning ability; while performance on the trained tasks improved, there was no such effect for any untrained measures of reasoning. Other studies that trained older participants on a working memory task found significant task improvement but no transfer to performance on similar untrained measures (Guye & von Bastian, 2017; Lange & Süß, 2015). These authors suggest that factors such as training intensity, intervention duration and level of adherence may account for lack of near-transfer. More research is necessary to understand exactly what characteristics of cognitive training studies are conducive to eliciting improvements in performance beyond the trained task.

Intervention success can also be conceptualised in terms of transfer to untrained cognitive domains (*far-transfer*). Establishing the existence of far-transfer is important as it would imply underlying mechanistic changes at a broader, more domain-general level, which could have further-reaching benefits (Hertzog et al., 2008). However, far-transfer is much less commonly observed. For example, in one of the largest studies of its kind, the ACTIVE trial recruited over 2000 participants aged 65-94 to engage in 6 weeks of cognitive training, targeted at either memory, reasoning ability or processing speed. Training typically involved the learning of strategies, followed by the application of these strategies through repeated practice on relevant cognitive tasks. Results showed significant improvements in the targeted cognitive domains, but there was no evidence of improvement in non-targeted abilities. For example, participants who underwent memory training demonstrated improved performance on tests of memory, but not reasoning or processing speed (Ball et al., 2002; Tennstedt & Unverzagt, 2013).

Some working memory training studies have found improvements in other domains, such as executive function, processing speed and language comprehension (Borella et al., 2010; Carretti et al., 2013) but others have found no such effects (Guye & von Bastian, 2017; Lange & Süß, 2015). A large body of research has examined the potential of training mnemonic strategies to improve memory performance in older adults. Improvements are often limited to measures of episodic memory (e.g., Craik et al., 2007), although some have reported improvements in other domains, such as working memory (e.g., Vranic et al., 2013). Generally, however, empirical evidence for far-transfer is more limited than for near-transfer (Kelly et al., 2014a; Sala et al., 2019).

Few studies have examined whether training may confer tangible benefits in everyday life, beyond those measured using lab-based tests. One memory training study gave participants a test to measure performance on tasks designed to resemble memory problems encountered in everyday life (e.g., remembering to deliver a message). Results showed no improvements in everyday memory for those in the training group (McDougall et al., 2010). The ACTIVE trial measured ‘everyday problem solving’ (i.e., correctly identifying information on medication labels), ‘everyday speed’ (i.e., time taken to look up a specific telephone number), driving habits (i.e., self-rated driving difficulty) and functional independence (ADL/IADLs). Evidence of improvements in these measures was observed only in participants who received training in processing speed (more specifically a subset who were randomised to receive additional 'booster training' after the main intervention; Ball et al., 2002). Those in this group performed significantly better on the measures of everyday speed and functional independence. While more research is clearly necessary to draw conclusions regarding the more real-world benefits of cognitive training, these findings provide little support for broad improvement in everyday abilities.

Given that targeting specific abilities may only lead to narrow improvements, a growing number of studies have broadened the scope of their cognitive training paradigms to engage a wider range of cognitive domains. Again, however, results are mixed. Some multi-domain training studies have evidenced cognitive improvements in older adults (e.g., Chambon & Alescio-Lautier, 2019; Küper et al., 2017). Cheng et al. (2012) trained memory, reasoning and visuospatial ability in adults aged 65-75 over a twelve-week period, and reported significant training-related improvements in performance on a test of global cognitive ability. This could indicate an underlying, domain-general enhancement of cognitive function.

There is also evidence that multi-domain training may not even elicit near-transfer effects. In one of the largest cognitive training studies yet reported, researchers tested the benefits of an online multi-domain training (reasoning, memory, attention and visuospatial) in a sample of over 10,000 individuals (Owen et al., 2010). While performance on trained tasks improved, there was no evidence of transfer to untrained measures of cognitive function. It should be noted that the sample here was limited to adults below the age of 60. To date, there have been no studies of the effects of multi-domain training in older adults with equivalent sample size. More high-powered studies of older adults are clearly needed to further establish if multi-domain training truly does enhance cognitive ability.

Another important issue is that of maintenance, that is, whether training leads to short-lived boosts in performance or sustainable, long-term improvements. If improvements are simply practice-aided, task-specific skill learning, then a sudden drop in performance would be expected once regular practice ceased. Like transfer, demonstrating maintenance of cognitive improvements would provide evidence of meaningful changes to underlying cognitive mechanisms (Hertzog et al., 2008). Furthermore, given that age-related cognitive decline occurs over a period of years, observing intervention effects that last over at least a similar time frame is necessary to truly establish a protective effect.

In their systematic review, Kelly et al. (2014a) reported that a majority of intervention studies that measured maintenance found both near and far-transfer effects lasting several months post-intervention. Few studies have followed up with participants for much longer than a few months. The ACTIVE trial retested participants ten years post-intervention; they found that the domain-specific improvements of reasoning and processing speed training were maintained, but that those who undertook memory training no longer showed improved memory performance (Rebok et al., 2014).

Despite mixed findings, cognitive training has become a business, with the development of commercially available games and apps marketed as ‘brain training’. Such products are typically packaged as a collection of games designed to stimulate different cognitive functions. Independent empirical support for the benefits of commercial brain training among older adults is mixed; some studies have reported transfer to objective neuropsychological tests (McDougall & House, 2012; Nouchi et al., 2012). Furthermore, a recent meta-analysis indicated that such products improve performance on measures of memory, attention and processing speed (Tetlow & Edwards, 2017). However, in their review, Simons et al. (2016) noted that evidence of far-transfer is weak. Furthermore, they identify notable quality issues with many studies investigating the effects of 'brain training', or indeed cognitive training more generally (e.g., non-RCT design, lack of pre-registration, the possibility of selective reporting, incorrect statistical analysis). The authors suggest that until more rigorous methods are applied, any conclusions must be treated with due caution. Similarly, a report by the Global Council on Brain Health (2017a) advised that "improvements in game performance have not yet been shown to convincingly result in improvements in people's daily cognitive abilities" (p. 4). Nonetheless, brain training is now a lucrative industry, with consumers spending an estimated £1.5 billion on such apps in 2018 (Weiss, 2019).

While rigorous experimental design is undeniably a key factor in establishing the effectiveness of cognitive training interventions, there are downsides to this approach. Conducting experiments with humans in highly controlled, laboratory-based settings can create an artificial environment that may influence results. Consider a study by Edwards et al. (2005) that trained speed of processing. Participants attended ten one-hour-long group sessions over a five-week period, during which they practiced computerised tasks under the supervision of a trainer. Results showed a significant improvement in untrained measures of processing speed, suggesting the intervention was a success. However, were this model translated out of the lab into the home-setting, without strict time constraints and experimenter supervision, effects could differ substantially. Indeed, evidence suggests that cognitive training studies delivered in individual home-based sessions are significantly less effective, and that group-based training is more effective (Lampit et al., 2014; Verhaeghen et al., 1992).

It may be that outside the highly supervised, supportive environment of a research study, motivation and adherence to repetitive cognitive training is lessened. This possibility, alongside the lack of consistent evidence supporting transfer effects, has led researchers to consider alternative approaches. One such approach is to engage participants in activities that stimulate a range of cognitive abilities in a less direct but more naturalistic way.

3.2. Cognitive Engagement Interventions

Engagement in mentally stimulating leisure activities has been associated with cognitive ability in old age, both globally and at the domain level (see Chapter 1, section 1.5.1). One might argue that such associations are a real-life demonstration of the kind of cognitive 'training' that humans engage in naturally. Rather than repetitive, context-free mental tasks, designed to hyper-target specific skills, people tend to engage in meaningful activities that stimulate their cognitive faculties in a more holistic way. Such activities might therefore offer an alternative approach to cognitive interventions, in which a broad range of cognitive abilities are stimulated through increased engagement in cognitively complex pursuits (Park et al., 2007). In the past decade or so, a growing body of empirical work aimed at testing this hypothesis has started to emerge. This nominally began in 2008, when findings from two research programmes were published: Senior Odyssey and Experience Corps.

The Senior Odyssey study (Stine-Morrow et al., 2008; Stine-Morrow et al., 2014) examined the effect of a novel, team-based competitive problem solving programme. Over a period of around six months, participants met once a week in small groups, during which they were challenged with a range of problem solving tasks. Challenges included both short, spontaneous problems (e.g., "name a type of water", with more points awarded for creative answers) and long-term problems (e.g., building a weight-bearing structure from balsa wood or presenting a musical interpretation of a famous historical event). Participants were not given strategic instruction but encouraged to be as innovative and collaborative as possible. Tournaments in which participants presented their solutions were held at the end of the programme to introduce a competitive element.

The authors theorised that the programme would stimulate a range of cognitive domains, during planning (reasoning ability, prospective memory), design (visuospatial ability), writing (verbal ability) and presentation (episodic memory). The programme was also designed to be creatively stimulating (through craft, design and performance aspects) and socially stimulating (through collaboration within teams and competition between teams). In an initial pilot study (Stine-Morrow et al., 2008), 181 older adults were randomised to either the intervention or a wait-list control group. They completed various tests measuring processing speed, working memory, reasoning, visuospatial ability and ‘divergent thinking’ (i.e., the ability to generate creative, original solutions to novel problems; Reese et al., 2001) both pre- and post-intervention. Results showed that, compared to controls, those who engaged in the programme improved significantly more in processing speed, reasoning ability and divergent thinking, as well as an overall composite measure derived from all cognitive tests.

A follow-up study (Stine-Morrow et al., 2014) recruited 461 participants aged 60-94, and randomly allocated them to one of three groups: the Senior Odyssey engagement programme, home based inductive reasoning training, or a waitlist control group. Improvements appeared to be selective to the type of intervention; those in the training group showed significantly greater improvements on tests of reasoning ability compared to those in the engagement programme and those in the control group, while those in the engagement programme showed significantly greater improvements in divergent thinking than those in the training and control groups.

The Experience Corps programme (Carlson et al., 2008) placed volunteer older adults into a scheme in which they helped to run elementary school libraries and mentored students over the course of an academic year. It was hypothesised that participation would stimulate memory and executive function through engagement in tasks such as reading exercises with children, library organisation and cooperative problem solving. The programme included an element of social engagement through interactions with students, teachers and other study volunteers.

One hundred and forty-nine adults aged 60 and over were recruited and randomly assigned to either start the scheme immediately or serve as wait-list controls. Dependent variables were tests of executive function, memory and processing speed. As hypothesised, results suggested that those in the programme improved on measures of executive function and episodic memory, although these changes in performance were small, and not significantly different from those of the control group.

Another smaller-scale study engaged 44 participants aged 60-75 using a wide array of activities selected to be mentally stimulating, including word puzzles, arts and crafts, board games and musical activities, over 10-12 weeks (Tranter & Koutstaal, 2008). Some activities were conducted by participants in their own homes, and some were conducted in laboratory-based group sessions. Participants in the engagement group showed significantly greater improvements in measures of visuospatial ability and overall fluid ability relative to no-contact controls.

Collectively, results from the studies discussed above offered promising insights into the potential benefits of a more engagement-based approach. Park et al. (2014) built on these findings with the Synapse Project. They attempted to delineate the effects of *productive* engagement (i.e., engagement in novel activities that involve active learning) with those of *receptive* engagement (i.e., familiar, passive activities that rely on existing knowledge). In this 14-week intervention, the productive engagement condition was operationalised as the learning of a new skill, through weekly classes teaching either digital photography, quilt-making, or a combination of the two. Those in the receptive engagement condition either attended a facsimile of a weekly social club (typically involving playing games, watching movies or going on outings) or were assigned to a placebo group with activities to do at home that did not involve any form of skill acquisition (i.e., watching documentaries, playing knowledge games or listening to classical music). The use of a comparison group that retained the social aspect of regular group meetings without any new learning alongside the more traditional 'placebo' group allowed the researchers to control for any improvements due to social stimulation alone.

Two-hundred and fifty-nine participants aged 60-90 were recruited. Participants completed a cognitive battery pre- and post-intervention, from which composite scores of processing speed, executive function, episodic memory and visuospatial ability were recorded. The three productive engagement conditions were combined and change in cognitive performance was compared with the two receptive engagement conditions combined. Those in the productive conditions improved significantly more in memory performance, but not in the other cognitive domains. When groups were broken down further, results showed that only those who learned photography showed significantly greater improvements in memory than those in the placebo group. Improvements in the photography group were also significantly greater than those in the social group, suggesting that benefits were not simply due to the social aspects of the classes. These were the first intervention results to suggest that intellectual engagement through active learning of a new skill might offer greater benefits than more passive activities.

Subsequent studies have further explored the possible cognitive benefits of new learning, with a particular focus on using new technology. In an extension of the Synapse Project, Chan et al. (2016) recruited 18 additional participants and enrolled them in a class where they learned how to use tablet computers. They found that compared to social and placebo groups (the same comparison groups used by Park et al., 2014), those who were in the tablet class showed significantly greater improvements in memory and processing speed. Vaportzis et al. (2017) allocated 48 participants aged 65 and over to either a tablet training group or a no-contact control group. As in Chan et al. (2016), those in the tablet training group showed significantly greater improvements in processing speed. Klusmann et al. (2010) recruited 259 women aged 70 and over, and randomised them to either a computer course, an exercise course or a no-contact control group. They found that both experimental groups showed significant improvements in memory performance. Results are not always indicative of improvements, however. Leanos et al. (2019) enrolled a group of older adults on a three month course where they attended classes in painting, Spanish and using a tablet computer. There was little evidence of any cognitive improvements relative to no-contact controls (although sample size was notably small; $N = 15$). Another larger study recruited 191 adults aged 64-75 to take part in three computer classes over two weeks, followed by 12 months of independent computer use at home, with regular internet-related assignments (e.g., emailing the research team). Those who underwent the computer training intervention showed no significant improvements in cognitive ability over and above no-contact controls (Slegers et al., 2009).

Overall, while the body of evidence in this area is currently small and by no means conclusive, there are some encouraging findings that suggest interventions designed to increase mental engagement through the learning of a new skill can elicit cognitive improvements in older adults. Other studies have examined whether increasing levels of physical engagement may also lead to similar cognitive benefits.

3.3. Physical Interventions

Improvements in cognitive performance have been reported in intervention trials testing a range of physical activities. For example, Nagamatsu et al. (2012) randomised a group of older women aged 70-80 to attend twice-weekly resistance training (i.e., exercises targeted at building muscular strength) classes over six months. Compared to a control group who engaged in stretching and balance exercises, those in the resistance training group improved significantly on measures of executive function and memory. Another study randomised participants aged 64-78 to either aerobic exercise training (i.e., exercises designed to enhance cardiovascular fitness) or to a control group (stretching and balance exercises; Jonasson et al., 2017). After six months of training three days per week, those in the aerobic exercise group showed a significantly greater improvement on a composite measure of global cognitive ability.

Interventions utilising more low-impact exercises have also demonstrated cognitive benefits; Gothe et al. (2014) reported improvements in measures of executive function and working memory in older adults aged 55-79 randomised to attend an eight-week yoga course. Maki et al. (2012) designed a three-month walking programme, during which adults aged 65 and over met weekly for walking groups, and were encouraged to increase their daily step count. Compared to controls, the walking group showed significantly greater improvements in verbal fluency. There is also evidence that dance-based interventions may be effective. For example, one study reported improvements in executive function among older adults who attended weekly contemporary dance classes for six months (Coubard et al., 2011).

Kelly et al. (2014b) conducted a meta-analysis of exercise-based RCTs in adults without cognitive impairment. Pooled effect estimates indicated significant improvements in reasoning ability from resistance training interventions when compared to controls who engaged in stretching/balance exercises. There were also significant improvements in processing speed and executive function as a result of Tai Chi interventions when compared to controls who engaged in social/education activities. Aerobic training did not significantly influence any cognitive outcomes. These findings support the efficacy of increased physical activity as a way to improve cognitive ability in older adults.

3.4. Social Interventions

Given the observed links between social activity and cognition, it is notable how few intervention studies have investigated the impact of increased social engagement on cognitive ability. Several of the aforementioned cognitive engagement interventions, such as the Senior Odyssey programme (Stine-Morrow et al., 2008) or Experience Corps (Carlson et al., 2008) were, by design, both mentally *and* socially stimulating. However, as both studies used wait-list controls, it was not possible to establish whether any cognitive improvements were due to increased mental engagement, social engagement or both. As noted previously, the use of a social comparison group in the Synapse Project study (Park et al., 2014) allowed the researchers to test whether cognitive improvements were due to the socially demanding aspects of the activity; results suggested this was not the case.

The few studies that have attempted social interventions have shown promising results. One study recruited older adults with self-reported feelings of loneliness to attend regular social group meetings, involving facilitator-led group discussions. Results showed a significant improvement in global cognitive ability in the intervention group compared to no-contact controls (Pitkala et al., 2011). Another study utilised technology to facilitate daily structured conversations with a trained interviewer via video-chat (Dodge et al., 2015). Over the course of the six-week intervention, those in the conversation condition improved more on measures of verbal fluency compared to no-treatment controls. Similar improvements in verbal fluency were found in another social intervention in which participants met for self-guided group discussions three times a week for around ten months (Mortimer et al., 2012). These findings raise the possibility that verbal fluency may be particularly enhanced by conversation/discussion-based interventions, but more research is needed to further explore this theory.

3.5. Creative Interventions

Interventions aimed at increasing creative engagement are rare. To date, there have been no experimental evaluations of the cognitive benefits of activities in the visual arts (e.g., drawing, painting or sculpture) in older adults. However, some of the effective mental engagement interventions described above, such as the Senior Odyssey study, did include creative aspects to their activities (i.e., writing, designing and crafting; Stine-Morrow et al., 2008). One study found evidence of improvements in memory, problem solving and verbal fluency among older adults who were given acting lessons (Noice & Noice, 2008). There is also evidence that musical training such as piano lessons can enhance executive function and processing speed in older adults (Bugos et al., 2007). As with some of the more mentally engaging interventions, results from these trials demonstrate the positive effects of learning a new skill.

3.6. Study Setting

Evidence suggests that engagement-based interventions, particularly those that involve new learning, may be cognitively beneficial. Interventions to increase physical and social engagement might also produce remedial effects. What all these kinds of intervention have in common is that they appear to result in generalised improvements in a range of cognitive abilities, without directly *training* those abilities.

However, there is still an underlying issue of ecological validity. In the case of engagement-based interventions, even though they offer a more true-to-life experience relative to the traditional cognitive training model, they still have many artificial aspects. Take, for example, the small body of literature regarding the benefits of learning how to use computers or tablets (Chan et al., 2016; Klusmann et al., 2010; Leanos et al., 2019; Slegers et al., 2009; Vaportzis et al., 2017). The classes that participants attended within these studies were all designed and delivered specifically for the study, and only study participants attended them. Thus, there is a risk that they may have been slightly idealised in their delivery, and not reflective of the experience of a computer class in the real world. The same could be said for social interventions, where the socialising is limited to being among other study participants, who may not be representative of the population. Physical interventions fare slightly better in this regard, as many are conducted in gyms or participants' own homes, typical of real-life exercise environments. However, exercise groups or classes organised specifically for study purposes incur the same issues with ecological validity.

A recent systematic review and meta-analysis attempted to address this issue by summarising only studies conducted in real-world, community-based settings (Vaportzis et al., 2019). Pooled effects suggested that community-based physical activity interventions (e.g., aerobic exercise in community centres or yoga at home) were associated with significantly greater improvements in performance on measures of visuospatial ability, processing speed and working memory compared to controls. Combined results from the (admittedly limited) studies on community-based mental engagement interventions (e.g., playing computer games at home or computer classes at a local library) showed no differences in cognitive change compared to controls.

Overall, although studies suggest that new learning and engagement may have positive effects on cognitive ability in old age, whether these findings translate into real-world settings remains unclear. Given that one of the ultimate goals of any intervention is to be taken up by the public in the real-world, this is a key issue for researchers in the area to consider going forward.

3.7. Personality and Cognitive Ageing Interventions

3.7.1. Intervention Adherence

Another issue in the field that is unclear is adherence to cognitive ageing interventions (i.e., how well an individual sticks to a given intervention protocol), which remains relatively unexplored. There is evidence that those who stick to an intervention protocol more closely show greater cognitive improvements. For example, results from the Senior Odyssey study (Stine-Morrow et al., 2014; see Section 3.2) showed a significant positive correlation between the number of group problem-solving sessions attended and performance change in divergent thinking. There was also a significant positive correlation between number of reasoning training packets completed and performance change in reasoning. Understanding what might cause differences in adherence level is thus an important issue in designing effective interventions.

As discussed in Chapter 2, there is evidence that personality traits are associated with level of everyday engagement in specific types of activity (e.g., higher Openness predicting higher engagement in mentally demanding activities; Hultsch et al., 1999). It is therefore possible that personality may also be associated with adherence to an activity-based intervention. To date, no cognitive ageing interventions have examined any personality-adherence associations.

3.7.2. Intervention Efficacy

Another underexplored question in the field of cognitive ageing interventions is the potential moderating influence of personality traits. That is, do certain personality traits predict the degree of cognitive change experienced as a result of a specific intervention? Understanding whether certain personality trait scores predispose individuals to experience greater or smaller cognitive improvements following specific types of intervention can help to tailor interventions towards individuals to make them as effective as possible. The importance of considering personality as a moderator of intervention efficacy has been highlighted as an important area for future research (Hill & Payne, 2016).

3.8. Summary

Interventions to increase older adults' activity engagement levels (including mental, physical, social and creative activity) may be protective against age-related cognitive decline. Cognitive training studies are the most common way that researchers have tested the effects of increasing individuals' mental activity. Results show that while improvements on trained tasks are common, transfer to other, untrained measures of cognitive ability are more limited. Other researchers have adopted an indirect approach, stimulating cognitive ability through increased engagement in mentally stimulating activities, such as competitive problem-solving, volunteering in local schools or learning a new skill. Findings from these studies indicate that such activities may support cognitive improvements without direct training. Regarding physical activity, evidence suggests that the health benefits of physical exercise interventions may also apply to cognitive ability. Interventions that are primarily socially or creatively engaging are less common, but there is evidence that they can produce cognitive improvements.

Whether these approaches remain effective outside of a highly controlled research environment remains an unanswered question. There is also a need for more research into individual differences in intervention-related cognitive change. In particular, the question of whether personality traits might influence both adherence to, and efficacy of, interventions for cognitive ageing remains a notable gap in the literature.

The proceeding chapters of this thesis begin to address these gaps. First, the results of a systematic review of studies that have examined whether personality may moderate intervention efficacy are presented (Chapter 4). This thesis then examines the potential cognitive benefits of a novel activity-based intervention conducted in a real-world setting using a sample of older adults (Chapter 5). Finally, this thesis examines whether personality traits predict intervention adherence (Chapter 6) and whether personality traits might moderate any cognitive change within this intervention (Chapter 7).

It is unlikely that any single intervention activity will be suitable for everyone. Any strategy designed to protect cognitive health in old age will need to be adaptable to individual circumstances to help as many people as possible. It is hoped that the research presented in the next chapters will illuminate how individual characteristics like personality traits may influence intervention success.

4. Investigating Associations Between Personality and the Efficacy of Interventions for Cognitive Ageing: A Systematic Review

Note. The contents of this chapter were published as 'Investigating associations between personality and the efficacy of interventions for cognitive ageing: A systematic review' by Marr et al. (2020). The published version is replicated below and can be found at: https://doi.org/10.1016/j.archger.2019.103992

4.1. Introduction

As average human life expectancy rises (Bennett et al., 2015), so does the need to find effective strategies to maintain cognitive function as we age. Mental abilities, including memory, reasoning and processing speed, all tend to decline, some from as early as middle age (Salthouse, 2004a; Wilson et al., 2002). The resulting impacts on health and social care, as well as the associated costs, continue to increase (Gow & Gilhooly, 2003). More importantly for the individual, age-related cognitive decline can affect health, independence, and overall quality of life (Hendrie et al., 2006; Johnson et al., 2007). Thus the need for effective interventions to maintain, or possibly improve, cognitive functioning in old age is a priority.

Evidence suggests that a number of factors are related to individual trajectories of cognitive change. In particular, higher levels of physical activity, social engagement and intellectual stimulation across the lifespan have been associated with a higher level of cognitive ability and/or reduced decline (Hertzog et al., 2008). As they are potentially modifiable, these factors also lend themselves well to intervention and a growing body of research examines the potential cognitive benefits of increasing physical, social and intellectual activity. For example, studies have investigated the potential cognitive gains associated with increased physical activity, through exercises such as aerobic and resistance training (Kelly et al., 2014b; Nagamatsu et al., 2012; Sink et al., 2015). Others have explored the cognitive impact of increased social stimulation (Pitkala et al., 2011). In terms of intellectual stimulation, research has often focussed on whether cognitive training may be beneficial. Studies have used techniques such as teaching mnemonics as memory aids (Derwinger et al., 2005; O'Hara et al., 2007) or training to improve specific skills such as working memory or processing speed (Ball et al., 2002; Guye & von Bastian, 2017; Rebok et al., 2014).

Cognitive training studies typically take place in a controlled lab-based setting, and tend to focus on specific abilities (e.g., memory, speed of processing). However, some interventions have adopted a more naturalistic approach, encouraging people to engage in a variety of novel physical, social and/or intellectual activities in less formal, community-based settings, with the aim of engaging a broader range of cognitive skills (Park et al., 2014; Stine-Morrow et al., 2008; Vaportzis et al., 2017). Results from a previous meta-analysis of 'real-world' interventions suggest that community-based physical interventions can lead to specific improvements in processing speed (Vaportzis et al., 2019). Such techniques may also have potential benefits that go beyond cognitive gains, such as improved physical health (Nagamatsu et al., 2012) or psychological wellbeing (Routasalo et al., 2009).

One aspect of cognitive ageing interventions that remains relatively unexplored is the influence of individual differences on intervention outcomes. In particular, the influence of personality has received little research attention (personality is here defined as the relatively stable characteristics that influence individuals' thoughts, feelings and actions, which can be conceptualised across several dimensions known as 'traits'). This gap in the literature is notable given observational studies suggest there are links between personality traits and cognitive function in old age.

With reference to the Big Five traits (Neuroticism, Extraversion, Openness to Experience, Agreeableness and Conscientiousness), higher Openness (intellectual curiosity, adventurousness and a desire for novelty) has been linked to better cognitive performance (Sharp et al., 2010). Furthermore, higher Neuroticism (the tendency to experience anxiety and negative emotions) has been associated with greater levels of cognitive decline, while higher Conscientiousness (organisation, self-discipline, goal-directed behaviour) has been associated with less decline (Chapman et al., 2012; Luchetti et al., 2016). Links between Extraversion (the tendency to be assertive and socially outgoing) and cognitive ability are less consistent, with some studies reporting a positive association with general cognitive ability (Martin et al., 2009) and others reporting a negative association (Luchetti et al., 2016). The relationship between cognitive ability and Agreeableness (altruism, prosocial behaviour) is similarly unclear; both positive (Aiken-Morgan et al., 2012) and negative (Allen et al., 2019) associations have been reported.

Aside from the Big Five traits, other personality conceptualisations, such as Need for Cognition, have similarly been linked to cognitive outcomes in old age. Need for Cognition conceptualises individual differences in the tendency to seek out and enjoy cognitively demanding activities (Cacioppo & Petty, 1982). High scores on this trait have been positively linked to global cognitive function and change in cognitive function over time (Baer et al., 2012; Cacioppo & Petty, 1982), possibly because such individuals tend to seek out more cognitively stimulating activities or environments. Trait Anxiety, which, similarly to the Big Five trait of Neuroticism, measures an individual's relatively stable tendency to experience anxious feelings, has also been linked to deficits in attention in old age (Hogan, 2003).

Personality traits also play an important role in acquiring and maintaining health-related behaviours (Chapman et al., 2011); for example, scores on the trait of Conscientiousness have been found to positively influence physical activity (Rhodes & Smith, 2006) and medication adherence (Molloy et al., 2014). However, to date, few studies have considered whether personality traits are associated with adherence to interventions specifically targeting cognitive ageing.

Furthermore, there has been limited consideration of the role of personality in intervention outcomes; in other words, whether certain traits predispose people to benefit more from certain types of intervention. Conscientious individuals are typically more organised, diligent and have more self-control (McCrae & John, 1992). Therefore one might expect them to benefit more from a demanding, repetitive cognitive training intervention (a study with a younger population reported such an association; Studer-Luethi et al., 2012). Similarly, someone scoring higher on Extraversion may benefit more from an intervention conducted in a less structured environment, with more opportunity for social interaction. If certain personality traits are conducive to improvement, then understanding such influences may help to optimise the effectiveness of interventions, through more individually-tailored approaches (Chapman et al., 2014; Chapman et al., 2011; NIH, 2011).

Researchers are beginning to acknowledge the potential importance of personality in promoting healthy ageing (Hill & Payne, 2016). The primary aim of this review was to provide a basis for further investigation by summarising the current literature regarding the influence of personality traits on non-pharmacological interventions targeting age-related cognitive decline. Specifically, two questions were examined: 1) is personality associated with the efficacy of interventions; and 2) is personality associated with intervention adherence?

4.2. Methods

The methods and results of this systematic review are reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). The review was pre-registered on PROPSERO (registration ID: CRD42018085533) and can be accessed online via the

University of York website

(http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42018085533).

4.2.1. Search Strategy

Searches of PubMed, PsycINFO and Web of Knowledge databases were conducted between 31 May 2018 and 1 November 2019. Search terms considered the three key concepts outlined in the research aims; namely, included studies had to: a) be interventions; b) be targeted at age-related cognitive decline; and c) include some form of personality assessment (while the most common conceptual framework of personality is some version of the Five Factor Model, no single type of personality measure was specified). Example terms included “cognitive training”, “brain training”, “cognitive decline” and “neuroticism”. Search terms were finalised by discussion among three members of the research team (CM, AJG and MD). The same search string was used for all three databases and is reproduced in Appendix E. No language or date restrictions were applied. Additional studies were identified through searching reference lists of included studies, hand searches of the authors’ own records and searches of Google Scholar.

4.2.2. Inclusion Criteria

Studies were included in the current review if they: 1) used an intervention (this included randomised controlled trials, non-randomised controlled trials, pseudo-randomised controlled trials or non-controlled trials); 2) were conducted with participants aged 50 or over; 3) were conducted with participants without any diagnosed neuropsychological condition (for the purposes of this review, samples including individuals with subjective memory impairments or Mild Cognitive Impairment [MCI] were retained); 4) included one or more cognitive assessments as an outcome measure; 5) reported a personality measure (a ‘personality measure’ is defined here as an assessment of relatively stable, consistent traits; other more dynamic, task-dependent psychological constructs such as self-efficacy, which has been examined as a potential moderator in some studies [e.g., Payne et al., 2012; Sharpe et al., 2014], are beyond the scope of the present review); 6) were published in English; and 7) were published in a peer-reviewed journal (i.e., book chapters, PhD theses and conference abstracts were excluded).

4.2.3. Selection Process

Search results were combined and any duplicates removed. Titles and abstracts were then screened by one reviewer (CM) according to the inclusion criteria. As the inclusion of personality measures was not always mentioned explicitly in the title or abstract, studies meeting the remainder of the criteria were retained at this stage.

Studies were then subject to full-text screening. This was performed by two reviewers (CM and EV/AJG) independently, with any resulting disagreements resolved through discussion. Any study that failed to meet all eligibility criteria was removed, with the reason for rejection recorded. Full-text screening allowed those studies not reporting a personality measure to be removed. If a personality measure was included but the study did not investigate its association with intervention efficacy, the study was retained and the authors were contacted for further information/data. If there was no response to an initial email or follow-up, or the author indicated that there were no available data, these studies were removed.

4.2.4. Data Extraction

Data were extracted using an electronic data form. Study characteristics recorded included design (i.e., RCT, non-RCT, pseudo-randomised), population, intervention type, cognitive outcome and personality measure.

4.2.5. Study Quality

Two reviewers (CM and EV) independently assessed the quality of the included studies using the Cochrane Collaboration's 'Risk of Bias' Tool (Higgins et al., 2011).

This assesses risk of bias in a given study across several domains, including sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting and any other issues. For each domain, a study is assigned either a high, low or unclear risk of bias based on the information reported in the given study. The decision to assign a high, low or unclear risk of bias is a qualitative judgement made by the reviewer, according to criteria laid out in the Cochrane Handbook (Higgins & Altman, 2008). For example, a study that did not report statistical results for all pre-specified outcomes would typically be rated as having a high risk in the domain of reporting bias. Any discrepancies in judgements were discussed between reviewers until a consensus was reached. The risk of bias table is presented in Appendix F.

4.3. Results

4.3.1. Study Selection

The initial database search yielded 2268 potential studies; additionally, 7 studies were identified via reviewing reference lists, lists of citing publications and searches of Google Scholar. Following removal of duplicates, the resulting 2100 studies were therefore subject to title/abstract screening. Of these, 116 were retained for full-text screening according to the criteria outlined above. Full-text screening resulted in the further exclusion of 96 studies; most were excluded due to not including a personality measure (see Figure 4.1).

Of the remaining 20 studies, eight reported an association between a personality trait and intervention efficacy while 12 reported the use of a personality measure but did not examine the influence of personality itself. The corresponding authors of these 12 studies were contacted via email to ascertain whether they had any unpublished findings regarding the effect of personality, and/or whether they would be willing to share any data for further analysis. Two authors (Gajewski & Falkenstein, 2012; McDougall et al.,

2010) responded and shared pertinent data, and their respective studies were therefore included in the review. Three authors responded that they had no available data to share and the respective studies were therefore excluded. Seven authors did not respond to an initial email or follow-up; those studies were excluded. Therefore, of the 20 studies identified in the full-text screening stage, 10 were retained and are summarised below.

None of the 20 studies retained after full-text screening reported the influence of personality traits on intervention adherence. Authors of 19 of the studies were contacted for any available information on intervention adherence (Hering et al., 2017, was not included in this follow-up as the study reported no drop-out over the four intervention sessions). Five authors responded that they did not examine the question of adherence. Twelve authors did not respond to an initial email or follow-up. Authors of two studies (McDougall et al., 2010; Cerino et al., 2020) provided information regarding personality and adherence.

4.3.2. Study Characteristics

Setting and Design. Study characteristics are summarised in Table 4.1. The ten included studies were published between 1989 and 2020. Five were conducted in the United States, two in Switzerland, one in Canada, one in Italy and one in Germany. Seven of the studies were RCTs; of the remaining three, one did not assign conditions randomly and did not include a control group (Finkel & Yesavage, 1989), one used random group assignment but lacked a control group (Gratzinger et al., 1990), and one consisted of a single intervention group and no controls (Carretti et al., 2011). Nine studies reported the effects of some kind of cognitive training intervention; seven of these were conducted in structured settings designed specifically for the study (i.e., in labs at a university or in local classroom facilities; Belleville et al., 2018; Carretti et al., 2011; Finkel & Yesavage, 1989; Gajewski & Falkenstein, 2012; Gratzinger et al., 1990; Hering et al., 2017; McDougall et al., 2010) and two were home-based (Guye et al., 2017; Stine-Morrow et al., 2014). Two also reported additional kinds of intervention; one physical intervention conducted in a gymnasium (Gajewski & Falkenstein, 2012) and one intellectual engagement program using team-based problem solving conducted in local schools (Stine-Morrow et al., 2014). Finally, one study reported the effects of a home-based social intervention (Cerino et al., 2020).

Sample Characteristics. Reported average age of study participants ranged from 67.3 - 75. Seven studies were conducted exclusively with cognitively healthy populations. Of the remaining three, one study (McDougall et al., 2010) included participants with Mini Mental State Examination (MMSE; Folstein et al., 1975) as low as 20/30 (the original eligibility cut-off of 23/30 was lowered at one study site in order to recruit participants with lower education; average scores were 28.05 and 27.98 in the intervention and comparison groups respectively), and another recruited both healthy participants and participants with MCI (Cerino et al., 2020). Another used an entirely MCI sample, characterised as individuals reporting a memory complaint and a performance at least 1.5 SD below the average of same-age peers on a battery of clinical tests; those scoring below 24/30 on the MMSE were excluded (Belleville et al., 2018). As these were the only three studies found to examine the role of personality in individuals with MCI (or possible MCI), it was decided that they would be included and reported alongside the studies using cognitively healthy samples, with differences in sample population noted (see Table 4.1).

4.3.3. Is Personality Associated with Intervention Efficacy?

Personality Measures. Internal consistency estimates of the personality measures reported here are from previous research examining the psychometric properties of the questionnaires and are included for descriptive purposes. Only three of the included studies (Carretti et al., 2011; Cerino et al., 2020; McDougall et al., 2010) reported consistency estimates from their own samples (see Table 4.2).

Six of the included studies used a questionnaire that assessed the Big Five personality traits. Two studies (Finkel & Yesavage, 1989; Gratzinger et al., 1990) used the full 240-item NEO-Personality Inventory (NEO-PI; Costa & McCrae, 1985); internal consistency estimates for each trait being Neuroticism: α = .93; Extraversion: α = .87; Openness: α = .89; Agreeableness: α = .76; Conscientiousness: α = .86 (Costa & McCrae, 1992b). Two (Gajewski & Falkenstein, 2012; Guye et al., 2017) used the shorter 60-item NEO-Five Factor Inventory (NEO-FFI; Costa & McCrae, 1992a); Neuroticism: α = .87; Extraversion: α = .74; Openness: α = .72; Agreeableness: α = .74; Conscientiousness: α = .84 (Egan et al., 2000). Stine-Morrow et al. (2014) used the International Personality Item Pool (IPIP; Goldberg, 1999); Neuroticism: α = .87; Extraversion: α = .84; Openness: α = .73; Agreeableness: α = .76; Conscientiousness: α = .77 (Gow et al., 2005a) to measure the big five traits. Cerino et al. (2020) employed the 44-item Big Five Inventory (BFI; John & Srivastava, 1999); Neuroticism: α = .84; Extraversion: α = .88; Openness: α = .81; Agreeableness: α = .79; Conscientiousness: α = .82.

Belleville et al. (2018) used the Eysenck Personality Inventory (Eysenck, 1968) which assesses the traits of neuroticism and extraversion (Neuroticism: α = .92; Extraversion: α = .89; Gabrys, 1982). Four studies used a version of the Need for Cognition scale (α = .91; Cacioppo et al., 1984); Guye et al. (2017) used a German version (Bless et al., 1994) and Hering et al. (2017) used a French version (Ginet & Py, 2000). McDougall et al. (2010) used the Spielberger State-Trait Anxiety Inventory (Spielberger et al., 1970); α = .89 (Barnes et al., 2002). This inventory also measures the more transient state anxiety; for the purposes of this review all results will exclusively focus on the effect of trait anxiety.

Personality Effects. Table 4.2 presents the main intervention effects of all included studies, along with relevant outcome measures and specific analysis methods used to investigate the influence of personality traits. In total, five of the included studies found that personality was associated with intervention outcomes, and five found no effect.

Regarding the Big Five traits, Openness to Experience (or a facet of Openness) was associated with greater cognitive gains post-intervention in three studies (Finkel & Yesavage, 1989; Gratzinger et al., 1990; Stine-Morrow et al., 2014). Finkel and Yesavage (1989) found that improvements in list recall following computer-aided mnemonic training were significantly greater for those who scored higher on Openness. Gratzinger et al. (1990) found that Fantasy, a facet of Openness, was associated with greater improvement in face-name recall following mnemonic training when training was combined with a visual imagery pre-training exercise, but not when it was combined with a relaxation pre-training exercise. Stine-Morrow et al. (2014) found that higher levels of Openness were associated with greater gains in divergent thinking following participation in a team-based cognitive engagement programme, but not following an individual-based reasoning training programme.

Cerino et al. (2020) found significant moderating effects of Extraversion, Agreeableness and Conscientiousness on improvement on a range of cognitive outcomes following their social intervention, during which participants engaged in daily computer-aided conversations. Those higher in Extraversion improved significantly more on a measure of language-based executive function (letter fluency), but showed less improvement on a delayed list-recall task, an executive function task (Trail Making Test B) and a working memory task (2-back). Those higher in Conscientiousness and Agreeableness improved significantly more on tests of language-based executive function (category fluency and letter fluency respectively).

Gajewski and Falkenstein (2012) provided their data for further analysis. This study investigated the effects of several interventions (cognitive training, physical training and relaxation training) on task-switching ability. A secondary analysis of data from this study carried out by the current authors suggested that none of the Big Five traits had an effect on change in task-switching performance (for a summary of these analyses see Appendix G). Finally, Guye et al. (2017) found no evidence of the Big Five personality traits influencing training-related changes in working memory performance.

Need for Cognition was positively associated with improved list recall in one cognitive training study (Carretti et al., 2011), but negatively associated with gains in divergent thinking in another study that employed a novel competitive problem solving intervention (Stine-Morrow et al., 2014). Two other studies that attempted to train working memory ability reported no effect of personality (Guye et al., 2017; Hering et al., 2017).

Neither of the Eysenck personality variables (Neuroticism or Extraversion) were reported as having an effect on memory performance following a cognitive training programme targeted at memory and attentional control (Belleville et al., 2018). Trait anxiety did not influence the effect of a memory training intervention (McDougall et al., 2010).

In summary, Openness to Experience was associated with increased intervention-related gains in memory in two studies and with increased gains in divergent thinking in another. One other study found beneficial effects of Agreeableness and Conscientiousness on language-based executive function, and mixed effects of Extraversion. Need for Cognition was positively associated with intervention-related memory gains in one study, but inversely associated with gains in divergent thinking in another. None of the other personality measures were found to have an effect.

4.3.4. Study Quality

An assessment of risk of bias by two independent reviewers found mixed results (see Appendix F). In line with recommendations by Higgins et al. (2011), a study that was assigned a high risk of bias for one or more domain is deemed to have an overall high risk of bias that may affect results. Only one study was found to have low risk of bias across all pertinent domains (Guye et al., 2017); this study found no evidence of personality traits influencing training-related change in working memory performance.

Among the five studies that found a significant influence of personality traits, risk of bias was generally high. Carretti et al. (2011) was assessed as having a high risk of bias in five domains (random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment and selective reporting). Finkel and Yesavage (1989) was assigned a high risk of bias in four domains (random sequence generation, allocation concealment, blinding of participants and personnel and blinding of outcome assessment). Gratzinger et al. (1990) and Stine-Morrow et al. (2014) each had a high risk of bias in one domain (blinding of participants and personnel). Cerino et al. (2020) was the only study reporting significant personality effects not to be assigned a high risk of bias in any domain.

4.3.5. Does Personality Influence Intervention Adherence?

No studies published analyses regarding the relationship between personality and intervention adherence. Upon request, authors of two studies (McDougall et al., 2010; Cerino et al., 2020) provided additional data. McDougall et al. (2010) provided estimated effect sizes of the association between trait anxiety and adherence to their memory training intervention (number of training sessions attended). The main effect of trait anxiety on number of sessions attended was negligible (η_p^2 = .004), as was the interaction between anxiety and group (η_p^2= .001). Cerino et al. (2020) shared correlations between the five personality traits measured by the BFI and adherence to their social intervention (number of conversation sessions completed), all of which were non-significant (Neuroticism: $r = .15$, $p > .05$; Extraversion: $r = -.06$, $p > .05$; Openness: $r = -.25$, $p > .05$; Agreeableness: $r = .08$, $p > .05$; Conscientiousness: $r = -.3$, $p > .05$).

4.4. Discussion

Finding effective ways to maintain or improve cognitive function in old age continues to be a research priority. While personality traits may play an important role in individuals' response to intervention, few studies have considered this. The current systematic review of the literature identified only ten studies addressing the question of how individual differences in personality might influence intervention outcomes.

4.4.1. Personality and Intervention Efficacy

Of the Big Five traits, Openness to Experience was the only trait found to have a significant association with intervention-related cognitive gains in more than one study. In two of the five studies that examined the Big Five traits, higher Openness was associated with greater improvement over the course of the intervention, while a third study found beneficial associations with a facet of Openness known as Fantasy. Two of these studies used mnemonic training (Finkel & Yesavage, 1989; Gratzinger et al., 1990) and one used a team-based competitive problem solving programme (Stine-Morrow et al., 2014).

Individuals higher in Openness to Experience tend to show greater intellectual curiosity, adventurousness and a preference for novelty and variety in their lives (McCrae, 1994; McCrae et al., 2015). One might expect, therefore, that such individuals would respond well to an intellectually stimulating activity, particularly a novel, interactive programme such as that employed by Stine-Morrow et al. (2014). Indeed, the authors reported there was no such effect of Openness for those assigned to a different intervention, consisting of a more controlled, repetitive cognitive training intervention.

Furthermore, Openness was also associated with improved gains after mnemonic training in two other studies. These studies both employed novel techniques as part of their training. One used a computer as a delivery method (which might have had an element of novelty for many of the participants at the time of publication; Finkel & Yesavage, 1989). Another taught mnemonics with a visual imagery technique which required participants to imagine transformations of people's names and faces (Gratzinger et al., 1990; notably, this particular study found a specific influence of the facet O1 Fantasy, which relates to individuals' affinity for imagination). Other training studies that used more traditional cognitive training techniques showed no effect of Openness (Gajewski & Falkenstein, 2012; Guye et al., 2017). Combined, these findings suggest Openness may positively influence intervention results when using less conventional methods.

Although no specific hypotheses were made prior to conducting this review, it was suggested that cognitive training techniques may be more beneficial to those higher in Conscientiousness, while less controlled, more socially engaging methods may work better for those higher in Extraversion. There was mixed support for these suggestions. Conscientiousness did not influence outcomes in any of the included cognitive training studies. It may be that the supervised, highly controlled nature of the training procedures did not allow people's natural diligence to exert much of an influence. Previous research has shown that chronic disease patients scoring higher on Conscientiousness are more likely to stick to a less structured treatment that allows them to exercise personal control, while those lower in Conscientiousness require more structure and supervision (Christensen & Smith, 1995). It is therefore possible that Conscientiousness could have a greater influence outwith the constrained setting of a research study, for example in a more true-to-life setting. Indeed, the one study that did find a beneficial effect of Conscientiousness (Cerino et al., 2020) was a social intervention, with daily computer-based conversations carried out in participants' homes. This less formal setting may have stimulated the more conscientious individuals to exert their natural diligence and commit more effort towards the study, thus resulting in greater benefits.

Concerning Extraversion, findings were again mixed. One study that employed a less structured, more sociable intervention found no evidence of any facilitating effects (Stine-Morrow et al., 2014). However, Cerino et al.'s (2020) social intervention did result in some increased gains in language-based executive function for more extraverted individuals. The intervention protocol in this study was purely social (daily structured conversations), which may have stimulated those high in Extraversion more than Stine-Morrow et al.'s (2014) more cognitively demanding problem-solving tasks. It should, however, be noted that higher Extraversion was also associated with reduced gains on other measures of executive function, episodic memory and working memory. The authors suggest that the benefits of extraversion may be selective towards language-tasks, as more 'nonconversational' tasks such as Trail Making and 2-back tasks fail to hold the attention of such individuals. Therefore, it may be possible that more purely social interventions stimulate more extraverted individuals, but that these benefits are only apparent for tasks that they find engaging. However, such conclusions must be treated with caution when based on only one study. Further research using a range of cognitive tasks is necessary to elaborate the links between personality traits and specific task content.

Interestingly, given that Neuroticism has been previously linked to cognitive decline in old age, there was no evidence that this trait influenced intervention outcomes. The effect of Neuroticism was examined in seven studies (Belleville et al., 2018; Cerino et al., 2020; Finkel & Yesavage, 1989; Gajewski & Falkenstein, 2012; Gratzinger et al., 1990; Guye et al., 2017; Stine-Morrow et al., 2014) and another examined the similar concept of trait anxiety (McDougall et al., 2010). It is notable that among the studies that reported sample personality characteristics, Neuroticism or trait anxiety scores were typically towards the lower end of the scale (Belleville et al., 2018; Gajewski & Falkenstein, 2012; Guye et al., 2017; McDougall et al., 2010), suggesting that more anxious individuals or those higher in Neuroticism, who may have responded differently, were generally under-recruited. Broader, more representative samples will be required to fully understand the role of these kinds of traits.

No predictions were made regarding the effect of Agreeableness. Among the studies included here, none of the cognitive training interventions were influenced by this trait. The only study to find a beneficial effect was Cerino et al.'s social intervention (2020), with those scoring higher improving more on a measure of language-based executive function. As the authors of this study note, the generally trusting and pro-social nature of people who score highly in Agreeableness may have led them to take to the conversation-based intervention more readily, and therefore benefit more from it.

The only other personality measure to show any significant effect was Need for Cognition. One study found that higher Need for Cognition predicted greater recall performance after memory training (Carretti et al., 2011). Conversely, Need for Cognition was associated with less improvement in divergent thinking after a team-based problem solving programme (Stine-Morrow et al., 2014). Individuals with higher Need for Cognition are more likely to enjoy and engage with cognitively stimulating activities (Cacioppo et al., 1984), so it seems sensible that they might benefit more from a cognitively stimulating intervention. The fact that they did appear to benefit more from a training intervention in one study but not from a more indirect approach is an interesting discrepancy. Stine-Morrow et al. (2014) note the conceptual overlap between Need for Cognition and Openness to Experience, and suggest that as Need for

Cognition measures an enjoyment of mental effort for its own sake, this may not suit the more creative and imaginative environment of the novel problem solving programme which appears to benefit more open individuals. This raises the possibility that Need for Cognition may be beneficial only for more traditional, rote learning-based training interventions. It should be noted, however, that Carretti et al. (2011) did not include a control or comparison condition in their study, making it unclear whether the beneficial effect of Need for Cognition was specific to the training paradigm used or whether it was predicting greater retest effects. Furthermore, two other studies employing more traditional cognitive training techniques found no effect of Need for Cognition (Guye et al., 2017; Hering et al., 2017). It is therefore difficult to draw any concrete conclusions regarding this trait; studies including both Need for Cognition and Openness to Experience may be required to clarify overlaps in these constructs, and adequate control or comparison groups will be necessary to account for confounding retest effects.

4.4.2. Personality and Intervention Adherence

Even among the limited number of studies that considered personality, none initially reported the association between personality and adherence. This question remains a notable gap in the literature, especially given evidence that adherence to an intervention may be positively associated with improvement (Stine-Morrow et al., 2014). If certain personality traits predict adherence, this may suggest one pathway through which personality exerts its influence on intervention efficacy.

For example, evidence shows that the relationship between conscientiousness and perceived health is mediated by medication adherence in older adults (Hill & Roberts, 2011). This is a case of personality influencing a health-related behaviour with a clear impact on health-related outcomes. Applying this to a cognitive ageing intervention, we might expect certain personality traits to be related to adherence to, for example, a cognitive engagement programme. To take the trait of Openness to

Experience, less open individuals (who are less likely to enjoy trying something new) may not follow a novel engagement programme as much as their more open counterparts. This, in turn, may minimise any potential benefits of the intervention itself. Such a process has already been demonstrated in an observational study, which found that level of engagement in stimulating activities mediated the association between Openness and cognitive function (Ihle et al., 2016). However, this personality-adherence-cognition relationship has yet to be examined in an intervention setting.

In an attempt to explore this issue, authors of the included studies were requested to share any unpublished data regarding personality and adherence. Authors of two studies (McDougall et al., 2010; Cerino et al., 2020) responded, providing results which revealed no effect of trait anxiety on adherence to a 3-month-long memory training regime, and no relationship between the Big Five traits and adherence to a conversation-based intervention. However, the lack of any other available data that can be used to address this question limits the ability to draw meaningful conclusions; if the goal of cognitive ageing interventions is to affect meaningful and sustained behaviour change in the real world, understanding how and why people adopt and maintain these behaviours is necessary. Further investigation of the role of personality differences in intervention adherence should therefore be a key research priority going forward.

4.4.3. Tailoring Interventions

'Personalised medicine', or the targeting of specific sub-groups of people who may respond more to a specific treatment, is a growing area of public health research (Hamburg & Collins, 2010). While much of this research has focused on genetic or biological factors, it has been suggested that personality may also be an important tool for tailoring treatments to individuals (Chapman et al., 2014). For example, one study found that those higher in Neuroticism benefitted more from pharmacotherapy compared to cognitive-behavioural therapy in the treatment of depression, which, as the authors noted, has direct implications for the treatment of these individuals (Bagby et al., 2008).

As the current review demonstrates, the body of research examining personality and response to cognitive ageing interventions is currently too small to make treatment recommendations. Future investigation will help to build this body of research and deepen our understanding of how personality traits influence response to interventions, and in doing so illuminate new ways in which we can tailor interventions to individuals. For example, if further research supported the hypothesis that individuals who score high on Openness respond better to less conventional interventions, perhaps these individuals could be directed towards such programmes in order to gain the greatest cognitive benefits. On a practical level, this could help make interventions more cost-effective, and provide a greater incentive for healthcare providers to adopt these approaches (Chapman et al., 2014).

However, this also raises the important question of what strategies to use for people who are lower on a particular trait. If, for example, more conscientious individuals benefit more from a home based intervention such as Cerino et al.'s (2020), how then do we engage their less conscientious counterparts? It may be that interventions could be adapted for such individuals in ways that can also enhance their levels of organisation, control and self-discipline. For example, there is evidence to suggest that short interventions to aid planning ability can enhance medication adherence (O'Carroll et al., 2013), and this has been suggested a potential way to improve adherence amongst those lower in Conscientiousness (Molloy et al., 2014). To apply this logic to a cognitive intervention, perhaps those with low Conscientiousness could benefit from a pre-intervention stage that targeted their planning skills, or regular reminders to encourage them to adhere to an intervention protocol.

Furthermore, recognising the importance of personality could inform the way interventions are promoted to the public. There is evidence that the way that health messaging is framed can influence people's health related behaviours (e.g., smoking habits or exercise; Gallagher & Updegraff, 2012). Understanding the role of personality could help to tailor the way such interventions are targeted towards certain individuals. Adopting the example of Openness, if less conventional methods are in fact more beneficial, then this aspect of the intervention can be emphasised when targeting people who are more open to trying new things.

4.4.4. Limitations

The ten studies included in this review cover a period of 31 years and use a variety of methods to examine the role of personality. Such a disparate sample made it difficult to draw firm conclusions. This is further compounded by the heterogeneity of the included studies, which vary in their intervention technique, duration, location and intensity, as well as the cognitive and personality measures employed. For example, most were cognitive training studies, but varied in the cognitive domain targeted. Intervention durations ranged from two weeks to six months, and some consisted of one class per week while others consisted of several per week. Most studies were conducted in typical lab-based settings, though three were conducted at home and another out in the community. Studies also varied in the cognitive outcomes used to assess intervention effects, with some relying on single tasks, such as list recall, while others created composite measures from a number of different tasks. It may be the case that, as suggested by Cerino et al. (2020), individuals who score highly on certain traits (e.g., Extraversion) may respond more to certain types of cognitive task (e.g., more conversational tasks). However, it is difficult to draw any conclusions about specific cognitive tests based on single studies. Personality assessments were also inconsistent, and even those that considered the same constructs often employed different versions.

Such variation likely reflects the fact that many of these investigations were exploratory and had little previous research to draw on. A more cohesive approach in future studies, with hypotheses based on the extant literature, will help to develop more concrete conclusions.

Furthermore, statistical analysis techniques also varied across studies. Some conducted correlation analyses between personality variables and the magnitude of change between pre and post-intervention. Others examined personality as a predictor of change through regression or latent growth curve modelling. Wang et al. (2007) previously pointed out the lack of consistency when it comes to examining and reporting individual differences in trial outcomes. In addressing this, interactions between treatment group and a moderating baseline variable have been recommended as the most appropriate method to examine heterogeneity in treatment effects (Wang et al., 2007; Yusuf et al., 1991). This method has previously been used to examine the moderating effect of other variables on cognitive ageing interventions, such as self-efficacy or APOE status (Sharpe et al., 2014; Solomon et al., 2018), and as such may represent a useful approach for future analyses concerning the influence of personality on intervention success. Statistical analysis should be an important consideration going forward, as adopting a more consistent method across future studies will aid in the synthesis of findings and recommendations of appropriate interventions.

The quality of the included studies also presents an issue. Four of the studies that found a significant effect of personality traits were assessed as having a high risk of bias in at least one pertinent domain. In particular, three of these studies did not employ a control group, and none adequately reported randomisation or blinding procedures. The result of this is a generally high risk of selection bias due to participants not being randomly assigned to groups, and a high risk of performance bias due to the possibility that participants were aware of the group they were allocated to and altered their performance accordingly. Any conclusions are therefore subject to the caveat that estimations of any intervention effects may have been affected by study design. Researchers should endeavour to minimise these risks by exploring the role of personality traits within a randomised, controlled design.

Finally, it should be noted that three studies were included that did not focus solely on healthy populations. One was conducted on a sample of individuals with MCI (Belleville et al., 2018), another was conducted on a mixed healthy and MCI sample (Cerino et al., 2020) and a third included participants with abnormal MMSE scores (McDougall et al., 2010). It may well be the case that the effects of personality differ between healthy and clinical populations (although it should be noted that Cerino et al., 2020, controlled for the effect of baseline cognitive status in their analyses). These studies are reported here with the caveat that, in future, further studies may examine potential variations by comparing populations.

4.4.5. Recommendations and Future Directions

As research interest grows in the field of cognitive ageing, future intervention studies should consider including measures of personality as potential moderators. It is hoped that this systematic review will provide a foundation for those studies to build on. However, as noted above, the small number of studies summarised here means that any conclusions should be treated as preliminary, and will only be supported by further investigation replicating the findings observed.

The studies summarised here are the first to explore the links between personality traits and intervention efficacy, and as such analyses are mostly exploratory. Future studies could build on these findings by planning to analyse the effect of personality at the design stage. Basing study designs on the previous literature would inform the selection of both personality measures and cognitive outcomes. The personality trait with the most consistent moderating effect was the Big Five trait of

Openness to Experience. Other Big Five traits (Extraversion, Agreeableness, and Conscientiousness) were also found to influence intervention outcomes. In light of this, future studies should consider using a questionnaire designed to assess the Big Five traits such as the NEO-PI-R (Costa & McCrae, 1992a); this would also allow future investigators to examine effects at the facet level rather than just broad traits.

For example, as results from memory training studies have shown that Openness can influence intervention efficacy (Finkel & Yesavage, 1989; Gratzinger et al., 1990), future studies employing a memory training intervention should include a personality measure that assesses the Big Five trait of Openness. This would allow for specific testing of hypotheses based on previous findings. Similarly, a more consistent analytic approach as outlined in the limitations section above would be useful for a potential quantitative synthesis in the future.

Future studies might also consider other potential moderators of intervention effects. While other psychological factors such as self-efficacy and motivation were beyond the scope of the present review, they may also influence the results of an intervention (Payne et al., 2012; Guye et al., 2017; Sharpe et al., 2014) and could offer further means through which interventions can be tailored to individuals.

4.4.6. Conclusion

In bringing together the current literature regarding the influence of personality traits on response to cognitive ageing interventions, this review provides a basis for future investigations. However, the heterogeneous nature of the results means that conclusions must be treated with caution.

Two research questions were examined. Evidence regarding the association between personality traits and intervention efficacy was mixed. The most consistent finding was that higher Openness to Experience was positively associated with improvement, potentially due to such individuals being comfortable with trying novel and unconventional methods. Evidence regarding other traits was less clear: one study found beneficial effects of Conscientiousness and Agreeableness, and both positive and negative effects of Extraversion. Another study found beneficial effects of Need for Cognition while others did not. Only two studies provided evidence regarding the second research question focusing on the relationship between personality and intervention adherence, with no associations found.

As interest in cognitive ageing interventions continues to grow, so too should the consideration of how to help individuals benefit most. Future research should aim to build on the findings presented here by investigating the role that individual differences might play in the promotion of healthy ageing. Personality could offer a useful tool for targeting and tailoring interventions, and therefore helping people to maintain their independence and quality of life for longer.

Figure 4.1

Summary of selection process according to the PRISMA guidelines

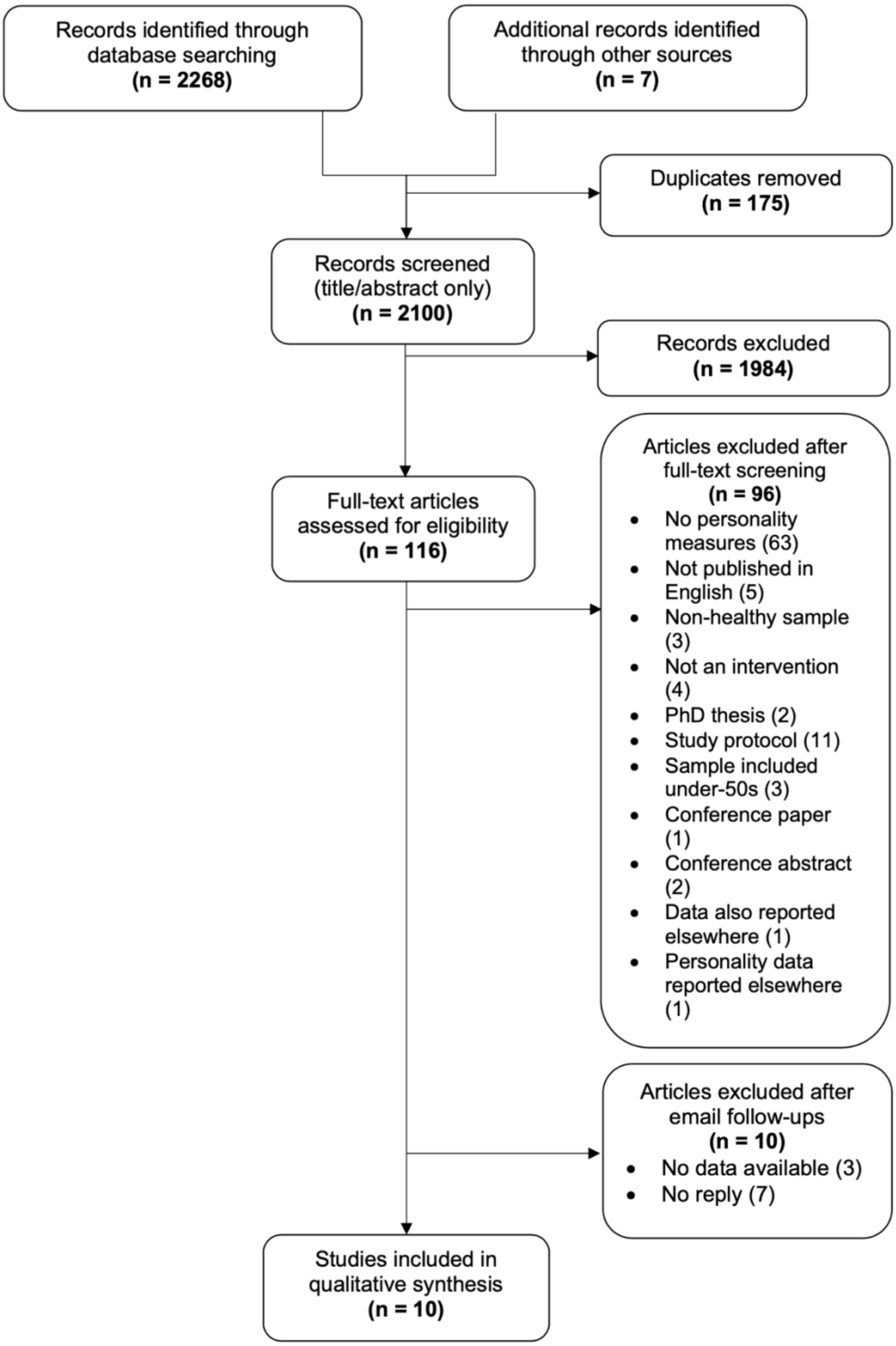


Table 4.1

Study Characteristics of all Included Studies

Study	Year	Country	Design	Mean Age (Range)	Population	Intervention	Setting	Duration (Frequency)	Experimental group(s)	Control group(s)
Belleville et al.	2018	Canada	RCT	NR (55+[ab])	MCI	Cognitive training (memory and attentional control)	Lab-based (group sessions [4-5 people per group], at universities in Canada)	8 weeks (2 hours per week)	Cognitive training (n = 49)	Active control (psychosocial intervention; n = 49); No-contact control (n = 47)
Carretti et al.	2011	Italy	Non-RCT[c]	68.8 (64-76)	Healthy	Cognitive training (strategic memory training using mental imagery)	Lab-based (individual sessions at university in Italy)	2 weeks (30-60 mins every two days)	Cognitive training (n = 81)	n/a
Cerino et al.	2020	USA	RCT	80.51 (70+[b])	Healthy and MCI	Online video-based conversation with trained interviewer	Home-based (computer provided by experimenters)	6 weeks (30-35 mins per day, five days per week)	Conversation intervention (n = 41)	No-contact control (n = 42)
Finkel & Yesavage	1989	USA	Non-RCT[d]	71.3 (58-81)	Healthy	Cognitive training (computer-aided or teacher-instructed mnemonic training)	Lab-based	NR	Computer-aided training (n = 62); Teacher-instructed training (n = 218)	n/a
Gajewski & Falkenstein	2012	Germany	RCT	70.9 (65+[b])	Healthy	Cognitive training (multi-domain training exercises for perceptual speed, attention, memory and reasoning); Physical training (cardiovascular, aerobic and strength exercises)	Lab-based (cognitive training); Gym-based (physical training)	16 weeks (90 minutes twice per week)	Cognitive training (n = 32); Physical training (n = 35)	Active control (relaxation and wellness training; n = 34); No-contact control (n = 40)

Study	Year	Country	Design	Mean Age (Range)	Population	Intervention	Setting	Duration (Frequency)	Experimental group(s)	Control group(s)
Gratzinger et al.	1990	USA	Non-RCT[c]	68.4 (55-87)	Healthy	Cognitive training (mnemonic training in addition to one of three different pre-training procedures – visual imagery pre-training, relaxation pre-training or visual imagery and judgement pre-training)	Lab-based	2 weeks (6 hours pre-training and 4 hours training)	Cognitive training (visual imagery pre-training; n = 56); Cognitive training (relaxation pre-training; n = 50); Cognitive training (imagery + judgement pre-training; n = 50)	n/a
Guye et al.	2017	Switzerland	RCT	70.4 (65-80)	Healthy	Cognitive training (several tasks targeted at working memory)	Home-based (online computerised training)	5 weeks (30-45 mins per week)	Cognitive training (n = 68)	Active control (visual search training; n = 74)
Hering et al.	2017	Switzerland	RCT	67.3 (60-82)	Healthy	Cognitive training (categorization working memory span task)	Lab-based (individual computerised training sessions at university)	2 weeks (45 minutes every 2-3 days)	Cognitive training (n = 29)	Active control (visual search training; n = 29)
McDougall et al.	2010	USA	RCT	75 (65-94)	Healthy and potential MCI	Cognitive training (memory training based on the four components of self-efficacy theory)	Community-based (classroom training sessions)	24 weeks (8 sessions over two months, followed by three-month interval, followed by four 2 hour weekly booster sessions over one month)	Cognitive training (n = 135)	Active control (health education classes; n = 117)

Study	Year	Country	Design	Mean Age (Range)	Population	Intervention	Setting	Duration (Frequency)	Experimental group(s)	Control group(s)
Stine-Morrow et al.	2014	USA	RCT	72.6 (60-94)	Healthy	Cognitive training (inductive reasoning training); Cognitive engagement (group based novel problem solving tasks)	Home-based (reasoning training); Community-based (group problem solving [either at university or local mall])	16 weeks (training = 10 weekly lessons and 6 weeks of crossword & sudoku puzzles; engagement = 16 weekly meetings, ~1.5hrs each)	Cognitive training (n = 188); Cognitive engagement (n = 130)	Waitlist control (n = 143)

Note. RCT = Randomised Controlled Trial; MCI = Mild Cognitive Impairment; NR = not reported; n/a = non applicable

[a] According to study protocol (Bier et al., 2015)

[b] No upper age-limit provided

[c] No control group

[d] Non-random assignment, no control group

Table 4.2

Main Intervention Effects and Influence of Personality Traits on Intervention Efficacy

Study	Cognitive outcome(s)	Main intervention effect	Personality measure	Personality variables	Internal consistency estimates of personality variables (α)	Analysis method	Personality effect[a]	Personality effect description
Finkel & Yesavage	List recall task	Significant improvement in list recall from baseline to follow-up for both computer-aided and teacher-instructed mnemonic training groups	NEO-PI	Neuroticism; Extraversion; Openness to Experience; Agreeableness; Conscientiousness	NR	Correlation (personality and change in recall scores from baseline to follow-up)	+	Openness to Experience significantly positively correlated with improvement in recall scores in the computer-aided instruction group (r = .293, n=59, $p < .05$, two-tailed test)
Gajewski & Falkenstein	Task-switching mixing costs in accuracy (error rates)	Significantly greater reduction in mixing costs from baseline to follow-up for cognitive training group compared to no-contact controls	NEO-FFI	Neuroticism; Extraversion; Openness to Experience; Agreeableness; Conscientiousness	NR	Regression (personality x group interaction predicting change in task-switching performance from baseline to follow-up)	0	No effect of personality variables (all *p*s > .05)[b]
Gratzinger et al.	Face-name association recall task	Significant improvement in face-name recall from baseline to follow-up for all three groups	NEO-PI	Neuroticism; Extraversion; Openness to Experience; Agreeableness; Conscientiousness	NR	ANCOVA (personality x group x time interaction predicting face-name recall performance)	+	O1 (fantasy) x time x group interaction ($F(4, 294) = 2.47$, $p < .05$): O1 related to greater improvement in the 2 groups with imagery pre-training, but not relaxation.

Study	Cognitive outcome(s)	Main intervention effect	Personality measure	Personality variables	Internal consistency estimates of personality variables (α)	Analysis method	Personality effect[a]	Personality effect description
Guye et al.	Average of performance on three working memory training tasks	NR[d]	NEO-FFI; Need for Cognition Scale	Neuroticism; Extraversion; Openness to Experience; Agreeableness; Conscientiousness; Need for Cognition	NR	Latent growth curve modeling (personality variables as predictors of estimated individual trajectories of performance over time)	0	Evidence did not support personality variables influencing training performance trajectories (no $BF_{H1} \geq 3$)
Stine-Morrow et al.	Divergent Thinking (latent construct derived from Alternate Uses Task and Opposites Task); Reasoning (latent construct derived from Letter Sets task, Number Series task, Letter Series task, Word Series task and Everyday Problem-Solving task)	Significantly greater improvement in reasoning in the training group compared to engagement group and controls; Significantly greater improvement in divergent thinking in the engagement group compared to training group and controls	IPIP; Need for Cognition Scale	Neuroticism; Extraversion; Openness to Experience; Agreeableness; Conscientiousness; Need for Cognition	NR	Correlation (personality and estimates of latent change in each cognitive outcome)	+/-/0	Higher Openness was associated with larger gains in divergent thinking in the engagement group ($r = .27$, $p < .05$); Higher Need for Cognition was associated with smaller gains in divergent thinking in the engagement group ($r = -.37$, $p < .05$); No effect of personality variables on gains in reasoning ability in the training group (all *p*s > .05)

Study	Cognitive outcome(s)	Main intervention effect	Personality measure	Personality variables	Internal consistency estimates of personality variables (α)	Analysis method	Personality effect[a]	Personality effect description
Cerino et al.	Letter fluency; Category fluency; Trail Making Task B; Word list delayed recall task; 2-back task	NR[e]	BFI	Neuroticism; Extraversion; Openness to Experience; Agreeableness; Conscientiousness	N = .80; E = .80; O = .77; A = .79; C = .79	Regression (personality x group interactions on 18-week follow-up scores, controlling for baseline performance on outcome measure and baseline global status)	+/-	Those higher in Conscientiousness improved more on category fluency (b = 3.52, SE = 1.35, p < .05). Those higher in agreeableness improved more on letter fluency (b = 6.06, SE = 2.40, p < .05). Those higher in extraversion improved more on letter fluency (b = 5.77, SE = 2.32, p < .05) and improved less on Trails B (b = 30.73, SE = 13.47, p < .05), delayed recall (b = −1.62, SE = .59, p < .01) and 2-back (b = −.11, SE = .04, p< .05).
Carretti et al.	List recall task	Significant improvement in list recall from baseline to immediate follow-up, maintained up to 3 and 6-month follow-ups	Need for Cognition Scale	Need for Cognition	.87	Stepwise regression (personality as a predictor of recall performance at each follow-up when controlling for baseline performance)	+	Need for Cognition significantly predicted performance on list recall at 3-month (β = 0.21, p < 0.05) and 6-month follow-up (β = 0.25, p < 0.001)

Study	Cognitive outcome(s)	Main intervention effect	Personality measure	Personality variables	Internal consistency estimates of personality variables (α)	Analysis method	Personality effect[a]	Personality effect description
Hering et al.	General verbal working memory component (identified with PCA, loading on CWMS and reading span tasks)	Significantly greater improvement in general verbal working memory from baseline to follow-up for cognitive training group compared to controls	Need for Cognition Scale	Need for Cognition	NR	ANCOVA (personality x group interaction predicting change in general verbal working memory from baseline to follow-up)	0	No effect of personality variables (statistics not reported)
Belleville et al.	Immediate memory composite score (derived from scores on word list recall task and face-name association task); Delayed memory composite score (derived from scores on word list recall task and face-name association task)	Significant improvement in delayed memory from baseline to 3 follow-ups for cognitive training group only	Eysenck Personality Inventory	Neuroticism; Extraversion	NR	Stepwise regression (personality variables as predictors of change in delayed memory scores from baseline to all three follow-ups in the cognitive training group)	0	No effect of personality variables (no statistics reported)

Study	Cognitive outcome(s)	Main intervention effect	Personality measure	Personality variables	Internal consistency estimates of personality variables (α)	Analysis method	Personality effect[a]	Personality effect description
McDougall et al.	Verbal memory (HVLT-R); Visual memory (Brief Visuospatial Memory Test – Revised); Everyday memory (RBMT)	No significant improvement in verbal, visual or everyday memory from baseline to follow-up	STAI	Trait anxiety	.89	3-way ANOVA (personality x group x time interactions predicting verbal, visual and everyday memory performance)	0	No effect of personality variable (all interactions η_p^2 = .00)[c]

Note. NR = Not reported; CWMS = Categorisation Working Memory Span; HVLT-R = Hopkins Verbal Learning Test-Revised; RBMT = Rivermeade Behavioural Memory Test; PCA = Principal Components Analysis; NEO-PI = NEO Personality Inventory; NEO-FFI = NEO Five Factory Inventory; IPIP = International Personality Item Pool; BFI = Big Five Inventory; STAI = Spielberger State-Trait Anxiety Inventory.

[a] + = positive association; - = negative association; 0 = no association

[b] Analysis conducted by current authors using data provided by original authors (Gajewski and Falkenstein, 2012)

[c] Analysis conducted by original author (McDougall et al., 2010) upon request for further data

[d] This paper is a further analysis based on data from a previously published intervention study; for full results see Guye and von Bastian (2017)

[e] This paper is a further analysis based on data from a previously published intervention study; for full results see Dodge et al. (2015)

5. The Intervention Factory: Can Real-World Activities Protect Against Cognitive Decline in Older Age?

5.1. Introduction

Engagement-based interventions offer a promising new approach to protect against cognitive decline in older age. Studies in which older adults engage in an activity designed to be mentally, physically, socially or creatively stimulating have reported improvements in cognitive ability (e.g., Carlson et al., 2008; Gothe et al., 2014; Klusmann et al., 2010; Mortimer et al., 2012; Nagamatsu et al., 2012; Noice & Noice, 2008; Stine-Morrow et al., 2014). However, many of these studies have tested the benefits of engagement within a controlled setting that may not be reflective of how activities are delivered, or engaged with, in the real world. Whether or not the cognitive benefits of activity engagement translate from a study setting into everyday life remains an important unanswered question in the field of cognitive ageing.

A recent review and meta-analysis explored the possible cognitive benefits of engagement-based interventions conducted outside of typical study environments, such as university laboratories or hospital facilities (Vaportzis et al., 2019). Results of the meta-analyses indicated that physical activity interventions delivered in real-world, community-based settings (including home-based yoga or dance classes in local community centres) could be cognitively beneficial. However, there was no evidence of improvements across the limited number of studies testing community-based interventions involving mentally engaging activities (including playing video games at home or engaging in problem solving activities in local schools). Only one community-based social engagement intervention was identified, which reported cognitive improvements among older adults who volunteered in local schools (Carlson et al., 2008).

Recent studies have suggested that increased engagement through the learning of a new skill, such as photography or using a tablet computer, could enhance cognitive ability in older adults (Chan et al., 2016; Park et al., 2014; Vaportzis et al., 2017). In these interventions, participants learned a new skill in a classroom setting designed for the purposes of the study. While this setting is likely more true-to-life than a more common lab-based cognitive training study, it is still the case that the researchers had control over the environment and delivery of the class. The question of whether cognitive improvements would persist in a class delivered outside of an experimental environment remains unanswered.

The Intervention Factory was designed to address this knowledge gap. Building on previous findings suggesting new learning could be a useful way to improve cognitive ability in older adults (e.g., Chan et al., 2016; Park et al., 2014; Vaportzis et al., 2017), this study allocated participants to take up a novel activity that involved some degree of new mental, physical or social engagement. These activities were delivered via existing classes or groups running in participants' local communities. Importantly, the researchers had no control over the delivery of the classes/groups. In this way, it was possible to examine whether cognitive improvements following new learning could be observed in a less controlled setting that was more akin to what participants would experience in the real world. As noted by Singal et al. (2014), while intervention studies conducted under highly controlled conditions maximise the likelihood of observing a true effect if it exists, interventions that are conducted under real-world conditions can provide further evidence of effectiveness that can be used to inform healthcare provision and policy-making.

5.1.1. The Present Study

As noted previously, the research for this thesis was conducted under the auspices of the larger Intervention Factory study. This study recruited a sample of adults aged 65 and over without a diagnosed cognitive impairment, and using a pseudo-randomised controlled design, tested the cognitive benefits of around ten weeks of novel activity engagement. Both pre- and post-intervention, participants completed a battery of cognitive tests. The present chapter reports results of analyses examining whether those allocated to a new activity showed improvements in cognitive performance greater than those in the control group. The analyses presented should be considered exploratory; given that this is the first study of its kind to examine the possible cognitive benefits of a range of real-world activities, other than the expectation that there would be activity-derived benefits, no specific hypotheses were generated regarding which types of activity would benefit more on which cognitive outcomes.

5.2. Methods

5.2.1. Participants

A total of 336 participants were recruited for the study (102 males, 234 females, mean age = 71.4 years [range = 65-92]). Full descriptions of study eligibility criteria, recruitment procedures and sample characteristics were provided in Chapter 2 (section 2.2.1).

5.2.2. Study Design

The Intervention Factory adopted a pseudo-randomised controlled trial design. Participants first attended a baseline assessment and were then allocated to one of six intervention conditions, consisting of a novel activity class/group conducted in the participant's local community or a no-contact control group. Participants attended their activity once a week for a period of around ten weeks, then returned to complete a follow-up assessment. The researchers conducting the follow-up assessments were aware of all possible intervention conditions, but blind to individual participants' allocation. Participants were aware of all possible intervention conditions and therefore not blind to their allocation.

5.2.3. Intervention Activities

Activity Selection. The activities to be used as interventions were selected using a user-engagement process, which is described in full in Appendix H[2]. An initial longlist was based on an audit of existing activity classes/groups running in Edinburgh and the surrounding areas in 2017. Duplicates or similar activities were removed, and only those activities that were offered at multiple sites in a reasonably consistent format (i.e., short courses that ran once a week for a period of around ten weeks) were included on a shortlist of 23 activities. The shortlist included activities such as Mindfulness and relaxation classes, Singing groups, Adult education classes (for example on subjects like Architecture, History or Philosophy), and a Digital photography course. Weekly groups or classes that were ongoing and did not have specific start/end dates were also included. The shortlist of activities is provided in Appendix H.

The goal of the activity selection process was to identify five activities from the 23 shortlisted activities that were predominantly mentally, physically or socially demanding, or some combination of the three, and an active control group consisting of an activity with low demand in all three areas. Therefore, ratings of mental, physical and social demand for each activity on the shortlist were collected. These ratings were provided by an independent sample of older adults (N = 106) and cognitive ageing experts (N = 63). Average ratings for each shortlisted activity are presented in Appendix H. Ratings were combined and discussed at a consensus meeting of the research team and expert Advisory Panel, resulting in five activities being selected from the shortlist. These activities were: computer classes (predominantly mentally demanding), dance/exercise/sport classes (predominantly physically demanding), social clubs (predominantly socially demanding), language classes (a combination of mentally and socially demanding) and handicraft/woodcraft classes (a combination of mentally and

[2] Activities were selected by the Intervention Factory research team in early 2017, prior to the commencement of this PhD project.

physically demanding). Bingo was selected as an active control group based on low ratings of mental, physical and social demands.

Overview of Activities. For each of the selected intervention activities, a list of possible classes/groups was drawn up. The list was as comprehensive as possible to provide participants with options in terms of location (so that, as far as possible, participants could remain in their local community) and day/time (to suit participants' individual schedules). In line with the Intervention Factory's aim to explore the effects of taking up a *new* activity, all classes/groups were suitable for beginners. Many of the classes/groups were provided by the City of Edinburgh Council, but some were also privately run or organised by community groups. All classes/groups were available to any member of the general public to attend (with some exceptions, discussed below).

Computer classes typically provided instruction and assistance in basic IT skills. Some classes were run as short courses, while others had a drop-in format under which participants could receive instruction and have questions answered on a more ad-hoc basis. Exercise classes included general fitness classes, dance classes, Pilates classes and sport classes. Language classes were beginner courses, mostly for European languages, including Spanish, Polish and British Sign Language. Handicraft/woodcraft classes included beginner courses in pottery, stained glasswork, woodwork, jewellery making, drawing/painting and printmaking. Social clubs were organised groups (usually of older adults) that met at least once a week to socialise, have discussions or go on outings. These groups did not involve learning a new activity or skill. Finally, the active control group involved weekly group meetings to play bingo. Importantly, games were played for fun, not for money.

Some activities were short courses that ran for a set number of weeks (usually ten, although this varied) in a term-based format. Most of the language classes and handicraft/wordcraft classes fell into this category. Other activities offered a drop-in format; these classes/groups ran continuously throughout the year, and participants could attend at their own discretion, or block-book a number of weeks at a time. Most of the exercise classes and social clubs fell into this category. For drop-in classes, participants were asked to attend for ten consecutive weeks. Some computer classes, exercise classes, social groups and bingo groups were specifically for older adults, while others were suitable for adults of all ages. Almost all language, handicraft and woodcraft classes were open to adults of all ages.

5.2.4. Procedure

Participant recruitment, assessment and delivery of the intervention was conducted on a rolling basis between June 2017 and February 2020. Participants were recruited, assessed and allocated in cohorts timed around the term dates of the classes run by the City of Edinburgh Council. Cohort 1 completed their activities from around September to December 2017; Cohort 2 from around January to April 2018; Cohort 3 from around April to July 2018; Cohort 4 from around July to October 2018; Cohort 5 from around September to December 2018; Cohort 6 from around January to April 2019; and Cohort 7 from around April to July 2019. An additional cohort of participants were recruited to form a no-contact control group (to be described fully below); these participants were recruited and tested between September 2019 and February 2020.

Baseline Assessment. Participants were first invited to attend a baseline assessment at Heriot-Watt University. During this assessment, participants first completed a demographic questionnaire. Participants then completed the Mini-Mental State Examination and the Clock Drawing Test, followed by the Hospital Anxiety and Depression Scale. Participants completed a battery of physical tests, including the Short Portable Physical Performance Battery and several other measures not considered here (handgrip strength, lung function and blood pressure). Participants then completed a battery of cognitive tests, followed by a personality questionnaire. At the end of the assessment, participants were given a questionnaire booklet to complete at home. The assessment normally lasted from 3 to 3.5 hours, and participants were allowed to take breaks when they wished.

Intervention Allocation. Participants were pseudo-randomised to an intervention group using a 'sealed-envelope' approach. Prior to the beginning of the study, randomly ordered lists of the six intervention groups (computer classes, dance/exercise/sport classes, social clubs, language classes, handicraft/woodcraft classes, bingo) were generated for each participant ID number. Once that ID was allocated to a participant, their respective list was modified if required. First, to ensure that the participant would be engaging in an activity that was *new* to them, if the participant was currently actively engaging in any of the six activities, or had done so in the recent past, those activities were removed from the list. For example, if a participant was already attending a language class they would not be allocated to this activity. Second, in an approach similar to that employed in the Synapse study (Park et al., 2014), participants could elect to remove up to two activities that they did not wish to be assigned to from their list. This was done to increase participant compliance, reduce attrition and embed a degree of 'real-world' validity into the research study. Participants were then allocated to the first activity remaining on the list.

In a further effort to reduce attrition, if a participant refused their initial activity allocation, they were offered the next activity on their randomisation list. Comprehensive data regarding the number of participants who refused their initial offer was not collected. However, records from a subsample of 72 participants (those in cohorts 6 and 7 who were allocated to an activity) indicated that 15 (20.8%) were reallocated after refusing their initial offer.

Allocation was conducted by the Research Associate or Study Administrator, normally via phone or email after participants' baseline assessment (although some participants were allocated in person at the end of their assessment). Once allocated to an activity, participants were provided with a list of potential days/times the relevant activity was available and allowed to select their preference based on timing, location, or any other pertinent details. The Research Associate/Study Administrator then dealt with any booking or payment processes (any up-front costs for class/group participation were covered by the project funds) and provided participants with the details of their allocated class/group.

New Activity Period. While class registration and payment were handled by the Research Associate/Study Administrator, it was the participants' responsibility to attend their class/group for the required number of weeks. If the participant incurred any class-related expenses during the intervention, these were reimbursed. Travel expenses for attending classes/groups were not reimbursed.

The research team had no input in class/group content or delivery, which was entirely the responsibility of the provider. Class instructors/group leaders were sometimes made aware that a member (or members) of the class was taking part in a research study at the booking stage; in the case that they were aware, they were asked not to treat the participant any differently from the rest of the class/group. Participants were free to disclose to the class instructor/group leader or to other members of the class/group that they were taking part in a research study.

Due to low availability of some activities over the summer months (particularly language and handicraft/woodcraft classes), additional classes were organised by the research team for the purposes of the study. These classes were arranged and delivered for participants in Cohorts 3, 4 and 7. For Cohort 3, a pottery class, a stained glasswork class and an Italian class were organised. For Cohort 4, a Spanish class was organised. For Cohort 7, a pottery class, a stained glasswork class and a printmaking class were organised. These classes were identical to those run by the City of Edinburgh Council during normal term times, with the same instructors, locations and class content, though they only included study participants.

Follow-up Assessment. Once participants had completed the activity class/group for the assigned period of time, they were invited back to Heriot-Watt University to complete the follow-up assessment. Prior to their follow-up assessment, participants were sent a follow-up questionnaire that included the same measures in the take-home questionnaire they completed following baseline assessment. The follow-up assessment was essentially identical to the baseline assessment, with the exception that participants did not complete the personality questionnaire a second time. At the end of the follow-up assessment, participants were given the opportunity to continue their participation by taking up a second new activity. Eighty participants did so and completed a second follow-up assessment; these data are beyond the scope of the present thesis. All other participants were debriefed and completed the study. All participants who completed follow-up assessments were given a £25 gift card.

5.2.5. No-Contact Control Group.

It was initially anticipated that those allocated to bingo would serve as an active control group (i.e., a group attending weekly sessions but not engaging in any meaningful level of new mental, physical or social activity). However, over the early part of the study it became clear that the bingo option was very unpopular, and that given the opportunity, most participants elected to remove the option from their randomisation list. Over the course of the study, only two participants agreed to be allocated to the bingo group.

To address the lack of an adequate control group, and after discussion and agreement with the study's Advisory Panel, an additional cohort of participants was recruited to serve as a no-contact control group. Recruitment, baseline assessment and follow-up assessment for this group of participants was conducted after all other cohorts had completed the study. Eligibility criteria for this group were the same as for all other participants, with the exception that already engaging in all study activities was no longer an exclusion criterion. Participants in this group were informed that they were taking part in order to examine the practice effects of repeating the same set of cognitive tests twice, and that their scores would be compared to those who took up a new activity. They completed identical assessments to those who were allocated to a new activity. Participants in this group were re-assessed after an interval of around 12 weeks, during which they continued their lives as normal. Thirty-three participants were recruited for this no-contact control group (comprising 9.8% of the 336 participants completing baseline assessments).

5.2.6. Materials and Measures

Primary Outcomes. The primary outcome variables for the present study were composite domain scores from the Wechsler Adult Intelligence Scale (4th [UK] edition; WAIS-IV; Wechsler, 2010a) and the Wechsler Memory Scale (4th [UK] edition [Older Adult Battery]; WMS-IV; Wechsler, 2010b). Scores on the ten subtests from the WAIS-IV were used to derive four domain-level composite measures: Verbal Comprehension, Perceptual Reasoning, Working Memory and Processing Speed. The global composite score of Full-Scale IQ was derived from scores on all ten WAIS-IV subtests. Scores on three subtests from the WMS-IV were used to derive four domain-level composite measures: Auditory Memory, Visual Memory, Immediate Memory and Delayed Memory. Full details of subtest administration and how composite scores were calculated are given in Chapter 2 (section 2.2.2)[3]. Subtests were identical and administered in the same order at both baseline and follow-up assessments.

Sample Characteristics. The following outcomes were compared between intervention groups to explore how well randomisation was achieved.

Demographics. Demographic variables included age, gender (male or female) and years of education (total number of years spent in primary, secondary and further/higher education). A measure of socioeconomic deprivation was obtained based on vigintile ranking (1-20) of the area that participants lived in (obtained via their postcodes) on the Scottish Index of Multiple Deprivation 2016 (SIMD16; Scottish Government, 2016).

Health Status. Participants rated their general health on a five-point scale (1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent). The Short Portable Physical Performance Battery (SPPPB; Guralnik et al., 1994) was used to assess participants' lower-extremity function. The test comprises three parts: balance, gait speed, and chair stands. For the balance test, individuals must hold three feet positions (side by side, semi-tandem and tandem) for ten seconds each. The gait speed test measures how long it takes individuals to walk four metres. The chair stand test measures the time it takes individuals to stand up from a seated position five times consecutively with their arms crossed over their chest. Individuals only complete each part of the test if they feel physically able to and that it is safe to do so. Scores range from 0-12, with higher scores indicating better physical function.

[3] Subtest scores from the WMS-IV can be combined in different ways to produce different composite variables (i.e., Auditory/Visual Memory or Immediate/Delayed Memory; see Chapter 2, section 2.2.2). In Chapter 2, only Auditory Memory and Visual Memory were examined to avoid inflating Type I error by analysing the same data twice in different configurations. Given the exploratory nature of the present study, it was decided that Auditory Memory, Visual Memory, Immediate Memory and Delayed Memory would all be considered as outcome variables. Similarly, Full Scale IQ (which is calculated by combining scores on all WAIS-IV subtests) was included as an outcome variable alongside the lower-order composite measures (which are calculated by combining scores on subsets of the WAIS-IV subtests).

The Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983) was administered to measure anxious and/or depressive symptoms. The scale comprises seven items measuring anxiety and seven items measuring depression, providing a score of 0-21 for each outcome.

The Mini-Mental State Examination (MMSE; Folstein et al., 1975) and the Clock Drawing Test (CDT; Agrell & Dehlin, 1998) were administered as indicators of global cognitive status. MMSE scores range from 0-30 (a full description of the test is given in Chapter 2, section 2.2.2). For the CDT, participants were given a pencil and paper and asked to draw a clock, put in all the numbers, and set the time to ten minutes past eleven. The scoring system proposed by Shua-Haim et al. (1996) was adopted; scores range from 0-6.

Personality. Scores on each of the Big Five traits (Neuroticism, Extraversion, Openness to Experience, Agreeableness and Conscientiousness) were measured using the UK edition of the NEO-Personality Inventory 3 (NEO-PI-3; McCrae et al., 2015; see Chapter 2, section 2.2.2 for more details).

5.2.7. Statistical Analysis

Missing Data. Missing data rates for cognitive outcome variables at baseline and follow-up and covariates are presented in Appendix I. Reasons for missing data included participants failing to complete certain tests during their assessment, errors in test administration and participants withdrawing from the study. Across all pertinent study variables, 4.7% of data were missing (536 cells missing out of 11,424 [34 variables across 336 participants]).

The entire study participation process, including specific reasons for withdrawal, is summarised in Figure 5.1. Thirty-four participants withdrew from the study after baseline assessment. Study attrition will be examined in more detail in Chapter 6. It is important to note that several of the participants who withdrew from the study did so prior to being allocated to an activity. As these participants had not been assigned to an intervention group, they could not be included in any group comparison analyses. To maintain a consistent approach, it was decided that all participants who withdrew from the study at any point would be excluded, and that where missing data remained, analyses would be conducted using case-wise deletion (i.e., complete case analysis, with valid *N*s are reported for all analyses). Excluding those who withdrew from the study, 1.7% of data were missing (170 cells missing out of 10268 [34 variables across 302 participants]).

Baseline Group Comparisons. Demographic, health, cognitive and personality variables were compared between intervention groups to examine how well randomisation was achieved. Conducting any analyses involving group comparisons required consideration of how to treat those participants who did not complete an activity as intended. Three participants were not allocated to an activity but returned for follow-up testing (one participant had become unable to commit to an activity due to personal circumstances, one participant did not respond to repeated attempts to contact them regarding their allocation, and one participant was not contacted due to an administrative error during staff handover); these participants were considered to have been re-allocated to the no-contact control group. Excluding no-contact controls, this left a total of 284 participants who were allocated to an activity. Eight of these participants stopped attending their initially allocated activity midway through their allocated intervention period and were reallocated to another intervention group. These participants were analysed according to the activity they were reallocated to. For example, a participant who attended a few weeks of a handicraft class before changing to an exercise class was considered to have attended only an exercise class for any analyses. Three participants swapped to a different exercise class midway through their allocated intervention period; this change did not affect their group allocation. Five participants did not attend any sessions of the activity they were allocated to (two participants had been allocated to a physical class, two to a handicraft class and one to a language class). Given that this essentially amounted to no new engagement within the study, these participants were considered to have been re-allocated to the no-contact control group.

As only two participants were allocated to attend bingo sessions, this group was considered too small to include in any analyses. It was decided that these participants would instead be merged with the group allocated to attend a social club (as the activity for these individuals was assumed to be predominantly social rather than mental or physical). This resulted in six groups for all analyses:

- Computer (attended computer classes, predominantly mentally demanding)
- Physical (attended dance/exercise/sport classes, predominantly physically demanding)
- Social (attended social clubs/bingo, predominantly socially demanding)
- Language (attended language classes, mixed mental/social demand)
- Creative (attended handicraft/woodcraft classes, mixed mental/physical demand)
- Control (no-contact control group, did not attend any new activity)

For all group comparisons, Levene's test was first used to test the assumption of homogeneity of variance. Where this assumption was met, groups were compared using between-groups ANOVA and Bonferroni corrected post-hoc between group t-tests. Where the assumption was violated, groups were compared using between-groups ANOVA with Welch's F correction and Games-Howell post-hoc comparisons. The Kruskal-Wallis test was used to compare groups when variables had notably non-normal distributions. Group differences in categorical variables were examined using Chi-squared or Fisher's exact tests.

Intervention Effects. Analyses first examined any possible variation in the interval between baseline and follow-up assessments. Assessment intervals (defined as the number of days between baseline and follow-up assessment) were compared between intervention groups using between-groups ANOVA. The overall interval was also broken down further to examine between-group differences in the number of days between baseline assessment and activity start, and the number of days between the activity end and follow-up assessment (these analyses necessarily excluded those in the no-contact control group who did not take up an activity).

As recommended by Hilbert et al. (2019), intervention effects were examined using linear mixed models. Predictors were the within-subjects variable of Time, the between-subjects variable of Group and the Time x Group interaction. The Time variable was coded to compare scores at baseline (0) to follow-up (1). Treatment contrasts for the categorical Group variable were coded to compare each individual intervention group (coded as 1) to a reference group (the Control group, coded as 0; see Table 5.1).

Models were estimated using the lme4 package in R (Bates et al., 2015). All models were specified with by-subject random intercepts and fitted using maximum likelihood estimation. Separate models were constructed for each cognitive outcome. Models were built hierarchically; an initial model included only the intercept, and additional parameters were added in stages: first Time, then Group, then the Time x Group interaction. At each stage, change in model fit was examined using a likelihood ratio test. A significant χ^2 value for the addition of the interaction term indicated the presence of a significant intervention effect.

In the full model containing the interaction, the parameter estimate for Time represents the change over time in the Control group and the individual parameter estimates for each Group contrast represent the difference between the respective activity group and the Control group at baseline. Parameter estimates for interactions between Time and each specific Group contrast represent the difference in change over time between the respective activity group and the Control group. Thus, a significant Time x Group contrast interaction would indicate that the respective activity group showed significantly different cognitive change to the Control group. For example, a significant interaction between Time and the Group (Computer) contrast would indicate that change in cognitive performance in the Computer group was different from that of the Control group. *p*-values for individual parameter estimates were computed using the Satterthwaite method via the lmerTest package (Kuznetsova et al., 2017). As this approach involves multiple comparisons between the Control group and each activity group, *p*-values for the parameter estimates were adjusted using the Benjamini-Hochberg correction, as recommended by Hilbert et al. (2019).

The original design of the study included an active control group (consisting of participants allocated to bingo). As discussed previously, only two participants were allocated to bingo which meant that this could not be used as a comparison group. These participants were therefore combined with those allocated to social clubs to form a single group, named Social. This group was considered as an activity group in its own right in the main analysis (i.e., cognitive changes in the Social group were compared with the no-contact Control group to examine the benefits of social engagement). However, additional supplementary analyses were conducted to compare cognitive change in the other activity groups (Computer, Creative, Language and Physical) to those in the Social group. In this way, the Social group served as an active control group (the role intended to be filled by bingo in the original study design). As all activity groups likely involved some level of social interaction, if one of the other activity groups showed significantly greater cognitive improvements than the Social group, this would suggest that the improvement was not a result of increased social engagement, but rather the mental or physical aspects of the activity. For these supplementary analyses, the no-contact group was excluded and the Social group was coded as the reference group for the Group contrasts.

5.3. Results

5.3.1. Baseline Group Comparisons

Descriptive statistics for health, personality and cognitive variables for the full sample at baseline are presented in Table 5.2 (descriptive statistics for demographic variables, self-rated health and MMSE score were previously provided in Chapter 2, Table 2.1). Means and standard deviations for all variables in each intervention group comprising the analytic sample (excluding those who withdrew from the study after baseline assessment) are presented in Table 5.3. As the distribution of SPPPB scores was notably non-normal, scores were compared between intervention groups using a Kruskal-Wallis rank sum test. Results showed no significant difference in baseline SPPPB score between groups, $H(5) = 3.77$, $p = .583$. Due to presence of expected frequencies of less than five for male participants in some groups, Fisher's exact test was used instead of a Chi-squared test to compare gender distributions across groups. There was no evidence of significant differences in terms of gender, $p = .430$.

Results of between-group ANOVA comparing intervention groups on other variables at baseline are presented in Table 5.3. There was a significant difference between groups in anxiety score from the HADS; Bonferroni corrected post-hoc pairwise comparisons indicated that those in the Control group had significantly lower anxiety scores compared to those in the Physical group, $t(96.13) = -3.47$, $p < .05$. There was also a significant difference between groups in Processing Speed at baseline; post-hoc comparisons revealed average scores in the Physical group were significantly higher than in the Social group, $t(20.83) = 4.24$, $p < .01$. There was a significant difference between groups in CDT score. Games-Howell pairwise comparisons were conducted due to violation of the assumption of homogeneity of variance for this variable. Scores in the Control group were significantly higher than those in the Creative group, $t(102.43) = 2.93$ $p < .05$. The F-statistic for the between-groups comparison on Age was significant, but no post-hoc pairwise comparisons reached significance after Bonferroni correction. There were no other significant differences between groups at baseline.

5.3.2. Assessment Intervals

Descriptive statistics regarding the duration between testing sessions and activities are presented in Table 5.4. As shown in Figures 5.2, 5.3 and 5.4, there were several notable outliers for whom assessment intervals were substantially longer. A between groups ANOVA comparing intervals from baseline to follow-up revealed a significant difference between intervention groups, $F(5, 293) = 5.40$, $p < .001$. Bonferroni-corrected pairwise comparisons revealed that assessment intervals were significantly shorter in the Control group ($M = 122.8$ days) compared to the Creative group ($M = 177.3$ days), $t(63.95) = -4.21$, $p < .01$, and the Language group ($M = 172.2$ days), $t(85.35) = -3.35$, $p < .05$. Assessment intervals were also significantly shorter in the Physical group ($M = 151.5$ days) compared to the Creative group, $t(165.00) = 3.20$, $p < .05$. No other group comparisons were significant.

There was also a significant difference between activity groups in the duration from baseline assessment to activity start, $F(4, 256) = 2.84$, $p < .05$. Bonferroni-corrected pairwise comparisons revealed that this interval differed significantly only between the Physical group ($M = 41.2$ days) and the Creative group ($M = 63.3$ days), $t(166.00) = 3.74$, $p < .01$. No difference between activity groups was found in the duration from the end of the activity to follow-up assessment, $F(4, 254) = 0.61$, $p = .66$.

Observed group differences in assessment intervals are problematic given that practice effects on cognitive test performance are likely to be stronger over a shorter period of time (Calamia et al., 2012). When modelling change in performance over time, such systematic between-group differences cannot be ‘controlled for’ statistically by including assessment interval as a covariate, as doing so would also remove a share of the variance associated with the Group variable, thus making it difficult to interpret the effect of the experimental manipulation (Miller & Chapman, 2001; Tabachnick & Fidell, 2001). Therefore, all analyses of intervention effects were run twice: first using the full available sample, then again excluding all participants for whom the interval between baseline assessment and activity start or activity end and follow-up assessment was greater than 90 days. Multiple cut-offs were considered (see Table 5.5 for a summary of the number of exclusions resulting from each potential cut-off), and a duration of 90 days pre/post-activity was selected to remove extreme outliers and help balance average assessment intervals between groups while still retaining the majority of the sample[4].

5.3.3. Intervention Results

Average changes over time between groups for each cognitive outcome are illustrated in Figure 5.5. Table 5.6 presents the overall model fit statistics for the addition of the effects of Time, Group and the Time x Group interaction for each respective cognitive outcome. For Full Scale IQ scores, results indicated that including the main effect of Time significantly improved model fit, but there was no further improvement in fit after including the main effect of Group or the Time x Group interaction. In other words, there was a significant change in Full Scale IQ scores over time across the whole sample, but no evidence that this change varied across groups. An examination of the parameter estimate of the variable Time in the model including Time

[4] It is important to note that this cut-off was selected purely based on the number of resultant exclusions, and supplementary analyses were run only *after* selecting the exclusion cut-off. Analyses were not run multiple times using different cut-offs.

only showed that overall scores improved from baseline to follow-up assessment (b = 2.51, $t(298.27) = 9.20$, $p < .001$).

This pattern of results (i.e., a significant improvement in performance over time but no variation between groups) was replicated across most of the cognitive domains. As shown in Table 5.6, the addition of the main effect of Time significantly improved model fit for all outcomes. Parameter estimates for the Time variable in the Time only models were as follows: Verbal Comprehension, $b = 1.93$, $t(299.88) = 5.28$, $p < .001$; Perceptual Reasoning, $b = 1.79$, $t(299.45) = 3.82$, $p < .001$; Working Memory, $b = 1.45$, $t(291.23) = 3.63$, $p < .001$; Auditory Memory, $b = 5.40$, $t(282.29) = 11.83$, $p < .001$; Visual Memory, $b = 7.40$, $t(296.12) = 13.72$, $p < .001$; Immediate Memory, $b = 6.29$, $t(283.78) = 13.01$, $p < .001$; Delayed Memory, $b = 7.46$, $t(278.29) = 15.21$, $p < .001$.

Processing Speed was the only cognitive outcome for which the inclusion of additional main effects or interactions significantly improved model fit, specifically the main effect of Group. An examination of the parameter estimates for the model including both Time and Group as predictors revealed that scores significantly improved over time, $b = 2.73$, $t(297.02) = 7.88$, adjusted $p < .001$. Regarding the main effect of group, an initially significant difference for the contrast comparing the Social group to the Control group was found, $b = -7.79$, $t(301.88) = -2.10$, $p < .05$, but this contrast became non-significant when adjusted for multiple comparisons, adjusted $p = .085$. All other group contrasts were also non-significant: Computer vs Control, $b = -6.72$, $t(303.42) = -1.90$, $p = .058$, adjusted $p = .101$; Creative vs Control, $b = 0.93$, $t(302.35) = 0.42$, $p = .675$, adjusted $p = .675$; Language vs Control, $b = -2.47$, $t(302.58) = -1.03$, $p = .304$, adjusted $p = .354$; Physical vs Control, $b = 3.71$, $t(302.37) = 1.57$, $p = .118$, adjusted $p = .166$.

In summary, for all cognitive outcomes, the addition of the Time x Group interaction did not significantly improve model fit. Full summaries of the parameter estimates for the models including the predictors Time, Group and their interaction are presented in Table 5.7[5]. Each model included five interaction terms, representing the difference in change over time between each activity group and the no-contact control group. These interaction terms were not significant for all cognitive outcomes when adjusted for multiple comparisons. In other words, there was no evidence of any meaningful differences in intervention related cognitive change in any of the activity groups compared to the control group.

As shown in Appendix J, results remained the same when rerun on a sample of only those who completed assessment within a 90-day window pre- and post-activity, with the exception of the main effect of Group on Processing Speed. Contrasts between the Control group and both the Computer group and the Social group were significant in the limited sample even after adjusting for multiple comparisons: Computer vs Control, $b = -12.59$, $t(242.09) = -3.17$, $p < .01$, adjusted $p < .01$; Social vs Control, $b = -8.48$, $t(242.10) = -2.21$, $p < .05$, adjusted $p < .05$. These results indicate that, within the limited sample, those in the Computer group and the Social group scored lower in this domain than those in the Control group overall.

Additional supplementary analyses examined between-group differences in cognitive change with the Control group excluded and the Social group coded to be the reference group (i.e., an active comparison group). Model summaries and parameter estimates are presented in Appendix K; results again showed a significant main effect of Time for all outcomes, but no significant Time x Group interactions. Again, results

[5] The parameter for Time in the full interaction models represents the change from pre- to post-assessment in the reference (Control) group only. Therefore, while the overall main effect of Time can be considered significant for all outcomes, the Time parameters in the models predicting Perceptual Reasoning and Working Memory score were not significant, indicating that those in the Control group did not improve over time in these outcomes.

indicated significant group differences at baseline on Processing Speed scores; both the Creative and the Physical group scored significantly higher than the Social group. However, there was no evidence that participants in the Computer, Creative, Language or Physical groups showed significantly different cognitive changes than those in the Social group.

5.4. Discussion

The present chapter examined the effects of a novel, community-based activity intervention for age-related cognitive decline. Three-hundred and thirty-six volunteer participants over the age of 65 were recruited and allocated to either a novel activity class/group in their local community or to a no-contact control group. Analyses compared change in performance over time in several cognitive domains between each activity group and the control group. Results showed no evidence that participants allocated to any of the activities demonstrated greater cognitive improvements than controls. These findings have important implications for the design and delivery of future activity-based cognitive ageing interventions.

Previous studies have shown that novel activity engagement may be an effective intervention for age-related cognitive decline. Activities such as group-based competitive problem solving (Stine-Morrow et al., 2008; Stine-Morrow et al., 2014), volunteering in local schools (Carlson et al., 2008), learning photography or quilting (Park et al., 2014) and learning how to use a computer/tablet device (Chan et al., 2016; Vaportzis et al., 2017) have all been shown to lead to cognitive improvements in older adults. In these studies, researchers had some level of control or supervision over the design and delivery of the intervention; although the interventions were delivered outside of the lab in a community-based setting, the activities themselves were conducted specifically for the purposes of the study. The present study instead utilised existing classes or groups that were already running in the local community, allowing for a greater degree of real-world validity than previous studies. However, this approach also introduced a greater degree of expected but uncontrolled variability in intervention delivery, in terms of activity content, instruction, intensity and duration. Such a trade-off between real-world validity and experimental control was part of the design of this study, which was intended to bridge the gap between the more controlled, experimental approach to testing the benefits of activity engagement and the reality of activity engagement in everyday life. The results reported here suggest that when using a more real-world approach, there was no evidence of any cognitive benefits beyond the observed effects attributed to practice. However, some study design limitations could have contributed to this (see limitations below).

A main effect of time was found for all cognitive outcomes, suggesting that performance improved regardless of intervention group allocation. This finding is indicative of a general practice effect, with participants improving on average due to increased familiarity with the assessment procedure at follow-up. The high degree of variability between participants' individual classes/groups makes it difficult to suggest specific reasons why the different intervention groups did not show a greater improvement relative to controls. Within each intervention group, individual participants' experience of their activity may have differed for numerous reasons. These include more surface-level features such as the day and time the class/group was running, whether the participant had to travel far to attend their class/group and whether the class/group was designed as a planned course or a series of drop-in sessions. Class/group learning environments may have varied; for example, two participants allocated to two different Spanish classes with different instructors may have been taught in different ways. There are likely also more idiosyncratic differences, such as how a participant interacted with others in their class/group or whether a participant actually enjoyed their activity rather than simply attended out of obligation to complete the study. There may be some ideal combination of these and other pertinent factors which would support meaningful cognitive improvements relative to controls though investigating this would require statistical power beyond that of the present study. The existence of such heterogeneity within this intervention is mentioned here to highlight the difficulties introduced when translating engagement-based interventions out of a more controlled research environment and into the real world. Those challenges, returned to below and in Chapter 8, must, however, be acknowledged and addressed if activity-based intervention research is to be the basis for public health recommendations. That is, those recommendations must be based on true, not optimal, effects.

Alongside these more general issues, it is possible that aspects of individual intervention groups could explain the lack of improvement. For example, the intervention group selected to be predominantly mentally demanding (Computer) did not show any evidence of cognitive improvements in the present study. This is in line with findings of a recent meta-analysis, which reported no evidence of any cognitive improvements from community-based interventions designed to be mentally stimulating (Vaportzis et al., 2019). Previous studies have shown that training in the use of computers/tablet devices may be cognitively beneficial, although these studies used training courses/materials designed specifically for the purposes of the study (Chan et al., 2016; Klusmann et al., 2010; Vaportzis et al., 2017). It should also be acknowledged that the Computer group was small; many participants were not allocated to this activity because they were already proficient with a computer, and the activity would therefore not involve any new learning for them. This limited the power of the study to detect an effect if it existed.

Vaportzis et al. (2019) reported that community-based physical activity interventions were linked to improvements on measures of visuospatial ability, processing speed and working memory in their meta-analysis. No such improvements were found in the Physical group in this study. Other physical interventions that have found significant effects have been administered over longer periods of time, such as six months of aerobic training three times per week (Jonasson et al., 2017), or six months of resistance training twice per week (Nagamatsu et al., 2012). It may be that the exercise classes used in this study (running once per week for roughly ten weeks) were not intensive enough, or long enough in duration, to elicit meaningful cognitive improvements. Furthermore, it is possible that the classes/groups engaged in did not then encourage greater physical activity outwith the context of the class/group itself (this possibility will be returned to in the next chapter).

Interventions for cognitive ageing designed to increase social engagement are less common, but previous findings suggest some cognitive benefits, such as improved verbal fluency (Dodge et al., 2015; Mortimer et al., 2012). In those studies, participants were only interacting with other study participants or researchers. The present findings suggest that when participants instead interact primarily with other members of the public in local social groups, there is no evidence of any resulting cognitive improvement. It should, however, be noted that, as with the Computer group, the number of people allocated to the Social group was notably lower than other groups, and as such the study may have also lacked the necessary power to detect an effect in this group.

The lack of evidence for cognitive improvement in the Language group is in line with a previous study that found no improvements across a range of cognitive domains after an 11-week beginners Italian course in a sample of older adults (Berggren et al., 2020). While it has been suggested that language learning could help reduce cognitive decline by stimulating a range of cognitive processes and promoting neural plasticity (Antoniou et al., 2013), the current findings do not support for this hypothesis.

Regarding the Creative group, some previous cross-sectional work has shown that engagement in crafts such as woodwork is positively associated with cognitive ability (Jopp & Hertzog, 2007). Our findings showed that engagement in a range of artistic and craft activities (including woodwork, pottery and stained-glass work) did not elicit any cognitive improvements. Interestingly, the activities that comprised the Creative group were likely to be more cohesive in their delivery than other intervention groups; almost all of these classes were run by the Edinburgh City Council Adult Education Programme, and thus classes followed a more standardised approach and were delivered in similar environments. Therefore, it is less likely that variation in class delivery can explain the lack of cognitive improvement beyond practice. Creative classes tended to require the use of specialist equipment, making practice outside of class less feasible for most participants. It is possible that this may have limited any potential beneficial effects by keeping the overall hours of engagement low.

5.4.1. Limitations

As acknowledged in Chapter 2, the sample recruited for this study is unrepresentative of the wider population of older adults. While the Intervention Factory attempted to recruit a diverse sample though a range of recruitment strategies, including widely distributing posters and flyers, newspaper adverts, social media posts, making contact with local community groups and using existing volunteer databases, participants were predominantly female, White, highly educated and living in less deprived areas. An unrepresentative sample limits the ability to generalise findings to the wider population of older adults. While there was no evidence of meaningful activity-related cognitive improvement in the present study, results could be different in a study that recruited older adults from a wider range of social, cultural and economic backgrounds. Future studies would benefit from moving beyond convenience sampling and adopting more representative population-based methods to fully explore the benefits of community-based activities in the wider population.

Another limitation concerns the allocation of participants to intervention groups. The ideal approach to testing any new intervention would be to use a randomised controlled trial (RCT) design. Under this approach, group allocation would be completely random, and participants would be blinded to their allocation. Each intervention group would be of an equal size, and there would be no systematic variation between groups in variables of interest. In the present study, participants were pseudo-randomly allocated to their activity; during the allocation process, participants were allowed to remove up to two activities that they did not want to do from their randomisation list. This approach was adapted from the Synapse study (Park et al., 2014), and was used in an attempt to ensure that participants would be allocated to an activity that they were willing to try (as would normally be the case in real life) and also to reduce study attrition due to participants withdrawing as a result of not enjoying their activity. In addition, even after participants had been pseudo-randomly allocated to their activity group, some changed to a different group, regardless of whether this was prior to starting the activity or after attending for a few weeks. Again, this was viewed as a more favourable alternative to losing these participants from the study altogether.

Allowing such a degree of participant choice into the allocation process likely led to the funnelling of participants away from the less popular activities (Computer and Social) and towards more popular activities (Creative, Language and Physical). This is illustrated by the notable variation in the number of participants allocated to each group, with almost a third of the sample being in the Creative group. This issue was likely further exacerbated by the fact that participants were not blind to their allocation; participants were aware of the groups they could have been allocated to, so may have opted to refuse certain activities in the hope of being allocated to another that they found more favourable. This could have introduced bias to the data if participants with certain characteristics were more likely to refuse certain activities. Comparisons between the intervention groups at baseline on variables of interest revealed few significant differences in demographics, personality traits or cognitive ability, but there may have been notable differences in unmeasured variables.

It was initially anticipated that participants allocated to attend bingo would serve as an active control group. However, very few participants were willing to engage in this activity. It became clear that the study would lack an adequate control group with which to compare cognitive changes in the other intervention groups. To address this issue, in consultation with the study Advisory Panel, it was decided that an additional cohort of participants would be recruited to serve as a no-contact control group. This cohort was recruited separately from the other participants and were also not blind to the fact that they were controls. In fact, these participants were explicitly told that they had been recruited to test for potential practice effects. This might explain why controls improved at similar rates to those who did activities even though they themselves did not. Those in the Control group might have had greater expectations of improvement because they were told that this was the likely outcome; these expectations may have increased participants motivation to improve at follow-up.

Furthermore, participants in the Control group could well have engaged in their own activities during the intervention period (possibly even those offered by the study). This would be problematic because such participants could no longer be considered as ‘true controls’; if those in the Control also engaged in activities then this could obscure any actual effects of the study activities. These issues highlight the difficulty of conducting a controlled intervention study in a real-world setting.

Another unanticipated consequence of recruiting a no-contact control group was that these participants completed their follow-up assessments over a significantly shorter interval than those in the other groups. The difference here is likely because the no-contact Control group were recruited and tested over a more concentrated period, with no extra time needed to allocate activities. This is problematic because previous research has shown that practice effects are likely to be stronger over shorter test-retest intervals (Calamia et al., 2012), meaning that improvements due to test familiarity were likely more pronounced in the Control group specifically. It is possible that a more pronounced improvement in the Control group due to shorter assessment intervals may have hidden significant improvements in other intervention groups that were due to the activities themselves. To account for this discrepancy, participants with assessment intervals longer than 90 days pre- or post-activity were excluded and analyses re-run, but this did not affect the results. Future studies should endeavour to eliminate any bias due to assessment intervals by maintaining a more consistent follow-up timeline across all groups.

5.4.2. Conclusion

The Intervention Factory adopted a new and relatively untested approach in the field of cognitive ageing interventions, by using existing community-based classes and groups to test the benefits of novel activity engagement in a sample of older adults. While participants allocated to five activity groups (Computer, Creative, Language, Physical and Social) did improve in performance across a range of cognitive domains, these improvements did not differ from participants in a no-contact control group. Several limitations of the study were identified, highlighting the difficulty of translating a controlled research study into a more real-world environment. As discussed, many of those were specific design considerations; the question of how best to address such issues will be returned to in Chapter 8.

The thesis now continues with the questions raised in Chapter 4; namely, whether personality traits could influence both intervention adherence and intervention efficacy. Results from the earlier systematic review suggested that personality (particularly Openness to Experience) may moderate intervention-related cognitive change. However, a clear need for more research in this area was highlighted by the limited number of studies reviewed. Building on these findings, the following chapters examine the role of personality in the context of the Intervention Factory. First, Chapter 6 will examine whether personality traits are associated with how well participants engaged with the intervention, in terms of study attrition and activity adherence. Then, Chapter 7 will examine whether personality traits moderated group-specific change in cognitive performance.

Figure 5.1

Study Participation Flowchart

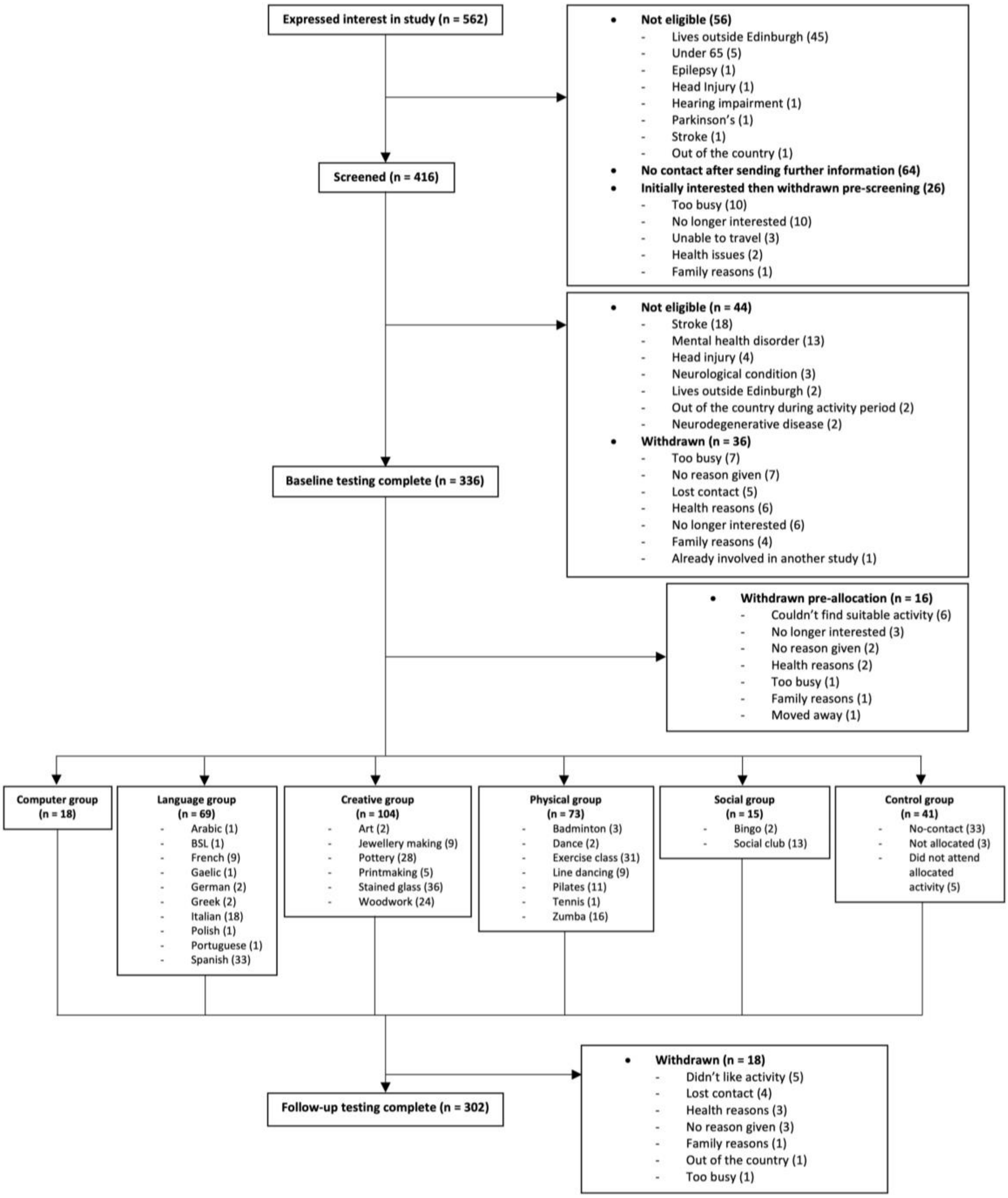
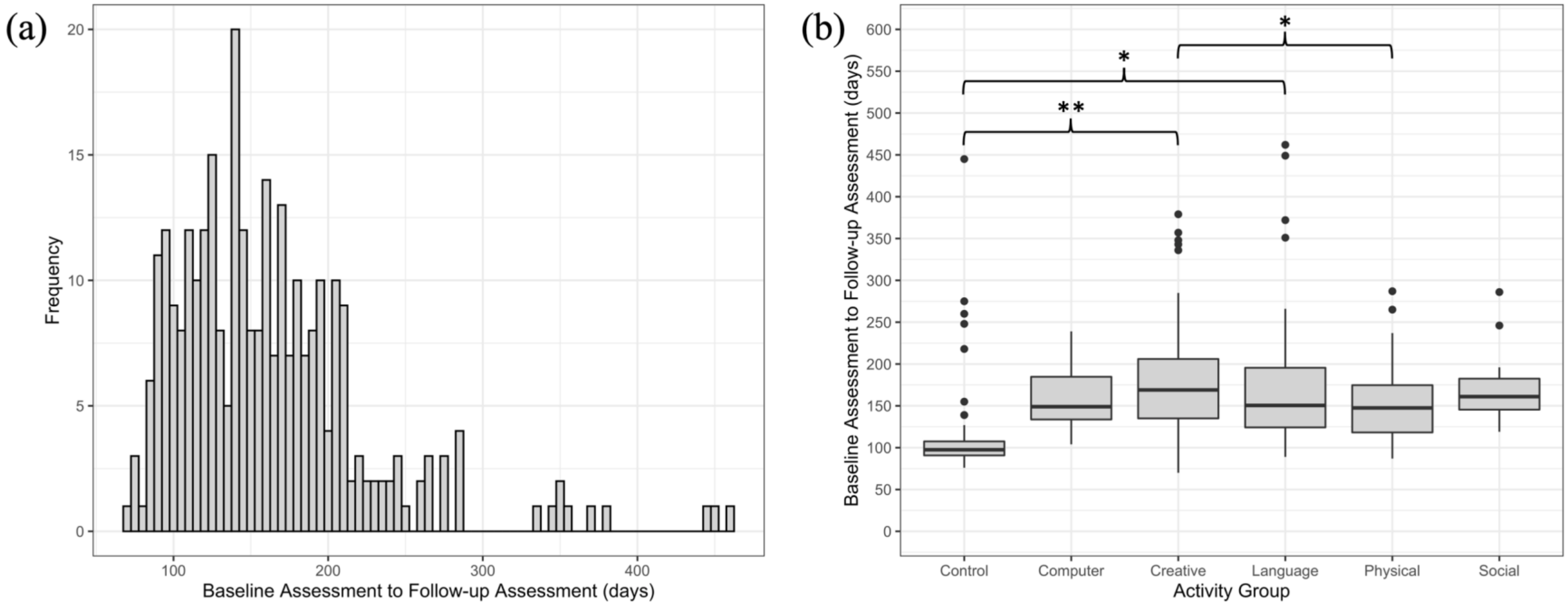


Figure 5.2

Distribution of Baseline to Follow-up Interval (a) Overall and (b) Within Intervention Groups

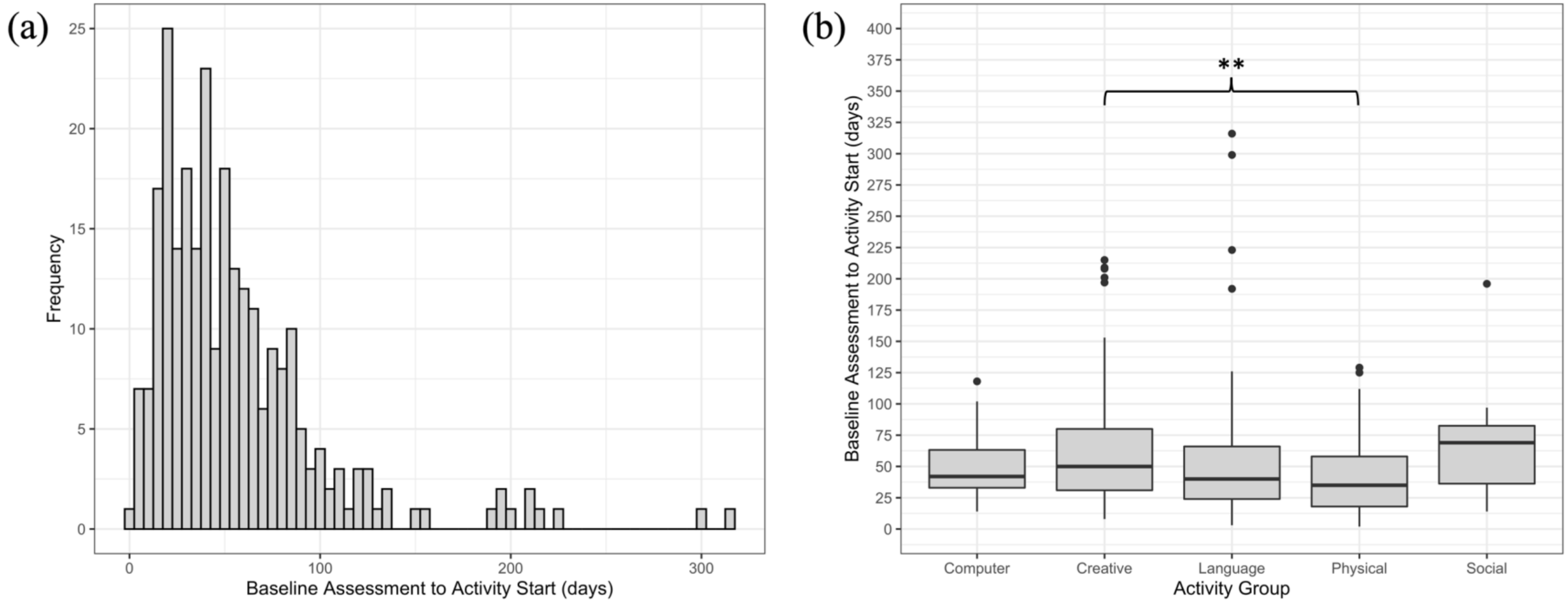


Note. Figure 5.2a presents the overall distribution of baseline to follow-up assessment intervals for the complete analytic sample. Figure 5.2b presents boxplots showing the range of these intervals within each intervention group. Brackets indicate significant between-groups differences.

*p < .05. **p < .01.

Figure 5.3

Distribution of Baseline to Activity Start Interval (a) Overall and (b) Within Intervention Groups

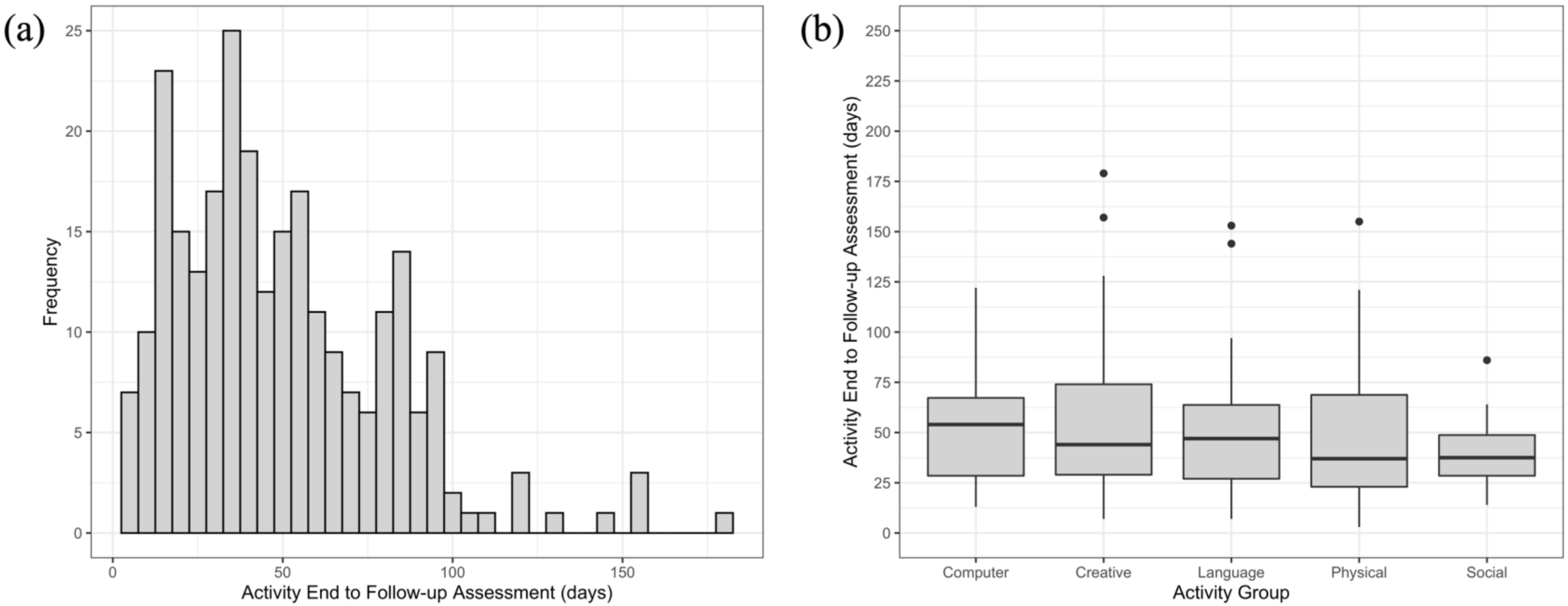


Note. Figure 5.3a presents the overall distribution of baseline assessment to activity start intervals for the complete analytic sample (excluding no-contact controls who did not engage in an activity). Figure 5.3b presents boxplots showing the range of these intervals within each intervention group. Brackets indicate significant between-groups differences.

*p < .05. **p < .01.

Figure 5.4

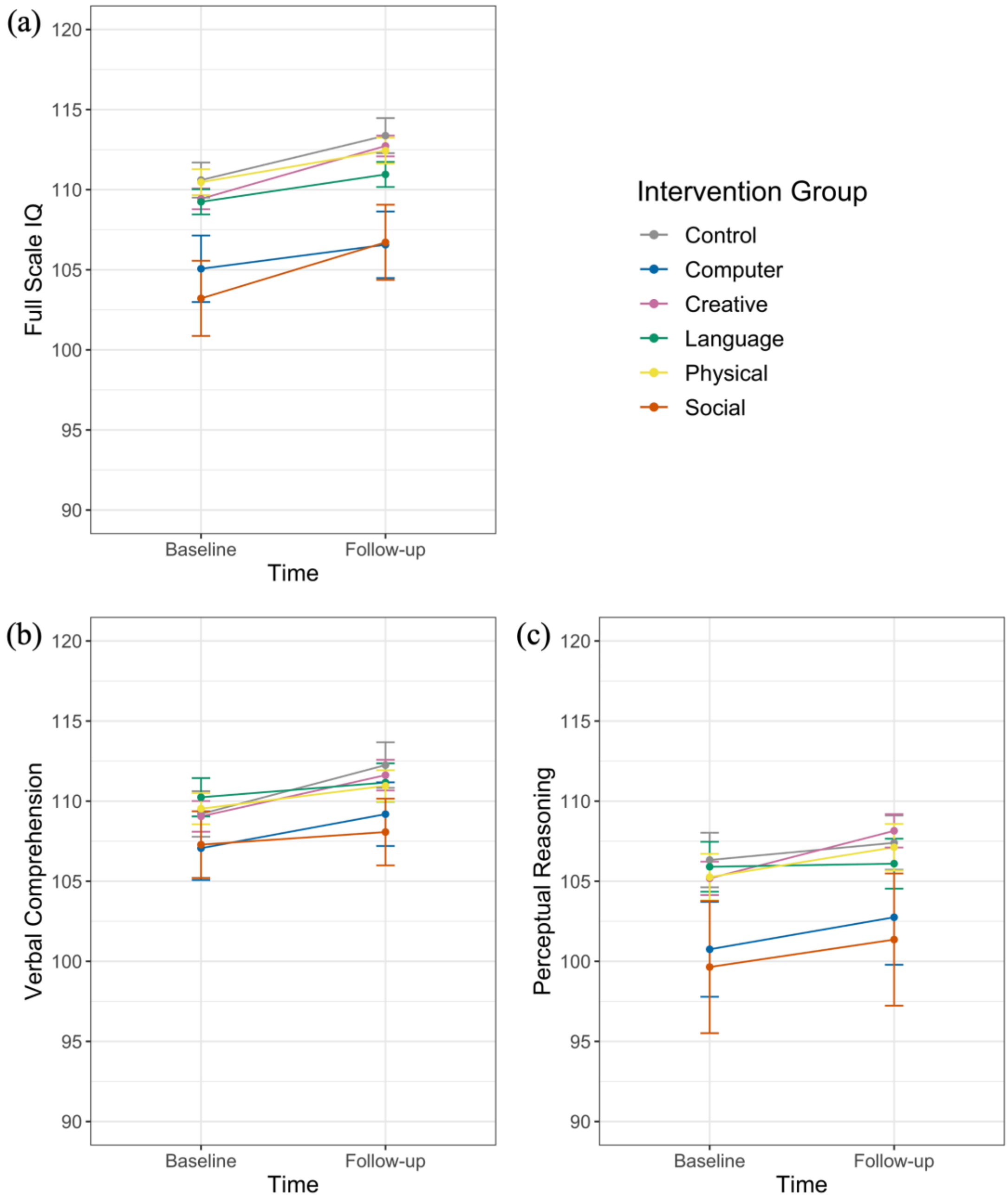
Distribution of Activity End to Follow-up Duration (a) Overall and (b) Within Intervention Groups

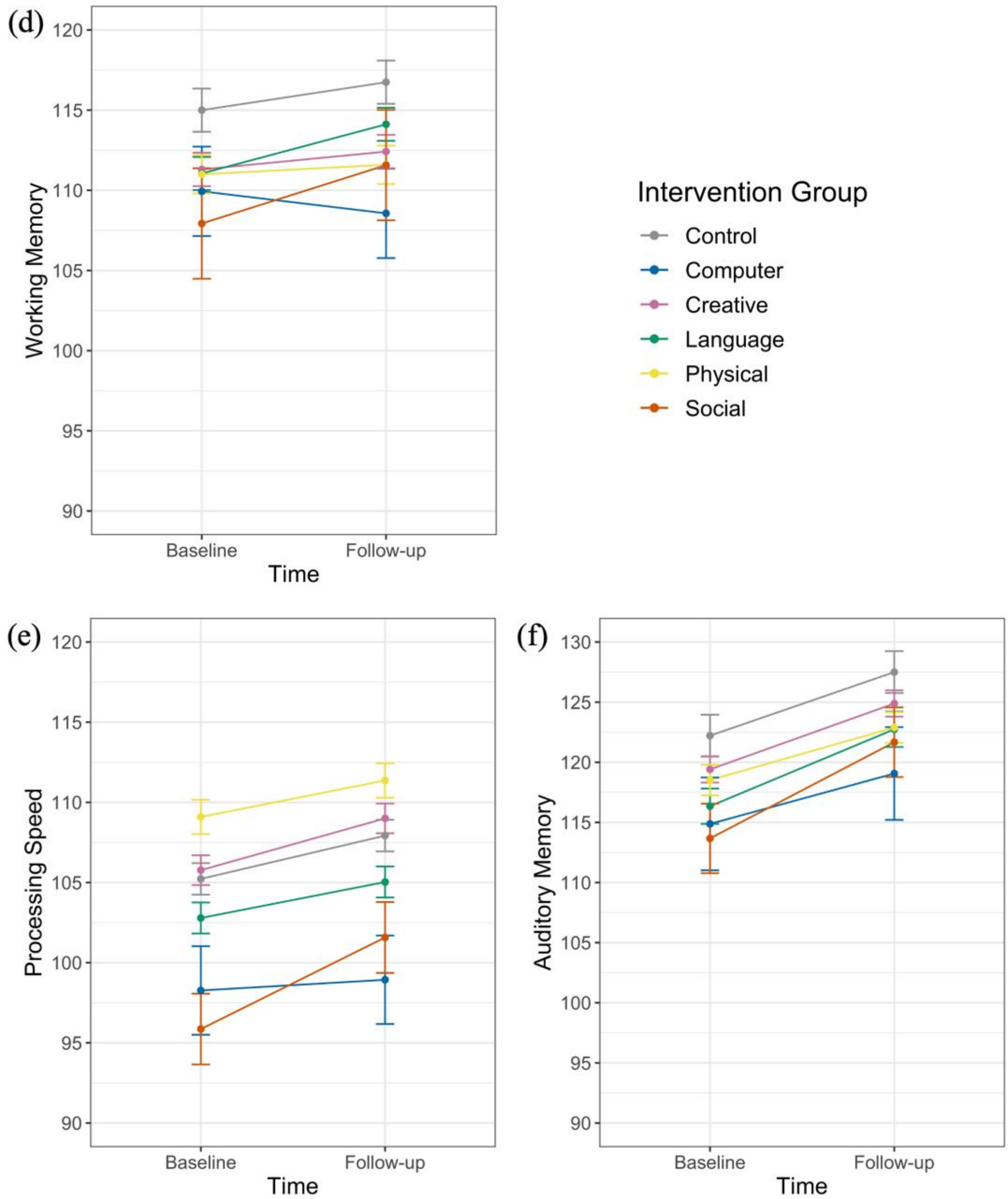


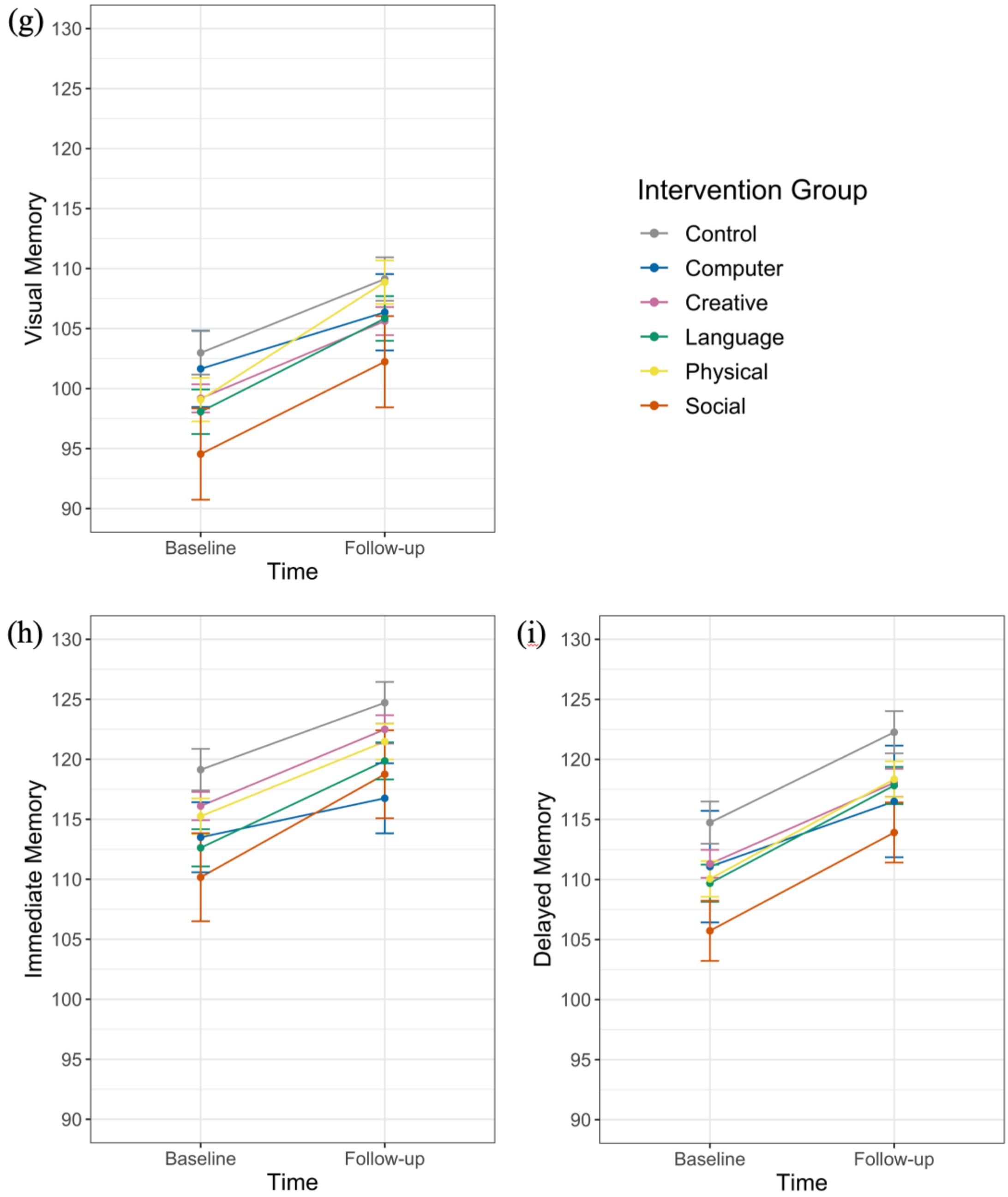
Note. Figure 5.4a presents the overall distribution of activity end to follow-up assessment intervals for the complete analytic sample (excluding no-contact controls who did not engage in an activity). Figure 5.4b presents boxplots showing the range of these intervals within each intervention group. No significant between-group differences were observed.

Figure 5.5

Average Change Over Time Between Intervention Groups in Cognitive Outcome Variables




(d)
Working Memory
Time
Baseline
Follow-up
Intervention Group
Control
Computer
Creative
Language
Physical
Social
(e)
Processing Speed
(f)
Auditory Memory



Note. Figures show average change over time in each respective outcome excluding missing data. Within-subjects error bars were created using the method described in Chang (n.d.), which is itself based on Morey (2008).

Table 5.1

Treatment Contrast Coding System for the Group Variable in Linear Mixed Models

	Contrasts				
Intervention Group	Computer	Creative	Language	Physical	Social
Control Group	0	0	0	0	0
Computer Group	1	0	0	0	0
Creative Group	0	1	0	0	0
Language Group	0	0	1	0	0
Physical Group	0	0	0	1	0
Social Group	0	0	0	0	1

Note. The Control group was coded as 0 for all contrasts, and thus served as the reference group. Each individual contrast can be considered as a dummy variable that compares the relevant activity group (coded as 1) to the Control group.

Table 5.2

Complete Sample Descriptive Statistics for Health, Personality and Cognitive Variables at Baseline

Variable	Valid *N*	Mean (*SD*)	*SE*	Min	Max	Skew	Kurtosis
HADS Anxiety	336	5.0 (3.1)	0.17	0	15	0.57	-0.05
HADS Depression	336	2.9 (2.2)	0.12	0	10	0.81	0.17
SPPPB	336	11.2 (1.6)	0.08	0	12	-3.46	16.14
Neuroticism	322	81.9 (22.4)	1.25	21	158	0.21	0.26
Extraversion	317	102.4 (17.4)	0.98	48	146	-0.32	0.11
Openness to Experience	323	120.6 (16.8)	0.94	67	174	-0.05	0.11
Agreeableness	322	131.1 (15.8)	0.88	79	178	0.00	0.27
Conscientiousness	319	113.1 (18.4)	1.03	59	166	-0.14	-0.22
CDT	320	5.1 (1.4)	0.08	0	6	-1.54	2.10
Full Scale IQ	335	108.5 (12.4)	0.68	72	141	-0.28	0.20
Verbal Comprehension	336	108.4 (11.8)	0.64	66	138	-0.31	0.74
Perceptual Reasoning	336	104.2 (13.5)	0.74	75	140	0.20	-0.49
Working Memory	329	110.9 (13.7)	0.76	71	145	-0.23	-0.13
Processing Speed	335	104.8 (12.7)	0.69	68	137	-0.15	-0.42
Auditory Memory	321	117.1 (14.9)	0.83	62	146	-0.79	0.62
Visual Memory	332	98.5 (14.2)	0.78	50	135	-0.59	1.01
Immediate Memory	321	114.1 (14.3)	0.80	67	145	-0.49	-0.03
Delayed Memory	317	109.4 (15.1)	0.85	49	146	-0.90	1.76

Note. HADS = Hospital Anxiety and Depression Scale. SPPPB = Short Portable Physical Performance Battery. CDT = Clock Drawing Test.

Table 5.3

Baseline Group Comparisons

Variable	Control		Computer		Creative		Language		Physical		Social			
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	*F*	*df*
Age	41	72.8 (5.3)	16	74.6 (7.4)	101	70.9 (4.7)	63	71.0 (5.3)	67	70.6 (5.1)	14	70.1 (5.1)	2.56*	5, 296
Years of Education	41	15.5 (3.4)	16	16.4 (3.9)	101	16.1 (3.2)	63	16.8 (3.5)	67	15.8 (3.5)	14	16.1 (2.9)	1.02	5, 296
Deprivation	41	16.1 (5.5)	16	17.4 (3.2)	101	16.6 (3.8)	63	16.8 (4.2)	67	15.7 (5.0)	14	13.7 (4.9)	1.70	5, 296
Self-Rated Health	41	3.8 (0.9)	16	3.5 (1.1)	101	3.8 (0.9)	63	3.7 (0.9)	67	3.8 (0.9)	14	3.6 (0.7)	0.34	5, 296
SPPPB	41	11.5 (1.2)	16	11.1 (1.2)	101	11.1 (1.8)	63	11.1 (1.7)	67	11.5 (0.9)	14	11.1 (1.4)	-	-
HADS Anxiety	41	3.5 (2.5)	16	6.0 (3.3)	101	4.9 (3.2)	63	4.8 (2.8)	67	5.4 (3.0)	14	6.1 (2.8)	3.05*	5, 296
HADS Depression	41	2.5 (2.1)	16	3.3 (2.5)	101	2.7 (2.1)	63	3.0 (1.9)	67	3.1 (2.2)	14	2.6 (1.7)	0.74	5, 296
Neuroticism	41	74.7 (19.8)	16	89.8 (19.6)	99	82.9 (23.1)	59	78.7 (22.8)	65	84.9 (20.5)	13	85.1 (26.4)	1.88	5, 287
Extraversion	41	102.6 (16.5)	15	97.9 (15.6)	97	102.2 (17.8)	59	104.2 (19.5)	64	101.8 (17.4)	14	101.6 (13.8)	0.34	5, 284
Openness	40	118.3 (17.4)	16	120.3 (11.1)	99	120.3 (16.6)	61	123.0 (18.1)	65	121.7 (17.2)	14	122.1 (13.2)	0.45	5, 289
Agreeableness[a]	41	130.2 (13.3)	14	128.9 (17.0)	98	131.6 (13.3)	61	133.8 (19.8)	65	132.5 (16.6)	14	126.9 (14.7)	0.61	5, 63.34
Conscientiousness	41	110.0 (18.5)	15	110.6 (16.9)	95	111.5 (17.8)	61	116.7 (16.8)	66	112.2 (18.2)	14	111.4 (20.4)	0.93	5, 286
MMSE	41	28.9 (1.0)	16	28.7 (1.5)	101	28.9 (1.1)	63	28.9 (1.2)	67	29.1 (1.0)	14	29.1 (0.8)	0.41	5, 296
CDT Total Score[a]	41	5.6 (1.0)	15	4.5 (1.8)	94	4.9 (1.4)	60	5.3 (1.1)	66	5.3 (1.3)	11	4.2 (1.8)	2.88*	5, 57.23
Verbal Comprehension	41	109.2 (9.6)	16	107.1 (10.9)	101	109.0 (11.6)	63	110.2 (9.9)	67	109.6 (12.0)	14	107.3 (10.4)	0.33	5, 296
Full Scale IQ	41	110.6 (12.5)	16	105.1 (11.1)	100	109.4 (11.7)	63	109.1 (11.4)	67	110.7 (11.5)	14	103.2 (10.1)	1.50	5, 295
Perceptual Reasoning	41	106.3 (14.0)	16	100.8 (13.1)	101	105.2 (13.2)	63	105.6 (13.5)	67	105.5 (12.7)	14	99.6 (11.8)	0.92	5, 296
Working Memory	41	114.3 (14.0)	16	109.9 (11.7)	96	111.3 (13.4)	62	110.6 (11.9)	67	111.5 (12.6)	14	107.9 (14.9)	0.68	5, 290
Processing Speed	41	105.1 (12.1)	15	98.3 (13.6)	101	105.8 (12.3)	63	102.9 (12.1)	67	109.1 (11.8)	14	95.9 (10.3)	4.51***	5, 295
Auditory Memory[a]	40	121.7 (13.1)	16	114.9 (16.0)	96	119.4 (12.6)	61	116.4 (14.8)	66	117.8 (16.8)	12	113.7 (6.3)	2.19	5, 68.45
Visual Memory	41	103.3 (12.5)	14	101.6 (10.6)	100	99.2 (13.4)	63	98.1 (15.8)	67	99.4 (13.7)	13	94.5 (12.2)	1.17	5, 292
Immediate Memory	40	118.9 (14.5)	16	113.5 (12.9)	96	116.1 (12.3)	61	112.4 (14.7)	66	115.0 (15.1)	12	110.2 (7.9)	1.54	5, 285
Delayed Memory	40	114.4 (11.8)	14	111.1 (16.4)	95	111.3 (12.7)	61	109.2 (15.9)	66	109.5 (16.2)	11	105.7 (6.1)	1.08	5, 281

Note. SPPPB = Short Portable Physical Performance Battery. HADS = Hospital Anxiety and Depression Scale. MET = metabolic equivalent of task.

BMI = Body Mass Index. MMSE = Mini Mental State Examination. CDT = Clock Drawing Test.

[a] Welch's F is reported due to significance of Levene's test for violation of homogeneity of variance assumption.

**p* < .05. ***p* < .01. ****p* < .001

Table 5.4

Descriptive Statistics for Assessment Intervals

Variable	*N*	Mean (*SD*)	Min	Max	Skew	Kurtosis	*SE*
Baseline to follow-up	299[a]	162.0 (63.2)	70	462	1.70	4.43	3.65
Baseline to activity start	261[b]	56.2 (46.4)	2	316	2.32	7.58	2.87
Activity end to follow-up	259[a, b]	49.5 (31.2)	3	179	1.05	1.41	1.94

Note. All durations are measured in days.

[a] Excludes participants who completed follow-up questionnaire but did not attend in-person follow-up testing session. [b] Excludes no-contact control group.

Table 5.5

Number of Exclusions for Each Potential Assessment Interval Cut-off

		N Excluded (% of group)						
Pre-activity cut-off (days)	Post-activity cut-off (days)	Whole Sample (*N* = 302)	Control (*N* = 41)	Computer (*N* = 16)	Creative (*N* = 101)	Language (*N* = 63)	Physical (*N* = 67)	Social/Bingo (*N* = 14)
30	30	244 (80.8)	6 (14.6)	15 (93.8)	93 (92.1)	58 (92.1)	58 (86.6)	14 (100.0)
60	30	208 (68.9)	5 (12.2)	12 (75.0)	84 (83.2)	47 (74.6)	46 (68.7)	14 (100.0)
90	30	196 (64.9)	5 (12.2)	12 (75.0)	80 (79.2)	46 (73.0)	42 (62.7)	11 (78.6)
120	30	189 (62.6)	4 (9.8)	11 (68.8)	76 (75.2)	46 (73.0)	41 (61.2)	11 (78.6)
60	60	142 (47.0)	5 (12.2)	7 (43.8)	60 (59.4)	29 (46.0)	31 (46.3)	10 (71.4)
90	60	103 (34.1)	4 (9.8)	6 (37.5)	44 (43.6)	23 (36.5)	23 (34.3)	3 (21.4)
120	60	88 (29.1)	2 (4.9)	5 (31.3)	38 (37.6)	20 (31.7)	20 (29.9)	3 (21.4)
90	**90**	**60 (19.9)**	**2 (4.9)**	**5 (31.3)**	**26 (25.7)**	**12 (19.0)**	**13 (19.4)**	**2 (14.3)**
120	90	42 (13.9)	1 (2.4)	3 (18.8)	18 (17.8)	9 (14.3)	10 (14.9)	1 (7.1)
120	120	28 (9.3)	1 (2.4)	1 (6.3)	13 (12.9)	8 (12.7)	4 (6.0)	1 (7.1)

Note. Exclusion cut-offs for the control group were calculated as the maximum allowable duration between assessments for a participant doing an activity (91 days [14 weeks of activity] + pre-activity cut-off + post-activity cut-off). **Bold** = chosen cut-off.

Table 5.6

Summary of Linear Mixed Models Analysing Intervention Effects for Each Cognitive Outcome

Model	No. of parameters	AIC	BIC	Log-Likelihood	χ^2	*df*	*p*
Full Scale IQ							
Intercept Only	3	4184.42	4197.61	-2089.21	-	-	-
Time	4	4112.02	4129.60	-2052.01	74.40	1	<.001
Time + Group	9	4114.49	4154.05	-2048.25	7.53	5	.184
Time + Group + Time x Group	14	4117.45	4178.99	-2044.73	7.04	5	.218
Verbal Comprehension							
Intercept Only	3	4269.12	4282.31	-2131.56	-	-	-
Time	4	4244.43	4262.02	-2118.21	26.69	1	<.001
Time + Group	9	4252.79	4292.38	-2117.39	1.64	5	.897
Time + Group + Time x Group	14	4257.95	4319.53	-2114.98	4.84	5	.436
Perceptual Reasoning							
Intercept Only	3	4515.67	4528.87	-2254.83	-	-	-
Time	4	4503.41	4521.00	-2247.70	14.26	1	<.001
Time + Group	9	4508.49	4548.08	-2245.25	4.91	5	.426
Time + Group + Time x Group	14	4513.71	4575.29	-2242.85	4.78	5	.443
Working Memory							
Intercept Only	3	4346.37	4359.52	-2170.18	-	-	-
Time	4	4335.50	4353.04	-2163.75	12.87	1	<.001
Time + Group	9	4341.54	4380.99	-2161.77	3.97	5	.554
Time + Group + Time x Group	14	4342.12	4403.49	-2157.06	9.42	5	.094

Model	No. of parameters	AIC	BIC	Log-Likelihood	χ^2	*df*	*p*
Processing Speed							
Intercept Only	3	4336.64	4349.82	-2165.32	-	-	-
Time	4	4282.39	4299.97	-2137.20	56.25	1	<.001
Time + Group	9	4272.36	4311.91	-2127.18	20.03	5	.001
Time + Group + Time x Group	14	4275.77	4337.28	-2123.88	6.60	5	.252
Auditory Memory							
Intercept Only	3	4461.59	4474.68	-2227.79	-	-	-
Time	4	4350.37	4367.83	-2171.19	113.22	1	<.001
Time + Group	9	4354.10	4393.38	-2168.05	6.27	5	.280
Time + Group + Time x Group	14	4360.64	4421.74	-2166.32	3.46	5	.630
Visual Memory							
Intercept Only	3	4697.62	4710.79	-2345.81	-	-	-
Time	4	4553.88	4571.44	-2272.94	145.74	1	<.001
Time + Group	9	4557.92	4597.45	-2269.96	5.95	5	.311
Time + Group + Time x Group	14	4560.97	4622.45	-2266.48	6.96	5	.224
Immediate Memory							
Intercept Only	3	4483.52	4496.61	-2238.76	-	-	-
Time	4	4353.48	4370.94	-2172.74	132.03	1	<.001
Time + Group	9	4356.34	4395.62	-2169.17	7.15	5	.210
Time + Group + Time x Group	14	4362.02	4423.13	-2167.01	4.32	5	.505
Delayed Memory							
Intercept Only	3	4554.85	4567.93	-2274.42	-	-	-
Time	4	4389.08	4406.52	-2190.54	167.77	1	<.001
Time + Group	9	4395.42	4434.65	-2188.71	3.67	5	.599
Time + Group + Time x Group	14	4402.44	4463.47	-2187.22	2.98	5	.704

Table 5.7

Parameter Estimates of Full Time x Group Interaction Model for Each Cognitive Outcome

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
Full Scale IQ						
(Intercept)	**110.59**	**1.84**	**325.42**	**60.22**	**<0.001**	**<0.001**
Time	**2.78**	**0.74**	**298.61**	**3.77**	**<0.001**	**0.001**
Group (Computer)	-5.52	3.47	325.42	-1.59	0.112	0.336
Group (Creative)	-1.16	2.18	325.42	-0.53	0.597	0.674
Group (Language)	-1.44	2.36	325.42	-0.61	0.541	0.674
Group (Physical)	0.13	2.33	325.42	0.06	0.955	0.955
Group (Social)	-7.37	3.64	325.42	-2.03	0.044	0.175
Time x Group (Computer)	-1.28	1.38	298.22	-0.93	0.356	0.647
Time x Group (Creative)	0.52	0.87	298.46	0.60	0.549	0.674
Time x Group (Language)	-1.06	0.95	298.54	-1.12	0.264	0.633
Time x Group (Physical)	-0.83	0.93	298.53	-0.88	0.377	0.647
Time x Group (Social)	0.72	1.45	298.21	0.50	0.618	0.674
Verbal Comprehension						
(Intercept)	**109.17**	**1.73**	**354.38**	**63.24**	**<0.001**	**<0.001**
Time	**3.05**	**0.99**	**300.52**	**3.08**	**0.002**	**0.013**
Group (Computer)	-2.11	3.26	354.38	-0.65	0.518	0.818
Group (Creative)	-0.12	2.05	354.38	-0.06	0.953	0.953
Group (Language)	1.04	2.22	354.38	0.47	0.641	0.818
Group (Physical)	0.43	2.19	354.38	0.19	0.846	0.923
Group (Social)	-1.89	3.42	354.38	-0.55	0.582	0.818
Time x Group (Computer)	-0.93	1.86	299.74	-0.50	0.617	0.818
Time x Group (Creative)	-0.48	1.17	300.21	-0.41	0.682	0.818
Time x Group (Language)	-2.13	1.27	300.37	-1.68	0.095	0.380
Time x Group (Physical)	-1.64	1.26	300.36	-1.31	0.192	0.577
Time x Group (Social)	-2.27	1.95	299.71	-1.16	0.245	0.588
Perceptual Reasoning						
(Intercept)	**106.29**	**2.08**	**360.84**	**51.10**	**<0.001**	**<0.001**
Time	1.08	1.27	300.14	0.85	0.394	0.801
Group (Computer)	-5.54	3.93	360.84	-1.41	0.159	0.623
Group (Creative)	-1.11	2.47	360.84	-0.45	0.652	0.801
Group (Language)	-0.67	2.67	360.84	-0.25	0.801	0.801
Group (Physical)	-0.77	2.64	360.84	-0.29	0.771	0.801
Group (Social)	-6.65	4.12	360.84	-1.61	0.108	0.623
Time x Group (Computer)	0.92	2.37	299.28	0.39	0.698	0.801
Time x Group (Creative)	1.89	1.50	299.80	1.26	0.208	0.623
Time x Group (Language)	-0.84	1.62	299.98	-0.51	0.607	0.801
Time x Group (Physical)	0.73	1.60	299.97	0.46	0.647	0.801
Time x Group (Social)	0.63	2.49	299.25	0.25	0.799	0.801
Working Memory						
(Intercept)	**114.27**	**2.04**	**340.72**	**56.05**	**<0.001**	**<0.001**
Time	1.84	1.07	291.62	1.72	0.087	0.325
Group (Computer)	-4.33	3.85	340.72	-1.13	0.261	0.419
Group (Creative)	-3.31	2.42	342.48	-1.37	0.173	0.346
Group (Language)	-3.92	2.62	341.65	-1.50	0.135	0.325
Group (Physical)	-2.81	2.59	340.72	-1.08	0.279	0.419
Group (Social)	-6.34	4.04	340.72	-1.57	0.118	0.325
Time x Group (Computer)	-3.22	1.99	290.37	-1.62	0.107	0.325
Time x Group (Creative)	-0.78	1.27	291.53	-0.61	0.541	0.541
Time x Group (Language)	1.23	1.38	291.63	0.89	0.372	0.424
Time x Group (Physical)	-1.31	1.35	291.17	-0.97	0.333	0.424
Time x Group (Social)	1.80	2.09	290.32	0.86	0.389	0.424

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
Processing Speed						
(Intercept)	**105.15**	**1.92**	**338.27**	**54.65**	**<0.001**	**<0.001**
Time	**2.71**	**0.93**	**297.11**	**2.90**	**0.004**	**0.024**
Group (Computer)	-5.71	3.65	344.42	-1.57	0.118	0.237
Group (Creative)	0.68	2.28	338.27	0.30	0.767	0.767
Group (Language)	-2.24	2.47	338.27	-0.91	0.365	0.548
Group (Physical)	3.93	2.44	338.27	1.61	0.109	0.237
Group (Social)	-9.29	3.81	338.27	-2.44	0.015	0.061
Time x Group (Computer)	-1.89	1.79	298.01	-1.06	0.291	0.498
Time x Group (Creative)	0.52	1.10	296.98	0.47	0.641	0.767
Time x Group (Language)	-0.48	1.20	297.20	-0.40	0.692	0.767
Time x Group (Physical)	-0.43	1.18	296.99	-0.37	0.714	0.767
Time x Group (Social)	3.01	1.83	296.53	1.64	0.102	0.237
Auditory Memory						
(Intercept)	**120.92**	**2.14**	**345.55**	**56.62**	**<0.001**	**<0.001**
Time	**5.20**	**1.24**	**283.34**	**4.20**	**<0.001**	**<0.001**
Group (Computer)	-6.05	4.02	342.55	-1.50	0.133	0.320
Group (Creative)	-1.69	2.55	344.83	-0.66	0.508	0.677
Group (Language)	-5.02	2.75	346.06	-1.83	0.068	0.226
Group (Physical)	-3.32	2.71	344.93	-1.22	0.222	0.444
Group (Social)	-7.82	4.38	352.88	-1.78	0.075	0.226
Time x Group (Computer)	-1.01	2.28	281.05	-0.45	0.657	0.716
Time x Group (Creative)	0.25	1.46	282.53	0.17	0.867	0.867
Time x Group (Language)	1.09	1.59	283.46	0.69	0.493	0.677
Time x Group (Physical)	-0.74	1.56	282.85	-0.48	0.635	0.716
Time x Group (Social)	2.69	2.53	283.32	1.07	0.287	0.492
Visual Memory						
(Intercept)	**103.29**	**2.10**	**378.14**	**49.29**	**<0.001**	**<0.001**
Time	**6.08**	**1.45**	**296.15**	**4.20**	**<0.001**	**<0.001**
Group (Computer)	-0.20	4.04	401.33	-0.05	0.961	0.961
Group (Creative)	-4.03	2.49	378.80	-1.62	0.106	0.211
Group (Language)	-5.17	2.69	378.14	-1.92	0.056	0.134
Group (Physical)	-3.87	2.66	378.14	-1.46	0.146	0.250
Group (Social)	-8.27	4.20	391.22	-1.97	0.050	0.134
Time x Group (Computer)	-0.92	2.83	300.82	-0.33	0.745	0.894
Time x Group (Creative)	0.39	1.71	295.89	0.23	0.821	0.896
Time x Group (Language)	1.68	1.86	295.94	0.91	0.365	0.548
Time x Group (Physical)	3.63	1.83	295.93	1.98	0.049	0.134
Time x Group (Social)	1.76	2.92	298.35	0.60	0.546	0.728
Immediate Memory						
(Intercept)	**118.24**	**2.05**	**359.24**	**57.79**	**<0.001**	**<0.001**
Time	**5.45**	**1.31**	**285.23**	**4.16**	**<0.001**	**<0.001**
Group (Computer)	-4.74	3.85	355.71	-1.23	0.219	0.430
Group (Creative)	-2.26	2.44	358.40	-0.93	0.355	0.435
Group (Language)	-6.06	2.63	359.85	-2.30	0.022	0.087
Group (Physical)	-3.47	2.60	358.51	-1.34	0.183	0.430
Group (Social)	-8.31	4.20	367.85	-1.98	0.049	0.146
Time x Group (Computer)	-2.20	2.41	282.47	-0.91	0.362	0.435
Time x Group (Creative)	0.91	1.55	284.26	0.58	0.559	0.610
Time x Group (Language)	1.76	1.68	285.38	1.04	0.298	0.435
Time x Group (Physical)	0.75	1.65	284.64	0.45	0.653	0.653
Time x Group (Social)	3.08	2.67	285.21	1.15	0.251	0.430

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
Delayed Memory						
(Intercept)	**113.62**	**2.22**	**348.33**	**51.11**	**<0.001**	**<0.001**
Time	**7.42**	**1.33**	**278.66**	**5.60**	**<0.001**	**<0.001**
Group (Computer)	-1.88	4.25	363.01	-0.44	0.659	0.736
Group (Creative)	-2.79	2.65	348.67	-1.05	0.293	0.587
Group (Language)	-4.83	2.86	348.87	-1.69	0.092	0.313
Group (Physical)	-4.28	2.82	347.68	-1.52	0.130	0.313
Group (Social)	-6.99	4.61	368.85	-1.52	0.131	0.313
Time x Group (Computer)	-1.86	2.55	280.21	-0.73	0.467	0.736
Time x Group (Creative)	-0.77	1.57	278.07	-0.49	0.625	0.736
Time x Group (Language)	0.70	1.70	278.79	0.41	0.683	0.736
Time x Group (Physical)	0.95	1.67	278.15	0.57	0.570	0.736
Time x Group (Social)	0.94	2.79	281.31	0.34	0.736	0.736

Note. The within-subjects predictor Time is coded as 0 = *baseline* and 1 = *follow-up*. The between-subjects predictor Group is dummy coded with the Control group serving as the reference group. The parameter estimate for (Intercept) represents the average score in the Control group at baseline. The parameter estimate for Time represents the change from baseline to follow-up in the Control group. The parameter estimates for the five Group contrasts represent the difference between the respective activity group and the Control group at baseline. The parameter estimates for the interaction terms between Time and each of the five Group contrasts represent the difference in change over time between the respective activity group and the Control group. p_{adj} = *p*-value adjusted using the Benjamini-Hochberg procedure to control the false discovery rate. **Bold** = $p_{adj} < .05$.

6. Does Personality Predict Adherence and Attrition in an Activity-Based Cognitive Intervention?

6.1. Introduction

Cognitive ageing intervention studies often require a sizeable commitment of time and effort from a participant, usually for a sustained duration. As such, some degree of participant attrition is common in studies of this kind. Even among those who complete a study, adherence to an intervention protocol is not always perfect. For example, Stine-Morrow et al. (2014) examined adherence rates in the Senior Odyssey intervention study (described previously in Chapter 3). They found that participants allocated to the group-based competitive problem solving programme attended an average of 11 out of 16 sessions (69%), and participants allocated to the home-based reasoning training programme completed an average of 12.9 out of 16 training modules (81%). Importantly, adherence was found to be positively correlated with change in cognitive outcomes over the course of the intervention, suggesting that there may be a degree of dose-response in the intervention-derived benefit. Understanding what factors predict adherence could therefore be essential in designing effective interventions.

This is a particularly important issue in the context of the Intervention Factory study. Results from the previous chapter showed no evidence that the activities in this study led to any meaningful cognitive improvements. A key design feature of this study was a lack of researcher supervision during intervention delivery. This was done to establish a study environment that was more reflective of how such an intervention might be delivered in the real world. While, as discussed, this approach introduced many challenges, it also provided a unique opportunity to examine how well older adults adhere to such an intervention when removed from a more controlled study environment. If it is the case that poor intervention adherence explains the lack of observed cognitive improvements, then understanding what factors predict adherence will be useful in informing the design of future interventions to encourage stronger uptake.

6.1.1. What Factors Predict Adherence to Interventions for Cognitive Ageing?

There are many potential reasons for variation in adherence to a given intervention. Even the most diligent of participants might miss one or two days due to unforeseen circumstances (e.g., a sudden illness or family emergency). Such events are inherently unpredictable and, to an extent, unavoidable. There may also be more systematic and predictable explanations (e.g., missing sessions due to a chronic health condition). However, within the field of cognitive ageing interventions, relatively few studies have examined adherence and the individual factors that might influence it.

Coley et al. (2019) examined the predictors of adherence to the Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability (FINGER) trial, a multi-domain intervention for dementia prevention in older adults (Ngandu et al., 2015). The intervention comprised computer-based cognitive training, gym-based exercise training, nutritional counselling and cardiovascular consultations (i.e., regular monitoring of cardiovascular risk factors such as blood pressure). Adherence was treated as a dichotomous variable; participants were classified as 'adherent' if they had attended at least 66% of the sessions offered for each intervention component. While the authors acknowledged that the ideal threshold level of adherence for cognitive interventions is currently unknown, this cut-off was chosen based on its use in previous non-cognitive intervention studies. Variables considered as predictors of adherence included demographics (e.g., age, gender, education), cognitive function, depressive symptoms, health-related behaviours (e.g., smoking, alcohol intake, physical activity) and cardiovascular risk factors (e.g., history of diabetes, high blood pressure or stroke). The study was somewhat exploratory; full multivariate regression models predicting adherence included twenty-one predictor variables.

Results suggested that for the exercise component, those who reported high levels of physical activity at baseline were more likely to reach the adherence threshold, while those with depressive symptoms and a history of diabetes were less likely to do so. For the nutritional component, those with depressive symptoms, smokers and those on low income were less likely to reach the adherence threshold, while females, those with a high BMI and those with history of stroke were more likely to do so. Smokers and participants holding a non-positive perception of the study were less likely to reach the threshold for cognitive training, while those with previous experience of computer use and those with previously high levels of physical activity were more likely to do so. When adherence to the cognitive training component of the intervention was considered as a continuous variable (i.e., number of sessions completed), the only significant predictor was previous computer use (Turunen et al., 2019). Coley et al. (2019) also examined overall adherence to another multidomain intervention for older adults (the Multidomain Alzheimer Preventive Trial [MAPT], which consisted of group sessions simultaneously comprising cognitive training and exercise/dietary advice; Vellas et al., 2014). They found that those who had depressive symptoms, lower global cognitive function, high BMI and history of high blood pressure were significantly less likely to meet the 66% adherence threshold.

Bagwell and West (2008) found that participants (middle-aged and older adults) who adhered more closely to their memory training intervention (i.e., those who attended more sessions, contributed more during sessions, completed homework assignments) had significantly more years of education and higher self-rated health. Lam et al. (2015) examined the benefits of group-based activity interventions, comprising either a social activity group, a cognitive activity group, a physical activity group or a mixed cognitive-physical activity group, in a sample of older adults with MCI. They found that overall adherence (i.e., percentage of sessions attended across all intervention groups) was positively associated with baseline cognitive ability and significantly higher in women.

Personality traits might represent an important factor in predicting adherence. For example, Double and Birney (2016) examined adherence to an online commercial brain training program in a sample of adults of all ages. They found that those who were more open to experience were significantly less likely to discontinue the program. To date, no published intervention specifically targeted at older adults has examined the association between personality and adherence. In the systematic review presented in Chapter 4, data shared by authors of two intervention studies (Cerino et al., 2020; McDougall et al., 2010) were used to examine the associations between intervention adherence and each of the Big Five traits in older adults (see Marr et al., 2020). No significant associations were found.

There is a particular need to consider the importance of personality in the design and implementation of engagement-based interventions. Rather than training participants on specific cognitive tasks, these interventions aim to enhance cognitive health through increasing participants' engagement in activities thought to be mentally, physically, socially or creatively stimulating. Personality traits have been linked to everyday engagement in these areas. For example, there is evidence that higher Openness predicts greater engagement in mentally demanding activities, higher Conscientiousness predicts greater levels of physical activity and higher Extraversion predicts greater levels of social activity (Hultsch et al., 1999; Krueger et al., 2009; Wilson & Dishman, 2015; see also results of Chapter 2). It is therefore possible that these traits also predict engagement in the context of an intervention.

6.1.2. Study Attrition

It is also possible that personality traits might be related to study attrition. Attrition refers to participants dropping out from an ongoing study following their initial assessment. Evidence from large national panel studies (longitudinal studies with samples designed to be representative of the general population) presents mixed results. Higher scores in Extraversion and Neuroticism, and lower scores in Openness to Experience and Conscientiousness have all been associated with attrition in studies of adults of all ages (Lugtig, 2014; Richter et al., 2014; Satherley et al., 2015). There is some mixed evidence regarding Agreeableness; Richter et al. (2014) found that lower Agreeableness predicted attrition, while Lugtig (2014) found that higher Agreeableness predicted attrition. Hansson et al. (2018) examined whether personality predicted attrition in a population-based longitudinal study of older adults specifically. They found that attrition was greater among those with higher scores in Extraversion and Neuroticism and lower scores in Agreeableness. Salthouse (2014) carried out a longitudinal study focused on cognitive ageing. He found that across all participants, those who dropped out had lower scores on Openness and Agreeableness, and that among older adults in particular, those who dropped out scored lower in Extraversion.

There is some evidence to suggest that personality may predict drop-out from randomised controlled trials. For example, Jerant et al. (2011) found that older adults who dropped out from a dementia drug trial had significantly higher Neuroticism scores. However, to this author's knowledge, no nonpharmacological cognitive ageing intervention has examined whether personality traits are associated with attrition.

6.1.3. The Present Study

The present study examined whether personality traits were associated with attrition from, and adherence to, the Intervention Factory activities. More specifically, analyses examined personality differences between those who withdrew from the study following baseline assessment and those who did not. Among those participants who did complete the study, analyses then examined whether personality traits predicted the proportion of activity classes/group sessions completed, and the amount of time spent on the activity. The real-world setting of this study, along with the lower level of supervision from the research team during intervention delivery, provided an opportunity to study adherence to an intervention for cognitive ageing in a more ecologically valid setting. Examining whether personality traits influence adherence to this intervention could help to identify those individuals who may need more support to engage with an intervention protocol outside of a highly controlled research study.

6.2. Methods

6.2.1. Participants

A total of 336 participants were recruited for the study and completed baseline assessment. Study eligibility criteria, recruitment procedures and sample characteristics were detailed previously (see Chapter 2, section 2.2.1, and Chapter 5, Table 5.2).

6.2.2. Design and Procedure

The Intervention Factory adopted a pseudo-randomised controlled trial design. Following baseline assessment, participants were allocated to a new activity group/class in their local community. From a list of six activities (computer classes, dance/exercise/sport classes, social clubs, language classes, handicraft/woodcraft classes and bingo, described in full in Chapter 5, section 5.2.3), any that the participant had previously engaged in were removed, and up to two additional activities could also be removed at the participant's discretion (as in Park et al., 2014). Participants were then randomly allocated to one of the remaining activities (for a complete summary of the allocation process, see Chapter 5, section 5.2.4). Participants were not blind to their own allocation, as they were aware of all possible activities.

As only two participants were allocated to what was originally intended to be an active control group (specifically a bingo group), an additional cohort of participants was recruited to serve as a no-contact control group. These participants did not engage in any new activity during the intervention period. The complete sample was thus configured into the six groups described fully in Chapter 5 (section 5.2.7): Computer, Physical, Social, Language, Creative and Control. Class/group term durations varied, but typically ran once per week for ten-week periods. Where classes/groups ran continuously throughout the year, participants were asked to attend once per week for ten weeks.

6.2.3. Materials and Measures

Adherence Measures. Participants recorded attendance for their new activity using a time log (reproduced in Appendix L). Time logs allowed participants to record the days they attended their class/group and how much time they spent on the activity on those days. Participants were also asked to record any time they spent on the activity outwith their class/group (e.g., homework).

Two measures of adherence were calculated: Percentage Adherence and Time Spent. Percentage Adherence was calculated as the number of weeks attended divided by the total number of weeks the class/group ran for, multiplied by 100. If the class was a drop-in class, the total number of weeks was set to ten weeks (the duration that participants were asked to attend for). If the class/group ran for a set number of weeks but there was no record of this number, this value was imputed as the standard ten weeks. Time Spent was recorded as the total number of minutes spent on an activity, both within and out of the class/group, for the duration of the study.

Predictors. All predictors were measured during the baseline assessment unless otherwise stated.

Demographics. Age, gender (male or female), years of education (total number of years spent in primary, secondary and further/higher education) and neighbourhood deprivation level (Scottish Index of Multiple Deprivation 2016 [SIMD16] vigintile ranking; Scottish Government, 2016) were considered as demographic predictors.

Health Status. A medical history questionnaire was administered to participants at the telephone screening stage, during which they were asked whether they had previously been diagnosed with high blood pressure or diabetes. During baseline assessments, participants rated their general health on a five-point scale (1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent). Participant's height and weight were measured and used to calculate their body mass index (BMI; kg/m^2). The Short Portable Physical Performance Battery (SPPPB; Guralnik et al., 1994; described previously in Chapter 5, section 5.2.6) measured participants' lower-extremity function. The Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983; see Chapter 5, section 5.2.6) measured anxious and/or depressive symptoms.

Health-Related Behaviour. Participants were asked whether they were a current smoker. The take-home questionnaire that participants completed following baseline assessment included the short version of the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003). Total metabolic equivalent of task (MET) minutes-per-week measured using the IPAQ was used as an indicator of overall current level of physical activity.

Cognitive Ability. Detailed descriptions of the battery of cognitive tests used were provided previously (see Chapter 2, section 2.2.2, and Chapter 5, section 5.2.6). The Mini-Mental State Examination (MMSE; Folstein et al., 1975) and the Clock Drawing Test (CDT; Agrell & Dehlin, 1998) measured global cognitive status. Domain level abilities were measured using composite scores from the 4^{th} (UK) edition of the Wechsler Adult Intelligence Scale (WAIS-IV; Wechsler, 2010a) and the 4^{th} (UK) edition of the Wechsler Memory Scale (WMS-IV [Older Adult Battery]; Wechsler, 2010b). These were Verbal Comprehension, Perceptual Reasoning, Working Memory and Processing Speed, Auditory Memory, Visual Memory, Immediate Memory and

Delayed Memory. A measure of global cognitive ability (Full Scale IQ) was also derived from the WAIS-IV.

Personality. The NEO-Personality Inventory 3 (NEO-PI-3; McCrae et al., 2015) measured scores on each of the Big Five traits (Neuroticism, Extraversion, Openness to Experience, Agreeableness and Conscientiousness; see Chapter 2, section 2.2.2 for more details).

6.2.4. Statistical Analysis

Missing Data. Missing data rates for additional predictor variables not previously included in Chapter 5 (MET-minutes per week, history of high blood pressure, history of diabetes, smoking status and BMI) and all adherence measures are presented in Appendix M. Across all study variables (i.e., predictors and activity adherence measures), 4.4% of data were missing (500 cells missing out of 11,424 [34 variables across 336 participants]). Excluding those who withdrew from the study, 3.0% of data were missing (313 cells missing out of 10,268 [34 variables across 302 participants]). As highlighted in Chapter 5, those who withdrew from the study prior to being allocated to an activity could not be included in any analyses that compared intervention groups. Therefore, for consistency, all missing data were handled using case-wise deletion, and valid *N*s are reported for all analyses.

Study Attrition. Welch's *t*-tests (or Wilcoxon rank sum tests when variables were highly non-normal) were used to examine differences between those who completed both baseline assessment and at least part of the follow-up assessment (completers) and those who withdrew from the study prior to the follow-up assessment (non-completers) on demographic, health, cognitive and personality variables. Chi-squared tests or Fisher's exact tests were used to examine whether completer status differed according to categorical variables. Fisher's exact test was used when contingency table cells had an expected frequency of less than five. For consistency, differences were examined on all variables that were considered as possible predictors of adherence (described below).

Adherence Analysis. Adherence levels were compared between intervention groups using between-groups ANOVA. Bivariate correlations were computed between Percentage Adherence (across all intervention groups), Time Spent (across all intervention groups), demographic variables, personality traits, and other variables that were notable predictors of adherence in previous cognitive intervention studies (prior level of physical activity, depressive symptoms, history of diabetes and high blood pressure, whether or not the participant was a smoker, BMI, baseline cognitive function and self-rated health; Bagwell & West, 2008; Coley et al., 2019; Lam et al., 2015). To examine any unique effects of personality traits on adherence rates, multiple regression was used. Separate models were tested for all intervention groups combined, then the Creative, Language and Physical groups individually. All five traits were included as predictor variables and both Percentage Adherence and Time Spent were treated as respective outcome variables. Separate regression models for the Computer and Social groups were not feasible due to the small number of participants in these groups. As participants in the Control group had no intervention to adhere to, they were not included in any analyses of adherence.

6.3. Results

6.3.1. Study Attrition

Of the 336 participants who completed baseline assessments, 16 withdrew from the study prior to being allocated to an activity and 18 withdrew after allocation (two participants from the Computer group, three participants from the Creative group, six participants from the Language group, six participants from the Physical group and one participant from the Social group). The remaining participants (N = 302; 89.9%)

completed at least part of the follow-up assessment (three participants did not attend a follow-up testing session but did complete and return their follow-up questionnaire).

Comparisons between completers and non-completers on demographic, health, personality and cognitive variables are presented in Table 6.1. Compared to those who completed the study, non-completers had significantly fewer years of education, $t(39.42) = 3.38$, $p < .01$, and significantly lower scores on the trait of Agreeableness, $t(35.26) = 2.56$, $p < .05$. Non-completers also had significantly lower scores on the MMSE, $t(35.50) = 2.57$, $p < .05$, Full Scale IQ, $t(36.92) = 2.69$, $p < .05$), Verbal Comprehension, $t(36.64) = 3.00$, $p < .01$, Perceptual Reasoning, $t(39.58) = 3.20$, $p < .01$), Auditory Memory, $t(33.27) = 3.66$, $p < .001$, Visual Memory, $t(39.17) = 3.35$, $p < .01$, Immediate Memory, $t(33.47) = 3.60$, $p < .01$, and Delayed Memory, $t(32.85) = 3.91$, $p < .001$. In other words, those who withdrew from the study tended to have lower levels of global cognitive ability, and lower levels of verbal, visuospatial and memory ability. It should be noted, however, that when adjusted for multiple comparisons using a Bonferroni correction, the only comparisons that remained significant were differences in education and scores on each of the WMS-IV domains.

As the distribution of SPPPB scores was highly non-normal in both completers (skew = -3.51, kurtosis = 17.04) and non-completers (skew = -2.84, kurtosis = 9.41), the Wilcoxon rank-sum test was used to compare the two groups; no significant difference was found, $W = 5798$, $p = .156$. Contingency tables reporting the numbers of completers and non-completers by gender, history of high blood pressure, history of diabetes and current smoking status are presented in Table 6.2. Chi-square tests revealed no differences between completers and non-completers in terms of gender, $\chi^2(1) = 0.02$, $p = 0.899$, or previous diagnosis of high blood pressure, $\chi^2(1) = 0.55$, $p = 0.459$. Because expected frequencies of non-completers who were current smokers or diabetic were both less than five, Fisher’s exact test was used to compare rates between completers and non-completers; there was no association between completer status and previous diagnosis of diabetes or current smoking status, *p*s = 1.00.

6.3.2. Activity Adherence

Of the 302 participants who completed follow up, 175 were allocated to activities with a set number of weeks (ranging from five to 14). Seventy-four participants were allocated to ongoing weekly drop-in classes with no set number of weeks (mostly computer classes, exercise classes or social clubs); these participants were asked to attend the activity for a ten-week period. Records were not available regarding class term duration for 12 participants, so their term duration was imputed as the standard 10 weeks. Fourteen participants did not return their completed time log, meaning that there was no record of how many weeks they attended; these participants were excluded from the adherence analyses. The 41 participants in the Control group were not included in the adherence analyses, as they did not engage in a new activity.

Some participants (N = 12) recorded that they continued to attend their activity for longer than required for the study. For all reported analyses, adherence for these participants was truncated to 100%. An additional four participants were excluded for all analyses involving Time Spent as although they recorded the number of weeks they attended, they did not record the amount of time they spent on their activity.

Descriptive statistics for adherence variables are presented in Table 6.3. Average activity term duration was 9.9 weeks; participants reported attending an average of 8.3 weeks. Participants attended 82.6% of sessions on average. The average amount of time spent on activities was 1186.9 minutes, which equates to 19.8 hours.

Levene's test for homogeneity of variance across activity groups was significant for both Percentage Adherence, $F(4, 242) = 2.49$, $p < .05$, and Time Spent, $F(4, 238) = 11.82$, $p < .001$. Therefore, ANOVA with Welch's F adjustment was conducted to compare both variables across groups. There was no significant between-groups difference in Percentage Adherence (Computer group: M = 77.5%; Creative group: M = 80.7%; Language group: M = 82.9%; Physical group: M = 88.7%; Social group: M = 70.0%), F(4, 50.55) = 2.53, p = .052 (see Figure 6.1). There was a significant difference between groups in Time Spent, F(4, 47.87) = 31.51, p < .001. Games-Howell post-hoc pairwise tests revealed that those in the Language group recorded a significantly greater amount of minutes spent on their activity (M = 1847.6) compared to those in the Computer group (M = 1046.3), t(35.07) = 4.48, p < .001, the Creative group (M = 1163.3), t(88.04) = 5.40, p < .001, the Physical group (M = 686.4), t(68.61) = 9.84, p < .001, and the Social group (M = 944.6), t(29.54) = 4.98, p < .001 (see Figure 6.2). Those in the Creative group also recorded a significantly greater amount of minutes spent on their activity compared to those in the Physical group, t(142.47) = 7.14, p < .001.

Table 6.4 presents correlations between the two adherence measures and demographic, health and personality variables. Percentage adherence was significantly positively correlated with years of education, as well as performance on all cognitive measures, although only the correlations with CDT score, Full Scale IQ, Perceptual Reasoning and Immediate Memory remained significant after Bonferroni correction (rs ranging from 0.22-0.29). There were also significant positive correlations between Time Spent and years of education, CDT score, Full Scale IQ, Verbal Comprehension and Perceptual Reasoning; none of these correlations remained significant after Bonferroni correction. No significant correlations were found between the adherence measures and any of the personality traits or other variables.

Multiple regression models predicting Percentage Adherence from personality traits across all group combined, and in the Creative, Language and Physical groups separately, are presented in Table 6.5. The model predicting Percentage Adherence across all groups was not significant, F(5, 216) = 1.57, p = .170, R^2 = 0.04, adjusted R^2 = 0.01; the coefficient for Neuroticism was significant, with higher scores predicting lower Percentage Adherence. The model predicting Percentage Adherence in the Creative group was not significant, $F(5, 75) = 1.63$, $p = .161$, $R^2 = 0.10$, adjusted $R^2 = 0.04$; no significant associations were found. The model predicting Percentage Adherence in the Language group was not significant, $F(5, 49) = 2.12$, $p = .078$, $R^2 = 0.18$, adjusted $R^2 = 0.09$; the coefficients for Neuroticism and Conscientiousness were both significant, with higher scores predicting lower Percentage Adherence. The model predicting Percentage Adherence in the Physical group was not significant, $F(5, 55) = 0.76$, $p = .583$, $R^2 = 0.06$, adjusted $R^2 = -0.02$; no significant associations were found.

Models predicting Time Spent are presented in Table 6.6. The model predicting Time Spent across all groups combined was not significant, $F(5, 213) = 2.01$, $p = .078$, $R^2 = 0.05$, adjusted $R^2 = 0.02$; the coefficients for Extraversion and Openness to Experience were both significant, with higher scores predicting less and more Time Spent respectively. The model predicting Time Spent in the Creative group was not significant, $F(5, 75) = 0.74$, $p = .595$, $R^2 = 0.05$, adjusted $R^2 = -0.02$; no significant associations were found. The model predicting Time Spent in the Language group was not significant, $F(5, 48) = 1.34$, $p = .265$, $R^2 = 0.12$, adjusted $R^2 = 0.03$; the coefficient for Neuroticism was significant, with higher scores predicting less Time Spent. The model predicting Time Spent in the Physical group was not significant, $F(5, 54) = 1.27$, $p = .289$, $R^2 = 0.11$, adjusted $R^2 = 0.02$; the coefficient for Openness to Experience was significant, with higher scores predicting more Time Spent.

6.4. Discussion

Engagement-based interventions may offer a way to help maintain or improve cognitive health in old age. Observational studies have shown that personality traits are associated with frequency of activity engagement in everyday life, but there has been little research examining whether there are associations between personality traits and engagement in the context of an intervention study. The present study addressed this gap by examining the association between personality traits and both attrition and adherence within a real-world, activity-based intervention study.

6.4.1. Study Attrition

Overall participant retention was high: 90% of those initially recruited completed at least part of the follow-up assessment. This proportion is slightly higher than those reported by other engagement-based interventions, including Experience Corps (79%; Fried et al., 2004), Senior Odyssey (86%; Stine-Morrow et al., 2014) and the Synapse Project (85%; Park et al., 2014). Of the Big Five personality traits, only Agreeableness was significantly different between study completers and non-completers, with non-completers exhibiting lower scores. This is a novel finding in the context of a cognitive intervention study but is interpreted cautiously as the comparison became non-significant after Bonferroni correction. It is notable that lower levels of Agreeableness have previously been shown to predict attrition from longitudinal studies (Hansson et al., 2018; Richter et al., 2014; Salthouse, 2014). The fact that lower Agreeableness is linked to attrition across different study designs suggests that Agreeableness may have a more general influence on behaviour in a research context. Higher Agreeableness has been empirically linked to more prosocial, helping behaviour (Graziano & Eisenberg, 1997; Graziano et al., 2007). It may be that those who score lower on this trait feel less compelled to 'help' researchers by fulfilling their obligation to a research study. This may be particularly true in the present study, where taking part involved a sustained commitment of time and effort over a period of months. However, further validation of this result in future studies will be necessary to improve confidence that this was not simply a chance finding.

Study completers had, on average, around two more years of education than non-completers. Longitudinal ageing studies have previously found that older adults with lower levels of education are more likely to drop out (Steptoe et al., 2013). This finding is problematic in the context of the present intervention because it indicates that the sample became more rarefied in terms of education level at follow-up. As such, estimates of both adherence and cognitive change may be less generalisable to the wider population (more specifically, to those with less formal education).

Stine-Morrow et al. (2014) reported that global cognitive ability and verbal ability were significantly higher in completers compared to non-completers in an engagement-based cognitive ageing intervention. Similar differences in Full Scale IQ and Verbal Comprehension were observed in the present study, but these differences became non-significant after correcting for multiple tests. However, differences between completers and non-completers on performance in all four memory domains remained significant after this correction; completers consistently scored higher in Auditory Memory, Visual Memory, Immediate Memory and Delayed Memory. These findings suggest that poorer memory performance may represent a notable risk factor for attrition in an intervention study. Furthermore, estimates of change in memory performance will likely be biased towards those who were higher functioning at baseline, again limiting wider generalisability. Future intervention studies may need to consider strategies for retaining participants with lower memory scores.

While reasons for study withdrawal were recorded where possible, numbers were too small to investigate any systematic differences between those who dropped out for different reasons. Future studies with larger samples may be able to compare study completers to, for example, those who drop out because they did not enjoy their activity versus those who drop out due to ill health. Similarly, small numbers precluded a statistical comparison of drop-out rates between intervention groups. Examining whether certain activities are linked to higher drop-out rates will be another important area for future research.

6.4.2. Intervention Adherence

On average, participants attended just over 80% of their assigned class/group sessions and spent an average of 20 hours engaging in their new activity. It is important to note that these averages do not include those who withdrew from the study after allocation; objective records of class/group attendance could not be collected from those participants, meaning that the actual number of classes they attended before withdrawing is unknown. It is likely that non-completers attended fewer classes or no classes at all (several non-completers reported disliking their activity as their reason for withdrawing). Average adherence is therefore likely to be lower in real terms. However, an adherence rate of over 80% among completers is encouraging given the intentionally low level of oversight by the research team during the period of new engagement.

Reporting of adherence rates to cognitive ageing interventions is relatively uncommon. Among those that have done so, Lam et al. (2015) reported an adherence rate of 73% among older adults with MCI in a similar intervention involving group activity engagement (either social, mental, physical or mixed; three sessions per week for 12 months). As noted above, Stine-Morrow et al. (2014) reported adherence rates of 69% (group-based problem solving) and 81% (home-based cognitive training) in the Senior Odyssey study over 16 weeks. While these figures suggest that adherence in the present study was high, data from other studies is necessary to fully place this finding in context.

Adherence rates did not significantly differ across groups. Average adherence was highest in the Physical group, at 89%. There exists a reasonably large body of research with which to compare this figure. A review of 21 exercise-based RCTs in older adults (targeted at various outcomes, not exclusively cognitive health) found that average adherence was 78% (Martin & Sinden, 2001). The authors also found that adherence among those studies that excluded drop-outs was 88% (a figure almost identical to that found in the present study), while adherence among those studies that included all drop-outs in an intention-to-treat analysis was significantly lower, at 63%. This again highlights the impact of attrition on adherence estimates.

Regarding adherence in the other groups, there is less existing research for drawing comparisons. Average adherence in the Social group was 70%. Dodge et al. (2015) reported that participants attended 89% of scheduled video-calls in their social intervention that comprised five calls per week for six weeks. The higher figure in Dodge et al.'s (2015) study may be related to the fact that the intervention was conducted in participants' own homes, removing any attendance barriers due to travel, weather or mobility issues. There is, to this author's knowledge, no previous evidence to draw upon for comparison with the remaining groups (Computer, Creative and Language). It is therefore important that future studies continue to build on these findings by measuring and reporting adherence rates. Doing so would help understand exactly which types of activities older adults are more likely to maintain over an extended period. This is particularly important given the possibility that intervention-related improvements may be positively associated with adherence rate (Stine-Morrow et al., 2014).

While participants spent an average of 20 hours on their activity over the course of the intervention, the amount of Time Spent varied between individuals. Time spent ranged from 20 minutes[6] to 77 hours, with a standard deviation equivalent to around 12 hours. Again, few previous studies have reported the amount of time participants spent on their intervention, making it difficult to place these findings in context. Participants in the Synapse study typically spent a much greater amount of time on their activity than in the present study. In the Synapse study, average Time Spent per week ranged from 15.84 to 18.11 hours across different intervention conditions over a 14-week

[6] Time spend at the lower end of the range largely consists of participants who only attended one or two weeks of their activity before discontinuing.

period (Park et al., 2014); in other words, some participants in the Synapse study were spending more time on their activity in one week than participants in the present study were over the entire intervention period. It should be noted that this discrepancy is likely a feature of the differing study designs. In the Synapse study, participants received five hours of formal instruction per week, which was longer than any of the classes used for the present study. Furthermore, participants in the Synapse study were provided with a dedicated learning environment to use for their activity outside of class time. In fact, participants were directed to spend an additional ten hours per week in this environment completing course assignments. Participants in the present study had no guaranteed access to such an environment. Such a discrepancy highlights the somewhat idealised design and delivery of previous activity-based interventions; while the Synapse study was able to provide a learning environment to facilitate greater engagement in their intervention, in the real world such a resource is rarely available, and providing one would likely involve significant cost.

A significant between-groups difference was found in terms of Time Spent: those in the Language group spent a greater amount of time engaging in their activity than all other groups. Participants in the Language group spent an average of 31 hours on their activity, around 12 hours more that the next highest group (Creative). This may be because participants in the Language group spent a greater amount of time practicing outside of class or completing homework assignments. Practice at home may have been less feasible for the other groups, for which access to specialist equipment (such as tools/materials, exercise equipment or a computer) was likely necessary. This cannot be determined empirically, as participants were not required to specify exactly what they did during the time they recorded. Future studies should consider collecting more detailed information regarding how participants engage with their activity outside of prescribed intervention time.

It is also interesting to note that while on average those in the Physical Group spent the least amount of time on their activity (11 hours, significantly lower than both the Language and Creative groups), this group had the highest average adherence rate. Generally, exercise classes tended to last for around an hour, while language and handicraft classes often ran for two hours. It is possible that the lower time commitment for those in the Physical group led to higher adherence rates. Detailed information on class/group session duration was not recorded, meaning that this theory could not be tested, but future studies should consider possible associations between aspects of the activity itself, such as time commitment, and adherence.

This study is, to the author's knowledge, the first to examine whether any of the Big Five personality traits predict adherence to an engagement-based cognitive intervention in older adults. Analyses initially considered adherence rates across all participants. These findings can be interpreted as a broader indicator of what factors might predict adherence to *any* intervention involving novel engagement, regardless of what the activity itself may be. Overall, little evidence was found of significant associations between personality traits and either Percentage Adherence or Time Spent. Across all participants who engaged in a new activity, correlations between trait scores and both Percentage Adherence and Time Spent were all close to zero and not significant. Multiple regression models further examined the predictive effect of each trait when controlling for all other traits. It should be noted that neither the model predicting Percentage Adherence nor the model predicting Time Spent were themselves significant, suggesting that personality traits collectively did not account for a meaningful proportion of the variance in either outcome. Individual regression coefficients should therefore be interpreted with caution.

The only trait significantly associated with Percentage Adherence across all participants was Neuroticism; across all activities, those who scored higher on this trait tended to miss a greater proportion of their class/group sessions. It is difficult to suggest why those who score higher in Neuroticism seem to be less likely to stick to a new activity. It may be the case that generally higher levels of mental distress in such individuals (McCrae & John, 1992) interfered with their attendance; further research with more detailed records on reasons for absence would be useful in testing this theory. Higher scores on Extraversion were associated with lower Time Spent in activity. More extraverted individuals tend to be more socially active (Krueger et al., 2009), which may have reduced the amount of free time they had to spend on their new activity. As one might expect, Openness to Experience was positively associated with Time Spent. Those who are open tend to be more curious and hold varied interests (McCrae, 1994), so it is intuitive that these individuals spent more time engaging in a new activity when given the opportunity. However, this finding also highlights that those who are less open may be less likely to stick to a novel activity, and might therefore require additional support or encouragement.

Analyses focusing on individual intervention groups revealed some significant associations, but again, none of the multiple regression models were significant, meaning that observed associations must be interpreted cautiously. It is perhaps notable that higher Neuroticism was significantly associated with poorer adherence and less time spent on activity specifically in the Language group. Language classes were selected as an intervention activity on the basis of being both mentally and socially demanding. Previous cross-sectional findings regarding the association between Neuroticism and mental/social engagement are mixed. Hultsch et al. (1999) found a significant negative correlation between Neuroticism and engagement in an activity domain they termed Novel Information Processing (which included an item measuring language learning) in a sample of older adults. Krueger et al. (2009) found significant negative correlations between Neuroticism and frequency of mental and social activity in older adults. In Chapter 2 of this thesis, a negative correlation was observed between Neuroticism and engagement in the social domain. However, Stephan et al. (2014) found no evidence of associations between Neuroticism and either mental or social activity in two large samples including adults of all ages. The present findings suggest that when directly assigned to an activity with presumed mental and social demands, older adults who score highly on the trait of Neuroticism tended to engage less. It may be that individuals high in Neuroticism, who are more likely to experience stress and negative affect (Lahey, 2009), reacted negatively to these demands and showed poorer adherence as a result. More robust evidence from future studies is necessary to support this theory.

Previous studies have found consistent evidence that individuals higher in Openness to Experience have a greater tendency to engage in mentally stimulating activities (Hultsch et al., 1999; Jackson et al., 2020; Soubelet & Salthouse, 2010). Indeed, results from Chapter 2 of this thesis indicated that participants who scored higher in Openness showed significantly higher everyday engagement in the Intellectual domain (which included activities typically thought to be mentally demanding). One might expect, therefore, that these participants would also show higher adherence to intervention activities that were selected to be mentally demanding (Creative and Language). No such associations were observed. It is possible that an important aspect driving cross-sectional associations between Openness and engagement is the act of an individual seeking out a novel, intellectually stimulating activity that appeals to them personally. Therefore, when the activity is selected for the individual, they may not feel such an affinity to it and therefore engage more with it.

Another possibility is that those willing to participate in a study designed around taking up a new activity were already particularly high in Openness, and thus the sample lacked individuals from the lower end of the scale necessary to fully investigate this association. There is some evidence to support this suggestion; the average Openness score for the recruited sample (120.6; see Chapter 5, Table 5.2) is roughly equivalent to the 72.6th percentile score in a representative sample of UK working age adults (McCrae et al., 2015). This indicates that Openness scores were slightly higher than would be expected on average in the present sample. A more representative sample would be beneficial for any future studies wishing to further examine any link between Openness and intervention adherence.

One factor that was related to intervention adherence across all activities was cognitive ability. Bivariate correlations between all nine composite scores from the WAIS-IV/WMS-IV and Percentage Adherence were positive and significant (although some became non-significant when adjusting for multiple comparisons). The fact that all cognitive domains were positively associated with adherence suggests the link may have been more domain-general than domain-specific. In other words, older adults who had higher levels of global cognitive ability attended a significantly greater proportion of class/group sessions. This is consistent with findings of other studies of intervention adherence (Coley et al., 2019; Lam et al., 2015). The fact that higher functioning individuals appear to adhere more closely to interventions targeted at age-related cognitive decline has important implications for the validity of results. It is possible that those who have lower levels of cognitive ability, and thus theoretically the most to gain from an intervention, are less likely to complete the protocol. Estimates of the 'true' effect of an intervention are therefore likely to be biased, as the only individuals who complete the full intervention regime constitute a rarefied sample of high-functioning older adults who are unrepresentative of the general population. These findings highlight the importance of examining adherence rates in a cognitive intervention, in addition to adherence or time-on-task being considered as a potential influence on any intervention-associated changes.

6.4.3. Limitations

As alluded to above, and noted in previous chapters, one limitation of the present study is the use of a volunteer, convenience sample. Convenience samples of older adults without cognitive impairment tend to be younger, more educated and have higher levels of cognitive ability than population-based samples (Brodaty et al., 2014). As such, the current sample is likely to be unrepresentative of the wider population. This may have been exacerbated further due to attrition; results showed that non-completers had significantly fewer years of education and lower scores across several cognitive domains, particularly memory ability.

The use of a self-report measure of adherence is also a limitation. Relying on participants to record their own adherence was a natural consequence of using existing classes and groups that the research team did not run. Because of this, if a participant failed to complete their time log, then their adherence to the activity was unknown. Even among those that did complete the time log, some participants may have failed to record their class/group attendance correctly, leading to under or over-estimation of adherence. The decision to impute class term duration as ten weeks when this was not recorded was derived from the majority of classes having run for ten-week terms. It is important to acknowledge that this could also have led to inaccurate estimates of adherence for some individuals when terms were actually longer or shorter.

Anecdotal evidence indicated that participants missed classes for various reasons, including illness, holidays or other prior engagements. Participants were not required to record specific reasons for missing class/group sessions, and therefore important data that could explain lower adherence was not available. It is possible that being able to statistically control for these predictors would have influenced estimates for other variables, including personality traits. Future studies should therefore consider recording reasons for absence to include as predictors of adherence.

6.4.4. Conclusion

The goal of cognitive ageing intervention research is to inform activities to be taken up by older adults outside of a research context. However, there are likely to be many factors that could influence adherence to such interventions. The present study addressed the lack of research regarding the association between the Big Five personality traits and intervention attrition and adherence. Analyses examined whether completers and non-completers differed in personality trait scores, and whether trait scores were associated with percentage of sessions attended or amount of time spent in a real-world, activity-based intervention. Participants who withdrew from the study scored significantly lower on the trait of Agreeableness. There was little evidence of activity-specific links between any personality trait and intervention adherence, although lower scores on Neuroticism and Extraversion and higher scores on Openness to Experience may be linked to better adherence across all activities. There was evidence to suggest that older adults with higher levels of cognitive ability showed significantly higher adherence rates.

The issue of adherence remains an important and often overlooked aspect of intervention design, and this study is among the first to consider the importance of personality. It is only through understanding the determinants of adherence that researchers can encourage wider uptake of strategies to protect cognitive health in old age, by designing activities or the messaging around participation with those individual characteristics in mind. This is particularly important given the possibility that adherence level may well be linked to the size of any intervention-related cognitive change. This thesis will now explore further whether adherence or any other factors, particularly personality traits, moderated cognitive change in the Intervention Factory.

Figure 6.1

Average Percentage Adherence Across Intervention Groups

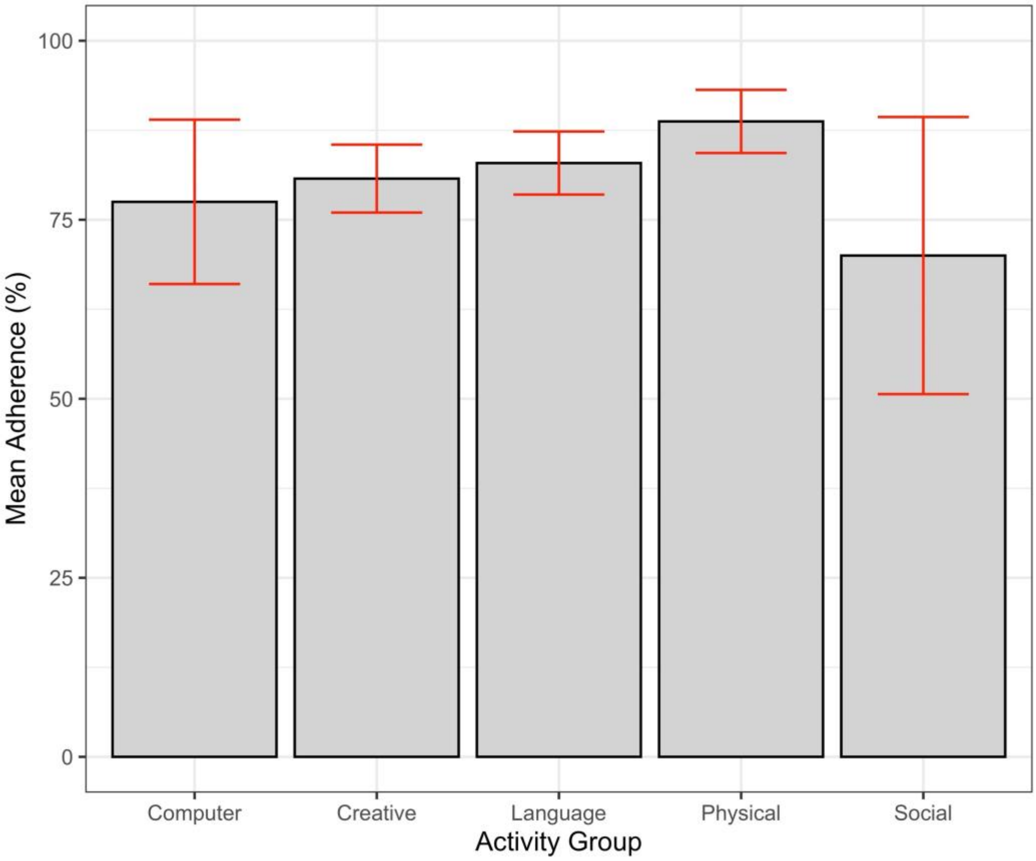
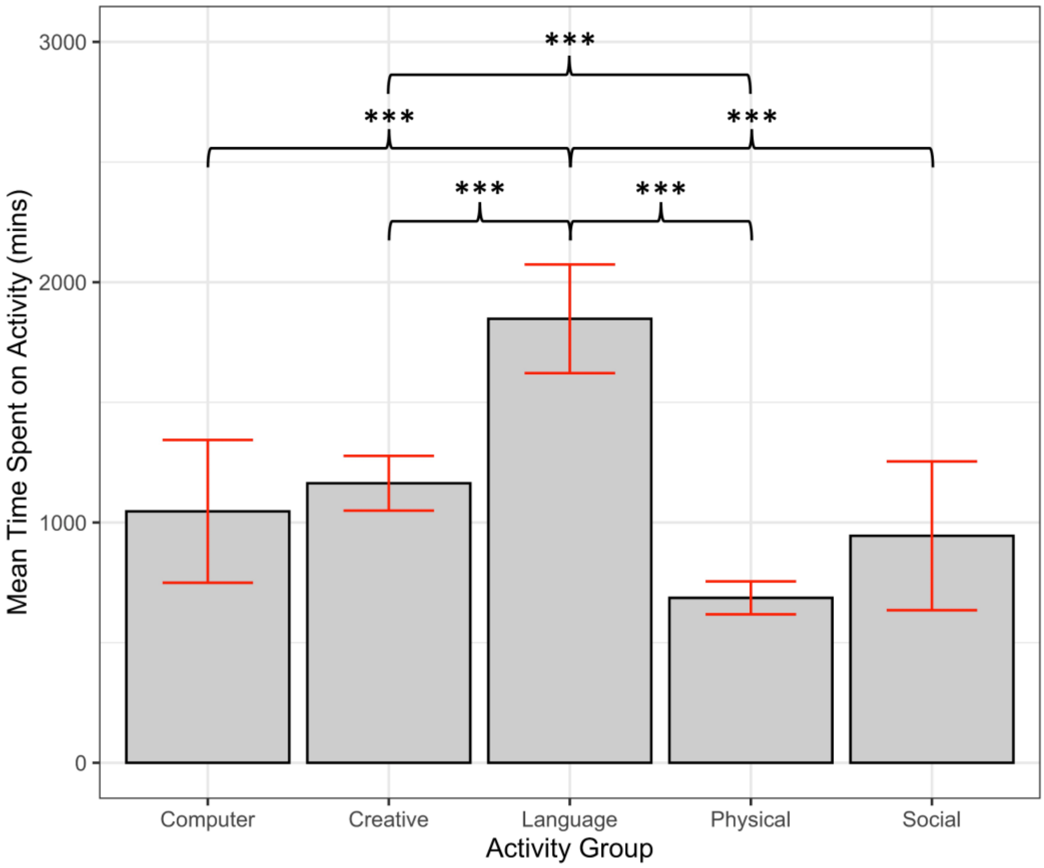


Figure 6.2

Average Time Spent on Activity Across Intervention Groups



Note. Brackets indicate significant group differences.

****p* < .001.

Table 6.1

Comparisons Between Completers and Non-Completers

Variable	Completers							Non-completers								
	Valid N	Mean (SD)	SE	Min	Max	Skew	Kurtosis	Valid N	Mean (SD)	SE	Min	Max	Skew	Kurtosis	*t*	df
Age	302	71.3 (5.3)	0.30	65.0	92.0	0.98	0.73	34	72.4 (6.5)	1.11	65.0	88.0	0.88	-0.32	-0.94	38.07
Years of Education	302	16.1 (3.4)	0.20	9.0	26.0	0.01	-0.41	34	13.8 (3.7)	0.64	9.0	23.0	0.61	-0.57	**3.38****	39.42
Deprivation	302	16.3 (4.5)	0.26	2.0	20.0	-1.25	0.62	34	15.8 (5.1)	0.87	4.0	20.0	-1.01	-0.35	0.51	39.07
Self-Rated Health	302	3.7 (0.9)	0.05	1.0	5.0	-0.46	-0.08	34	3.5 (1.1)	0.19	1.0	5.0	-0.28	-0.85	1.34	38.20
SPPPB	302	11.2 (1.5)	0.09	0.0	12.0	-3.51	17.04	34	10.9 (2.0)	0.34	2.0	12.0	-2.84	9.41	-	-
HADS Anxiety	302	4.9 (3.0)	0.17	0.0	15.0	0.58	0.01	34	5.9 (3.4)	0.58	0.0	14.0	0.35	-0.65	-1.70	39.18
HADS Depression	302	2.9 (2.1)	0.12	0.0	10.0	0.76	0.00	34	3.6 (2.6)	0.44	0.0	9.0	0.83	-0.18	-1.67	38.06
MET-minutes per week	283	2700.0 (2384.7)	141.76	0.0	13545.0	1.80	4.16	25	2166.3 (2263.3)	452.66	0.0	10158.0	1.95	3.89	1.13	28.92
BMI	300	27.3 (4.7)	0.27	16.7	53.0	1.29	4.02	34	27.7 (5.4)	0.92	16.4	38.3	0.16	-0.74	-0.46	39.02
Neuroticism	293	81.8 (22.2)	1.30	21.0	158.0	0.30	0.40	29	82.6 (24.8)	4.61	28.0	122.0	-0.45	-0.84	-0.16	32.57
Extraversion	290	102.3 (17.5)	1.03	48.0	146.0	-0.32	0.16	27	103.1 (16.1)	3.09	75.0	134.0	-0.16	-1.09	-0.23	32.05
Openness to Experience	295	121.0 (16.7)	0.97	67.0	174.0	-0.06	0.19	28	116.3 (17.5)	3.31	80.0	148.0	0.09	-0.73	1.37	31.84
Agreeableness	293	131.7 (15.8)	0.92	79.0	178.0	0.00	0.25	29	124.6 (14.2)	2.63	92.0	158.0	-0.20	0.14	2.56*	35.26
Conscientiousness	292	112.5 (17.9)	1.05	59.0	152.0	-0.27	-0.30	27	120.2 (22.8)	4.40	84.0	166.0	0.16	-0.97	-1.71	29.02
MMSE	302	28.9 (1.1)	0.06	24.0	30.0	-1.40	2.70	34	28.1 (1.9)	0.33	23.0	30.0	-1.08	0.25	2.57*	35.50
CDT	287	5.1 (1.3)	0.08	0.0	6.0	-1.62	2.40	33	4.8 (1.4)	0.24	1.0	6.0	-0.93	0.06	1.26	39.28
Full Scale IQ	301	109.3 (11.6)	0.67	72.0	141.0	-0.17	0.18	34	101.6 (16.3)	2.79	72.0	135.0	0.01	-0.80	2.69*	36.92
Verbal Comprehension	302	109.2 (10.9)	0.63	74.0	138.0	-0.10	0.16	34	100.9 (15.8)	2.71	66.0	134.0	-0.15	0.25	3.00**	36.64
Perceptual Reasoning	302	105.0 (13.2)	0.76	75.0	136.0	0.17	-0.54	34	96.8 (14.3)	2.45	77.0	140.0	0.85	0.64	3.20**	39.58
Working Memory	296	111.4 (13.0)	0.76	74.0	145.0	-0.11	-0.25	33	106.9 (18.7)	3.25	71.0	142.0	-0.25	-0.99	1.35	35.53

Variable	Completers							Non-completers							t	df
	Valid N	Mean (SD)	SE	Min	Max	Skew	Kurtosis	Valid N	Mean (SD)	SE	Min	Max	Skew	Kurtosis		
Processing Speed	301	105.0 (12.5)	0.72	68.0	137.0	-0.14	-0.26	34	102.6 (14.4)	2.48	79.0	127.0	-0.06	-1.52	0.95	38.75
Auditory Memory	291	118.2 (14.2)	0.83	62.0	146.0	-0.76	0.61	30	106.4 (17.1)	3.12	67.0	130.0	-0.61	-0.51	**3.66*** **	33.27
Visual Memory	298	99.5 (13.8)	0.80	50.0	135.0	-0.61	1.22	34	90.2 (15.5)	2.66	50.0	125.0	-0.26	0.08	**3.35****	39.17
Immediate Memory	291	115.1 (13.8)	0.81	75.0	145.0	-0.44	-0.12	30	104.1 (16.2)	2.95	67.0	129.0	-0.33	-0.72	**3.60****	33.47
Delayed Memory	287	110.6 (14.2)	0.84	49.0	146.0	-0.78	1.64	30	97.3 (18.1)	3.30	49.0	122.0	-0.89	0.20	**3.91*** **	32.85

Note. Scores compared using Welch's t-test. SPPPB = Short Portable Physical Performance Battery. HADS = Hospital Anxiety and Depression Scale. MET = metabolic equivalent of task. BMI = Body Mass Index. MMSE = Mini Mental State Examination. CDT = Clock Drawing Test. For descriptive purposes, comparisons that remain significant after Bonferroni correction (α = .05/25) are presented in **bold**.

*p < .05. **p < .01. ***p < .001

Table 6.2

Contingency Tables for Categorical Predictors of Completer-Status

	Completed study		Did not complete study		Total	
	N	%	N	%	N	%
Gender						
Male	92	30.5	10	29.4	102	30.4
Female	210	69.5	24	70.6	234	69.6
History of high blood pressure						
Yes	105	34.8	14	41.2	119	35.4
No	197	65.2	20	58.8	217	64.6
History of diabetes						
Yes	20	6.6	2	5.9	22	6.5
No	282	93.4	32	94.1	314	93.5
Current Smoker						
Yes	11	3.6	1	2.9	12	3.6
No	291	96.4	33	97.1	324	96.4
Total	302	100.0	34	100.0	336	100.0

Table 6.3

Descriptive Statistics for Adherence Variables

Variable	*N*	Mean (*SD*)	Min	Max	Skew	Kurtosis	*SE*
Activity Duration (Weeks)	261	9.9 (1.8)	5.00	14.00	0.49	1.65	0.11
No. of weeks attended	247	8.3 (2.6)	1.00	16.00	-0.41	0.62	0.17
% Adherence	247	82.6 (21.4)	7.14	100.00	-1.51	2.07	1.36
Time Spent (mins)	243	1186.9 (722.2)	20.00	4620.00	1.49	3.09	46.33

Table 6.4

Adherence Correlations

	% Adherence		Time Spent	
	Valid *N*	Coefficient	Valid *N*	Coefficient
Age	247	-.01	243	.11
Gender[a]	247	.05	243	-.08
Years of Education	247	.17**	243	.13*
Deprivation	247	.05	243	.07
Self-Rated Health	247	.11	243	.04
SPPPB	247	.05	243	-.05
MET-minutes per week	236	.04	233	.01
HADS Depression	247	.04	243	.03
History of Diabetes[b]	247	.02	243	.00
History of High Blood Pressure[b]	247	.00	243	.05
Current Smoker[b]	247	.02	243	-.06
BMI	245	.03	242	-.02
Neuroticism	238	-.05	235	-.08
Extraversion	236	-.10	233	-.06
Openness to Experience	241	.01	238	.09
Agreeableness	238	-.04	235	.05
Conscientiousness	237	-.07	234	.02
MMSE	247	.15*	243	.05
CDT	234	**.28*** **	230	.17**
Full Scale IQ	246	**.29*** **	242	.13*
Verbal Comprehension	247	.19**	243	.14*
Perceptual Reasoning	247	**.28*** **	243	.17**
Working Memory	241	.20**	237	.12
Processing Speed	246	.13*	242	-.08
Auditory Memory	238	.16*	234	.07
Visual Memory	244	.17**	240	.10
Immediate Memory	238	**.22*** **	234	.07
Delayed Memory	235	.13*	231	.09

Note. For all dichotomous variables (Gender, History of Diabetes, History of High Blood Pressure and Current Smoker), point-biserial correlations are presented. As SPPPB scores were highly non-normal, Kendall's τ is presented for correlations with this variable. For all other variables, Pearson's *r* is presented. For descriptive purposes, correlations that remain significant after Bonferroni correction are presented in **bold**.

[a] Coded as Male = 0, Female = 1. [b] Coded as No = 0, Yes = 1.

*p < .05. **p < .01. ***p < .001

Table 6.5

Multiple Regression Models with Personality Traits Predicting Percentage Adherence in the Creative, Language and Physical Groups

Predictor	*b*	*SE*	*t*	*p*
All Groups Combined				
(Intercept)	**137.22**	**22.73**	**6.04**	**<.001**
Neuroticism	**-0.17**	**0.08**	**-2.15**	**.033**
Extraversion	-0.14	0.09	-1.50	.136
Openness to Experience	0.07	0.09	0.74	.461
Agreeableness	-0.12	0.09	-1.31	.193
Conscientiousness	-0.16	0.10	-1.61	.109
Creative Group				
(Intercept)	**195.30**	**46.02**	**4.24**	**<.001**
Neuroticism	-0.23	0.15	-1.59	.115
Extraversion	-0.22	0.17	-1.32	.191
Openness to Experience	0.10	0.18	0.59	.559
Agreeableness	-0.36	0.20	-1.80	.076
Conscientiousness	-0.33	0.19	-1.79	.078
Language Group				
(Intercept)	**152.84**	**33.12**	**4.61**	**<.001**
Neuroticism	**-0.28**	**0.13**	**-2.13**	**.038**
Extraversion	0.04	0.13	0.30	.763
Openness to Experience	0.22	0.14	1.57	.124
Agreeableness	-0.21	0.16	-1.34	.187
Conscientiousness	**-0.43**	**0.19**	**-2.23**	**.031**
Physical Group				
(Intercept)	**104.57**	**28.15**	**3.71**	**<.001**
Neuroticism	-0.06	0.11	-0.56	.575
Extraversion	-0.10	0.12	-0.91	.369
Openness to Experience	-0.02	0.12	-0.17	.863
Agreeableness	-0.09	0.13	-0.67	.506
Conscientiousness	0.14	0.12	1.22	.230

Table 6.6

Multiple Regression Models with Personality Traits Predicting Time Spent in the Creative, Language and Physical Groups

Predictor	*b*	*SE*	*t*	*p*
All Groups Combined				
(Intercept)	1268.52	774.50	1.64	.103
Neuroticism	-4.69	2.78	-1.69	.093
Extraversion	**-6.66**	**3.10**	**-2.15**	**.033**
Openness to Experience	**8.10**	**3.23**	**2.51**	**.013**
Agreeableness	0.23	3.24	0.07	.944
Conscientiousness	-0.40	3.32	-0.12	.905
Creative Group				
(Intercept)	1739.74	1143.83	1.52	.132
Neuroticism	0.66	3.64	0.18	.857
Extraversion	-4.84	4.16	-1.16	.248
Openness to Experience	5.24	4.41	1.19	.239
Agreeableness	-6.64	4.96	-1.34	.184
Conscientiousness	0.96	4.65	0.21	.837
Language Group				
(Intercept)	**3932.93**	**1674.48**	**2.35**	**.023**
Neuroticism	**-14.78**	**6.74**	**-2.19**	**.033**
Extraversion	-5.02	6.82	-0.74	.466
Openness to Experience	11.46	7.21	1.59	.119
Agreeableness	-1.44	8.26	-0.17	.862
Conscientiousness	-14.37	9.83	-1.46	.150
Physical Group				
(Intercept)	461.17	559.83	0.82	.414
Neuroticism	-1.41	2.24	-0.63	.530
Extraversion	-4.63	2.35	-1.97	.054
Openness to Experience	**5.23**	**2.49**	**2.10**	**.041**
Agreeableness	0.94	2.58	0.36	.718
Conscientiousness	0.48	2.36	0.20	.840

7. Does Personality Moderate the Efficacy of a Real-World, Activity-Based Cognitive Ageing Intervention?

7.1. Introduction

The Intervention Factory study tested the potential cognitive benefits of a range of community-based activities in a sample of older adults. As described in Chapter 5, there was no evidence that those allocated to a new activity showed differential change to those in a no-contact control group. However, previous studies have suggested that not all participants experience the same degree of change. In particular, it may be that personality traits influence the degree of improvement experienced in a given cognitive ageing intervention (Finkel & Yesavage, 1989; Gratzinger et al., 1990; Stine-Morrow et al., 2014). The present chapter tests this theory within the Intervention Factory study by examining whether any group-specific cognitive changes were moderated by individual differences in personality.

7.1.1. The Moderating Effect of Personality

The systematic review presented in Chapter 4 (Marr et al., 2020) drew together the small body of literature that has tested whether personality traits might be associated with the efficacy of non-pharmacological interventions for age-related cognitive decline. The review identified ten highly heterogeneous studies that had tested the influence of personality, limiting the possibility of drawing wide ranging conclusions. Regarding the Big Five traits, two mnemonic training interventions (Finkel & Yesavage, 1989; Gratzinger et al., 1990) and one engagement-based intervention (the Senior Odyssey group-based competitive problem solving programme; Stine-Morrow et al., 2014) found that higher scores on Openness to Experience (or a facet of Openness) were associated with greater improvements in cognitive performance. The only other study to find any effects of Big Five personality traits was a social engagement intervention involving structured daily conversations over video chat (Cerino et al., 2020). This study found that higher Conscientiousness and Agreeableness were associated with greater improvements, while higher Extraversion was associated with greater improvements on some tests, and smaller improvements on others. Results from two other cognitive training studies, one training multiple domains (Gajewski & Falkenstein, 2012) and the other focused on working memory (Guye et al., 2017), showed no evidence of associations between any Big Five traits and intervention-related cognitive change.

The present study is, to this author's knowledge, the first to examine whether personality moderates the efficacy of an intervention involving novel activity engagement in a community setting. If results suggest that certain personality trait scores predispose individuals to benefit more from a specific activity, then this information can be used to tailor more effective interventions by directing people to the activity that would have the greatest benefit for them. Similarly, if certain trait scores were linked to smaller benefits, this could help to identify individuals who may require more support, perhaps by adapting intervention protocols to their needs. Tailoring interventions according to individual personality traits has been highlighted as an important consideration for future research (Chapman et al., 2014).

The Intervention Factory presents an opportunity to test a more person-centred approach by exploring these potential personality effects across a range of different activities. Given the dearth of previous research regarding the moderating effect of personality on engagement-based interventions, no specific hypotheses were proposed; rather, all possible moderating effects were considered. However, the systematic review in Chapter 4 found some evidence that Openness to Experience was associated with greater improvements in interventions that required participants to engage in somewhat novel activities (e.g., a mnemonic strategy that involved using one's imagination, or a competing in groups to solve novel problems; Gratzinger et al., 1990; Stine-Morrow et al., 2014). Given that the present intervention also involved novel activity engagement, one might expect the same facilitating effect of Openness in the present study.

7.1.2. Other Potential Moderators

Age. There is evidence that age can influence the efficacy of cognitive ageing interventions, though cognitive training studies have provided mixed results. Some studies have reported negative associations between participant age and training-related cognitive improvements (Borella et al., 2014; Verhaeghen et al., 1992; Zinke et al., 2014), suggesting that the oldest adults appear to benefit less from these interventions. However, there is also evidence that age is positively linked to training-related gains (Nguyen et al., 2019), while other studies have found no evidence of a moderating effect of age (Guye et al., 2017). Several explanations have been offered to explain why older adults have been found to improve less in certain training interventions. Verhaeghen et al. (1992) posited that age-related reductions in processing capacity (e.g., processing speed and/or working memory capacity) that are more severe among the oldest adults could limit their ability to acquire and apply strategies learned during training. Where older adults improve more, it has been suggested that this may be due to older adults' lower baseline performance providing greater potential for improvement than younger adults (Nguyen et al., 2019; Toril et al., 2014).

There is some evidence that older participants benefit less from engagement-based interventions. For example, results from the Senior Odyssey study (Stine-Morrow et al., 2014) showed a negative association between age and improvement in divergent thinking among those who were allocated to a group-based problem solving programme. To date, no studies have examined whether the oldest adults respond differently to interventions that involve the learning of a new skill or activity. Alongside the effects of individual differences in personality, understanding whether age predicts cognitive change within an activity-based intervention is particularly important in establishing whether interventions are more effective when delivered earlier or later in older age.

Baseline cognitive status. There is some evidence that lower cognitive ability at baseline (i.e., pre-intervention) is also associated with less cognitive improvement in cognitive training interventions (Bissig & Lustig, 2007; Hill et al., 1989; Langbaum et al., 2009; Matysiak et al., 2019; Stine-Morrow et al., 2014). In other words, these findings suggest that higher functioning individuals show greater training-related gains. This may be because individuals with lower baseline function have less capacity for improvement due to slower speed of processing or poorer initiation of effortful controlled processing (Bissig & Lustig, 2007; Langbaum et al., 2009). However, other studies have found that lower ability predicts greater training-related gains (Langbaum et al., 2009; Roheger et al., 2020), possibly because those who are already high-functioning at baseline have less room for improvement (Lövdén et al., 2012).

Few studies have examined the moderating role of baseline cognitive ability in engagement-based interventions, and current findings are mixed. In the Experience Corps project (Carlson et al., 2008), researchers stratified their sample by baseline executive function (based on scores on the Trail Making Test part B, the sample was divided in to ‘impaired’ [those with scores in the lowest tertile] and ‘unimpaired’ [all other participants]). Results suggested that those in the ‘impaired’ group showed greater improvements in executive function and memory performance, again suggesting that interventions may be more effective among those with the most to gain. Stine-Morrow et al. (2014) found that baseline global cognitive status was positively correlated with improvement in divergent thinking among those in the Senior Odyssey programme. This suggests that those who were higher functioning at baseline improved more. However, they also found that baseline level of verbal ability was negatively correlated with improvement, suggesting that those with lower levels of verbal ability improved more. The authors suggested that the positive association between global cognitive ability and change reflects the fact that those with higher baseline ability may have more capacity for cognitive plasticity, and as such benefit more. The negative association between verbal ability and change may be because those with lower verbal ability have less accumulated knowledge due to less prior exposure to mentally enriching environments, thus the mental stimulation from the intervention had a compensatory effect for these individuals (Stine-Morrow et al., 2014).

There is a clear need to examine exactly how baseline cognitive ability could influence individual differences in the benefits gained from engagement-based interventions. This is a particularly important area of investigation to ensure that interventions are effective for those who have the most to gain (i.e., those who have lower cognitive function at baseline). If it is the case that only those who are already high functioning seem to benefit, then this suggests additional strategies may be necessary to help those with lower baseline cognitive function gain more from an intervention.

7.1.3. The Present Study

Evidence suggests that the effects of engagement-based interventions for age-related cognitive decline are not uniform across individuals. The present study goes beyond testing the broader efficacy of a real-world, activity-based intervention, and examines whether individual factors might influence intervention effects. As described previously, a sample of adults aged 65 and over without any diagnosed cognitive impairment was recruited; participants were allocated to one of six groups (five activity groups, and one no-contact control group). The primary aim was to examine whether improvements in any of the activity groups were moderated by individual differences in Big Five personality traits, as well as age and baseline cognitive status. Although no significant intervention effects were observed (i.e., none of the activity groups improved more than controls for any cognitive outcome; see Chapter 5), it is still possible that group-specific improvements may have varied according to the hypothesised moderators. For example, if those in the Language group with high Conscientiousness improved more than the Control group, and those in the Language group with low Conscientiousness improved less, then then the overall change in the Language group across all individuals might average out to equal that of the Control group. In this hypothetical case, there was a meaningful improvement only among those participants with high Conscientiousness, but this is masked when considering the group as a whole. The moderator analyses conducted were exploratory; given the lack of previous research regarding the moderating effects of personality and the mixed findings regarding the moderating effects of age and baseline cognitive status, no directional hypotheses were made.

Activity groups were selected for the Intervention Factory based on perceived levels of mental, physical and social demand. This was determined via ratings provided by older adults and experts in the field of cognitive ageing. However, given the broad range of classes and groups utilised in this study, it is likely that the actual demands that participants experienced varied substantially even within a specific intervention group. Therefore, an additional supplementary aim of the present study was to examine whether participants' subjective ratings of the mental, physical and social demands of their allocated activity may have predicted changes in cognitive performance regardless of group allocation. It is also possible that personality traits might moderate the association between subjective demands and cognitive change. Previous studies that found a moderating effect of Openness to Experience were all designed to be predominantly mentally stimulating (Finkel & Yesavage, 1989; Gratzinger et al., 1990; Stine-Morrow et al., 2014); another study found that Extraversion, Agreeableness and Conscientiousness all moderated the efficacy of an intervention designed to be predominantly socially stimulating (Cerino et al., 2020). Analysis therefore also examined whether Openness moderated the association between subjective mental demand and cognitive change, and whether Extraversion, Agreeableness and Conscientiousness moderated the association between subjective social demand and cognitive change. These analyses considered changes in all cognitive outcomes and no domain-specific hypotheses were made.

7.2. Methods

7.2.1. Participants

The recruited sample (N = 336) has been fully described previously (see Chapter 2, section 2.2.1, and Chapter 5, Table 5.2). Analyses presented in this chapter include only study completers (N = 302), excluding all participants who withdrew from the study following their baseline assessment. Descriptive statistics for study completers and non-completers were provided in Chapter 6 (Table 6.1).

7.2.2. Design and Procedure

As described previously, the Intervention Factory adopted a pseudo-randomised controlled trial design. Participants first completed a baseline assessment, which comprised a battery of cognitive tests, physical tests and a personality questionnaire. Participants were then allocated to a novel activity class/group in one of five intervention conditions (Computer, Physical, Social, Language or Creative) or a no-contact Control group. For full details of activities and the allocation process, refer to Chapter 5, section 5.2. Participants attended their class/group for a period of around ten weeks, then returned to complete a follow-up assessment, during which they repeated all cognitive tests.

7.2.3. Materials and Measures

Primary Outcomes. Primary outcome variables were composite scores from the Wechsler Adult Intelligence Scale (4th [UK] edition; WAIS-IV; Wechsler, 2010a): Full

Scale IQ, Verbal Comprehension, Perceptual Reasoning, Working Memory and Processing Speed; and the Wechsler Memory Scale (4th [UK] edition [Older Adult Battery]; WMS-IV; Wechsler, 2010b): Auditory Memory, Visual Memory, Immediate Memory and Delayed Memory. Test administration and scoring were previously described in Chapter 2, section 2.2.2 and Chapter 5, section 5.2.6.

Moderator Variables. Potential moderators considered were personality traits, age (in years), and baseline cognitive status. Scores on each of the Big Five personality traits (Neuroticism, Extraversion, Openness to Experience, Agreeableness and Conscientiousness) were measured at baseline using the UK edition of the NEO-Personality Inventory 3 (NEO-PI-3; McCrae et al., 2015; see Chapter 2, section 2.2.2 for more details). Baseline global cognitive status was measured using the Mini-Mental State Examination (MMSE; Folstein et al., 1975). MMSE scores can range from 0-30, with lower scores indicating potential cognitive impairment (a full description of the test is given in Chapter 2, section 2.2.2).

Adherence. Intervention adherence was measured in two ways, as described in Chapter 6 (section 6.2.3). Percentage Adherence measured the percentage of activity class/group sessions attended (number of weeks attended / total number of weeks x 100). Time Spent measured the total number of minutes participants reported engaging in their activity, both in and out of formal class/group sessions.

Subjective Activity Ratings. At the end of the intervention period, participants provided subjective ratings of the mental, physical and social demands of their new activity. The subjective ratings were collected via a short questionnaire in which participants indicated what activity they had engaged in, and rated how mentally, physically and socially demanding they found the activity to be on a scale from 0 (not demanding) to 10 (highly demanding).

The subjective ratings were collected as part of a larger series of questionnaires participants completed prior to their follow-up assessment (the fuller questionnaires included measures of quality of life and wellbeing not considered here). Participants had previously completed these other questionnaires at baseline. Participants were either emailed a link to complete the questionnaire online or sent a paper copy in post according to their preference. Those participants recruited specifically to be no-contact controls did not provide any ratings as they did not engage in a new activity.

7.2.4. Statistical Analysis

Missing Data. Missing data rates for cognitive outcomes, personality trait scores, age and MMSE score were presented in Appendix I. Missing data rates for adherence measures were presented in Appendix M. Across all outcomes and possible moderators, the total missing data rate for the full sample was 7.3% (686 cells missing out of 9,408 [28 variables across 336 participants]). The missing data rate excluding those who withdrew from the study was 3.0% (253 cells missing out of 8,456 [28 variables across 302 participants]). Missing data rates were the same for each of the three subjective activity ratings (79 missing out of 336 [23.5%]; when excluding study non-completers and the Control group: 6 missing out of 261 [2.3%]). As in previous chapters, missing data was handled using case-wise deletion.

Moderators. Analysis of potential moderator effects was done by extending the modelling approach used to test for intervention effects in Chapter 5 (see section 5.2.7). Moderator effects were examined with additional exploratory linear mixed models, testing for the presence of a Time x Group x Moderator interaction effect (Wang et al., 2007). As in Chapter 5, models were built hierarchically, specified with by-subject random intercepts and maximum likelihood estimation was used. Models were estimated using the lme4 package in R (Bates et al., 2015). As including all possible moderators and their interactions would result in a model with a prohibitively large number of parameters, an initial analysis step was conducted to explore which moderators were related to cognitive change in each cognitive outcome, and thus should be tested in the final models. Bivariate correlations were computed to examine whether the proposed moderators (personality traits, age and baseline cognitive status) were associated with variables that quantified change in score for each cognitive outcome from pre- to post-intervention. Separate correlations were calculated within each individual intervention group. Significant correlations were not interpreted, but rather used to identify potential moderators to be tested in linear mixed models (for this reason, *p*-values of the correlation coefficients were not adjusted for multiple tests at this stage). If there was a significant correlation, then models were constructed for the relevant cognitive outcome, including Time, Group, the potential moderators and all possible interactions as predictors. Where there were missing data for the moderator, this necessitated running the model on a reduced sample size (participants with missing data excluded), and therefore these models should be considered exploratory and interpreted with caution. As before, *p*-values in the full model were adjusted using the Benjamini-Hochberg correction.

Subjective Activity Ratings. Additional supplementary analyses examined whether subjective ratings of mental, physical and social demands predicted cognitive changes among all participants who engaged in a new activity (excluding the Control group as no subjective ratings were possible). Analyses examined whether these subjective ratings differed between intervention groups using between-groups ANOVA and post-hoc pairwise comparisons. Hierarchical regression was used to examine whether subjective ratings predicted cognitive change regardless of group allocation. Separate models were constructed for each cognitive outcome. In an initial step, age, baseline MMSE score, activity adherence, assessment interval and personality traits were added as predictors, then in the second step the three subjective ratings were added, then in the third step the hypothesised interactions between personality traits and subjective ratings were included. At each step changes in model fit were examined.

7.3. Results

7.3.1. Moderators

Correlations between cognitive change in each outcome and age, baseline MMSE score, personality traits and intervention adherence measures[7] are presented in Table 7.1. Due to the small number of participants in both the Computer (N = 16) and Social group (N = 14), correlation significance tests are reported but not interpreted; only potential moderators of change in the Creative, Language and Physical groups were tested for inclusion in the linear mixed models.

Among participants in the Control group, age was significantly negatively correlated with change in both Full Scale IQ score, r = -.41, p < .01, and Working Memory score, r = -.45, p < .01; for those who did not engage in any new activity, older adults improved less in global cognitive ability and working memory performance. Baseline MMSE score was significantly positively correlated with change in Auditory Memory score in the Control group, r = .34, p < .04; those with higher baseline cognitive status improved more. Neither age nor baseline MMSE score were significantly correlated with cognitive change in the Creative, Language or Physical groups.

Extraversion was significantly negatively correlated with change in Perceptual Reasoning score in the Creative group, r = -.23, p < .05, and change in Delayed Memory score in the Physical group, r = -.28, p < .05. Openness to Experience was significantly positively correlated with change in Perceptual Reasoning score in the Control group, r = .38, p < .05, and change in Immediate Memory score in the Physical

[7] Correlations between Percentage Adherence/Time Spent and change in each cognitive outcome are reported for descriptive purposes, but could not be included as a moderator in the linear mixed models because adherence data was not recorded for those in the Control group who did not attend a new activity.

group, $r = .29$, $p < .05$. Agreeableness was negatively correlated with change in Immediate Memory score in the Physical group, $r = -.29$, $p < .05$. Conscientiousness was significantly positively correlated with change in three memory component scores in the Language Group (Visual Memory, $r = .29$, $p < .05$; Immediate Memory, $r = .34$, $p < .05$; Delayed Memory, $r = .37$, $p < .01$) but negatively correlated with change in Immediate Memory score in the Physical group, $r = -.33$, $p < .01$. Neuroticism was not significantly correlated with cognitive change in the Creative, Language, Physical or Control group.

In the Creative group, Percentage Adherence was positively correlated with change in Full Scale IQ score, $r = .23$, $p < .05$, Perceptual Reasoning score, $r = .21$, $p < .05$, and Immediate Memory score, $r = .21$, $p < .05$. Conversely, Percentage Adherence was negatively correlated with change in Perceptual Reasoning score in the Language group, $r = -.27$, $p < .05$. Time Spent was positively correlated with change in Delayed Memory score in the Creative group, $r = .26$, $p < .05$.

In summary, there was some evidence that for Perceptual Reasoning, Extraversion could have moderated change in the Creative group. For Visual Memory, there was evidence that Conscientiousness could have moderated change in the Language group. For Immediate Memory, there was evidence that Conscientiousness could have moderated change in the Language group and that Conscientiousness, Agreeableness and Openness to Experience could have moderated change in the Physical group. For Delayed Memory, there was evidence that Extraversion could have moderated change in the Physical group, and that Conscientiousness could have moderated change in the Language group. These potential moderating effects were therefore further tested using exploratory linear mixed models.

For the model examining the moderating effect of Extraversion on improvements in Perceptual Reasoning in the Creative group, results showed that the addition of the three-way Time x Group x Extraversion interaction significantly improved model fit (Table 7.2). Parameter estimates for the full model are presented in Table 7.3. The estimate for the Time x Group (Creative) x Extraversion interaction can be interpreted as testing whether the intervention effect in the Creative group (i.e., the difference in cognitive change between the Creative and Control groups) varied according to Extraversion score. This interaction was initially significant; the parameter estimate was negative, indicating that for those who scored lower on Extraversion, improvements in the Creative group were greater than the Control group, but this difference in performance change decreased for those who scored higher in Extraversion. However, this estimate became non-significant when adjusted for multiple comparisons, $b = -0.22$, $t(288.66) = -2.55$, $p < .05$, adjusted $p = .054$. Therefore, the results did not support a moderating effect of Extraversion in the Creative group.

The estimate for the Time x Group (Social) x Extraversion interaction was significant, $b = -0.54$, $t(288.21) = -3.09$, $p < .01$, adjusted $p < .05$. The parameter estimate was negative, indicating that the difference in change over time between the Social and the Control group was smaller for those who scored higher in Extraversion. In other words, while those in the Social group who were less extraverted showed greater improvements than the Control group, this between-group difference decreased for those who were more extraverted (for a visual depiction of this effect, see Appendix N). However, given the number of participants in the Social group, it is likely that this estimate could be disproportionately influenced by a small number of individuals, and therefore this effect should be interpreted with caution.

For the model examining the moderating effects of Openness, Agreeableness and Conscientiousness on improvements in Immediate Memory, only the addition of the Time x Group x Conscientiousness interaction improved model fit (see Table 7.4). Two potential moderating effects of Conscientiousness were tested: in the Language group and the Physical group. As shown in Table 7.5, the Time x Group (Language) x Conscientiousness interaction was initially significant; the parameter estimate was positive, suggesting the difference in change between the Language and the Control group was greater for those who scored higher in Conscientiousness. However, the estimate became non-significant when adjusted for multiple comparisons, $b = 0.20$, $t(271.02) = 2.02$, $p < .05$, adjusted $p = .536$. The Time x Group (Physical) x Conscientiousness interaction was not significant, $b = -0.09$, $t(270.42) = -0.92$, $p = .358$, adjusted $p = .878$. Therefore, there was no evidence of any moderating effects of personality traits on improvement in Immediate Memory.

There was no evidence that Conscientiousness moderated improvement in Visual Memory in the Language group; the addition of the Time x Group x Conscientiousness interaction did not improve model fit (see Table 7.6), and the parameter estimate for the Time x Group (Language) x Conscientiousness was not significant, $b = 0.17$, $t(284.92) = 1.67$, $p = .095$, adjusted $p = .915$ (see Table 7.7). There was also no evidence that Extraversion moderated improvements in Delayed Memory in the Physical group, nor that Conscientiousness moderated improvements in Delayed Memory in the Language group. Addition of the three-way interactions did not improve model fit (see Table 7.8), and parameter estimates for the group-specific contrasts were non-significant (Time x Group [Physical] x Extraversion: $b = -0.13$, $t(265.68) = -1.39$, $p = .165$, adjusted $p = .660$; Time x Group [Language] x Conscientiousness: $b = 0.26$, $t(268.26) = 2.65$, $p < .01$, adjusted $p = .153$; see Table 7.9).

7.3.4. Subjective Activity Ratings.

Descriptive statistics for the subjective ratings of mental, physical and social demands across all participants who engaged in a new activity are presented in Appendix O. Comparisons of average ratings of demands between intervention groups are presented in Appendix P and Appendix Q. Significant between-group differences were found for all three ratings. Post-hoc pairwise comparisons revealed that participants in the Language group rated their activity as significantly more mentally demanding than those in each of the other groups, and that those in the Creative group rated their activity as significantly more mentally demanding than those in the Social group. For physical demands, ratings were significantly higher in the Physical group compared to each of the other groups and also significantly higher in the Creative group compared to the Computer, Language and Social groups. For ratings of Social demands, the only significant difference was between the Language and the Physical group, with the Language group rating social demands higher.

Results of hierarchical regression models examining whether subjective ratings predicted change in cognitive test scores are presented in Appendix R. Across all cognitive outcomes, there was no evidence that mental, physical or social demands predicted cognitive change among those who engaged in a new activity when accounting for age, baseline cognitive status, Percentage Adherence, assessment interval and personality traits. The only outcome in which one of the predicted Personality x Subjective Rating interactions was significant was Working Memory: the interaction between Conscientiousness and social demands was significant for this outcome, indicating that the positive association between subjective social demands and change in Working Memory decreased as Conscientiousness score increased. In other words, more conscientious individuals improved less in Working Memory when the social demands of their activity were higher. However, the addition of the hypothesised interactions did not significantly improve the fit of the regression model, meaning this effect must be interpreted with caution.

7.4. Discussion

The question of who benefits most from a given intervention is important and, in the field of cognitive ageing, remains largely unexplored. While establishing evidence of broad improvement across a target population is essential in the design of effective public health interventions, it is also possible that individual characteristics, such as personality traits, might influence the magnitude of any such improvement. The present study examined this possibility in the context of a novel, community-based activity intervention for age-related cognitive decline. A sample of volunteer participants over the age of 65 were recruited and allocated to either a novel activity class/group in their local community or to a no-contact control group. Analyses examined whether intervention-related changes in cognitive performance varied according to individual personality traits, age and baseline cognitive status. Results showed little evidence that any of the proposed moderators influenced intervention-related cognitive change.

7.4.1. Moderators

Regarding the moderating effect of age, there was no evidence that age was associated with cognitive change in any of the activity groups. This finding differs from a previous engagement-based intervention which found a negative association between age and intervention-related change after a group-based competitive problem solving programme (Stine-Morrow et al., 2014). While the age range of the present study included adults from age 65 to 92, the majority were towards the younger end of this range (only 83 participants aged 75 or over were recruited out of a total of 336 [24.7%]). It is possible that the sample simply did not include enough 'old-old' adults to determine if age moderates intervention efficacy. When all activity groups were considered collectively, there was a significant negative association between age and improvement in Full Scale IQ score. This model did not, however, account for a significant proportion of the variance in Full Scale IQ change, so the negative association between age and Full Scale IQ change should be interpreted cautiously. While this association may indicate that the oldest adults improve less in global cognitive ability when taking up a new activity regardless of what the activity is, it may also simply reflect smaller practice effects in older adults, an effect that has been found previously (Calamia et al., 2012). This is supported by the negative correlation between age and Full Scale IQ change in the Control group, who did not engage in any new activity.

There was also no evidence that baseline cognitive status (as measured by MMSE score) was associated with intervention-related cognitive change. As with the effects of age, the ability of the present study to examine this relationship was likely limited due to lack of variability in the sample. Most of the participants scored towards the top of the scale, suggesting that the sample largely comprised high-functioning individuals. The present findings do not preclude the possibility that intervention effects may have differed among those with lower baseline status; the current sample did not include enough such individuals to fully investigate this question. Future research could examine the possible benefits of community-based activities in those who have already experienced a degree of accelerated cognitive decline (e.g., people with mild cognitive impairment).

Regarding the possible moderating effects of personality traits, the present study did not begin with concrete hypotheses due to the lack of published research on the subject. Exploratory analyses examined group specific correlations between personality traits and cognitive change in each outcome. Few significant correlations were found, and there was little conceptual evidence to suggest that these occurred due to anything other than chance (none of the observed moderator-change correlations were significant if adjusted for multiple tests using a Bonferroni correction). The only somewhat consistent finding was that Conscientiousness was positively correlated with change in memory performance in the Language group, as measured by scores in Visual Memory, Immediate Memory and Delayed Memory. Given that more conscientious individuals tend to be more organised and diligent, one might expect that they apply themselves more to learning a new language and therefore gain greater benefits from it. This would be considered a novel finding – as indicated in Chapter 4, no previous studies have examined the moderating effect of personality in an intervention involving language learning. However, when possible moderator effects were tested, the three-way interaction between Time, Group and Conscientiousness was not significant for any of the outcomes. In other words, there was no evidence that Conscientiousness predicted the *difference in performance change* between the Language and the Control group (i.e., the actual estimate of intervention efficacy).

Previous research suggested that because of the novel nature of the intervention, those who scored higher on Openness to Experience may receive greater benefits (see Chapter 4; Marr et al., 2020). However, no such effect was found; Openness to Experience did not moderate cognitive improvement in any of the intervention groups for any outcome. As discussed in Chapter 5, the fact that the intervention involved trying something new may have discouraged those who scored lower in Openness from volunteering to take part, thus limiting the possibility of fully observing the effect of this trait.

A significant moderating effect of Extraversion on change in Perceptual Reasoning in the Social group was observed; those who scored lower in Extraversion improved more than the Control group, while those who scored higher improved less. This effect is interpreted cautiously due to the small number of participants in the Social group and the fact that the model was estimated on a reduced sample (excluding those missing Extraversion scores). It is possible that those who were more extraverted appeared to benefit less in the Social group because they already had an active social life (Stephan et al., 2014) and therefore the additional social engagement from a social club did not make much difference. Conversely, those who were less extraverted may not have been as socially active, and thus benefitted more from the supported social interaction. More robust future evidence will be necessary to support this suggestion.

7.4.2. Subjective Ratings

The present study also examined whether changes in cognitive performance were related to subjective ratings of mental, physical and social engagement. Results showed that across all cognitive outcomes, there was no evidence that participant's perceived level of mental, physical or social demands of their activity influenced change in performance. Cross-sectional and longitudinal studies have reported associations between engagement in mentally, physically and socially demanding activities and both higher cognitive ability in older age and reduced cognitive decline (Blondell et al., 2014; Kuiper et al., 2016; Opdebeeck et al., 2016). This has led researchers to suggest that engagement in these types of activity may have a protective effect on cognition in older age. Here, however, results suggested that when given the opportunity to increase their level of activity engagement, participants' change in cognitive performance was unrelated to how mentally, physically or socially engaging they felt those activities were. There may be other important aspects to activity engagement that influence any beneficial effect. For example, in previous cross-sectional work, participants reported their engagement in activities that they chose to do in their everyday lives and presumably enjoyed. Here, however, participants were allocated to their activity, and although they may have found the activity demanding, this does not necessarily mean they enjoyed it and/or fully engaged with it. This could explain why demand itself was not a predictor of change here. In addition, and as noted earlier, that the activities considered here were 'real' might have limited the degree of demand they provided. Future studies may therefore explore specific activities but manipulate the level of difficulty and challenge. That is, compare activity groups offering a spectrum of engagement, from the 'real' (and likely low) levels explored currently to the higher expectations of, for example, the Synapse study (which, as discussed in Chapter 6, offered a much higher degree of weekly engagement; Park et al., 2014).

Analyses also examined whether personality traits moderated any change due to subjective level of engagement. Despite previous evidence that Openness to Experience might be related to greater gains in interventions designed to be mentally stimulating (Finkel & Yesavage, 1989; Gratzinger et al., 1990; Stine-Morrow et al., 2014), there was no evidence that Openness moderated the association between subjective mental demand and improvement in cognitive performance. The only evidence that personality may have moderated the association between subjective demands and cognitive change was in the domain of working memory; the association between subjective social demand and change in Working Memory score decreased with higher Conscientiousness. A previous intervention designed to be socially stimulating found no evidence that Conscientiousness had a moderating effect on improvement in working memory (as measured by performance on the n-back test; Cerino et al., 2020). It is difficult to speculate why engaging in a socially demanding activity might be particularly beneficial for those who score lower in Conscientiousness. As discussed above, given the fact that the addition of this effect did not significantly improve model fit, it is possible that the significance of the individual parameter is simply due to chance.

7.4.3. Limitations

As discussed previously (see Chapter 5, section 5.4.1 and Chapter 6, section 6.4.3), there are several limitations to the approach adopted in the Intervention Factory, including sampling, design and intervention implementation. Regarding the analysis of any potential moderating effects, a pertinent limitation is the variability in individuals' experience of their activity. To examine whether individual differences such as personality traits moderate the efficacy of a specific activity, it is important that the activity is delivered consistently across individuals. In the present study, there were numerous contextual factors that may have influenced intervention efficacy, such as class duration, location or term length. The present study lacked the power to control for all possible factors, making it difficult to isolate any 'true' moderator effects.

Sample size also limited the possibility of fully examining any possible moderating effects. For example, correlations between potential moderators and cognitive change were essentially uninterpretable in the smaller groups (specifically Computer and Social, which both had fewer than 20 participants). Furthermore, having multiple intervention groups resulted in a large number of interaction terms in the models testing for moderator effects, which in turn required careful control of the false discovery rate to avoid overinterpreting significant findings that were due to chance. This issue is also partly a result of the exploratory nature of the analyses conducted; as noted above, due to the lack of previous research on the moderating effect of personality traits (highlighted in Chapter 4; Marr et al., 2020), all possible moderating effects were explored. Future studies should continue to build on these findings with a view to establishing concrete and testable hypotheses.

7.4.4. Conclusion

The Intervention Factory adopted a new and relatively untested approach in the field of cognitive ageing interventions, by using existing community-based classes and groups to test the benefits of novel activity engagement in a sample of older adults. This study explored not only whether engaging in a new activity led to changes in cognitive ability, but whether any changes varied according to several individual factors, particularly personality traits. While participants allocated to five activity groups (Computer, Creative, Language, Physical and Social) did improve in performance across a range of cognitive domains, these improvements did not differ from participants in a no-contact control group. Furthermore, there was no consistent evidence that group-specific improvements varied according to personality traits, age or baseline cognitive status. As discussed throughout, there were specific design limitations that could have influenced these findings, which will be returned to in the next chapter. While future studies could continue to develop and refine the approach introduced here, for now there is no strong evidence to suggest that personality moderates the efficacy of real-world activity engagement as an intervention for age-related cognitive decline.

Table 7.1

Bivariate Pearson Correlations Between Cognitive Change Scores and Age, Baseline MMSE and Personality Traits

	FSIQ Change		VC Change		PR Change		WM Change		PS Change		AM Change		VM Change		IM Change		DM Change	
	N	*r*	N	*r*	N	*r*	N	*r*	N	*r*	N	*r*	N	*r*	N	*r*	N	*r*
Control Group																		
Age	40	-.41**	40	-.16	40	-.22	39	-.45**	40	-.25	38	.17	40	-.15	38	.05	38	.04
MMSE	40	-.11	40	-.10	40	-.19	39	.25	40	.10	38	.34*	40	-.23	38	.00	38	.28
Neuroticism	40	-.15	40	-.19	40	-.02	39	-.11	40	-.06	38	-.01	40	.10	38	-.01	38	.15
Extraversion	40	.29	40	.19	40	.29	39	.17	40	-.03	38	.01	40	-.18	38	-.09	38	-.03
Openness to Experience	39	.26	39	.17	39	.38*	39	-.07	39	-.23	37	-.01	39	.05	37	.06	37	-.01
Agreeableness	40	.15	40	.14	40	.02	39	.17	40	.06	38	.05	40	-.11	38	-.06	38	.04
Conscientiousness	40	.19	40	.16	40	.11	39	.05	40	.22	38	-.12	40	.01	38	-.02	38	-.15
Percentage Adherence	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Time Spent	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Computer Group																		
Age	16	-.46	16	-.26	16	-.17	16	-.50*	15	-.20	16	-.12	14	.02	16	-.27	14	.15
MMSE	16	-.29	16	-.22	16	-.21	16	-.44	15	.17	16	-.18	14	.73**	16	-.02	14	.50
Neuroticism	16	.17	16	-.12	16	.18	16	.11	15	.22	16	-.36	14	-.18	16	-.48	14	-.28
Extraversion	15	.29	15	.30	15	.13	15	.20	14	.07	15	.15	13	-.01	15	.34	13	.31
Openness to Experience	16	.18	16	-.05	16	.13	16	-.02	15	.32	16	-.32	14	-.04	16	-.04	14	-.36
Agreeableness	14	.16	14	.24	14	.11	14	.20	13	-.16	14	-.03	12	.17	14	.27	12	-.09
Conscientiousness	15	.41	15	.16	15	.32	15	.36	14	.17	15	.33	13	-.04	15	.41	13	.25
Percentage Adherence	15	.27	15	.09	15	.22	15	.39	14	-.02	15	-.21	14	-.45	15	-.22	14	-.44
Time Spent	15	.05	15	.08	15	-.06	15	.29	14	-.05	15	-.22	14	-.45	15	-.24	14	-.43
Creative Group																		
Age	100	-.14	101	-.11	101	-.01	96	.04	100	-.19	96	-.04	100	-.01	96	-.03	95	-.03
MMSE	100	.17	101	.13	101	.02	96	.18	100	.02	96	-.06	100	.06	96	-.05	95	.00
Neuroticism	98	.03	99	.03	99	.09	94	-.09	98	-.08	94	-.12	98	.02	94	-.15	93	.01
Extraversion	96	-.18	97	-.05	97	-.23*	92	-.07	96	.07	92	-.16	96	.12	92	.11	91	-.20
Openness to Experience	98	.02	99	-.03	99	.00	94	.10	98	-.03	94	.03	98	.15	94	.07	93	.10
Agreeableness	97	-.06	98	.05	98	-.01	93	-.08	97	-.14	93	-.01	97	-.17	93	-.02	92	-.14
Conscientiousness	94	-.14	95	-.12	95	-.16	90	.11	94	.01	90	-.07	94	-.13	90	-.10	89	-.12
Percentage Adherence	92	.23*	93	.11	93	.21*	88	.09	92	.07	89	.18	92	.11	89	.21*	88	.13
Time Spent	92	.15	93	.07	93	.16	88	-.02	92	.08	89	.12	92	.14	89	.05	88	.26*

	FSIQ Change		VC Change		PR Change		WM Change		PS Change		AM Change		VM Change		IM Change		DM Change	
	N	*r*	N	*r*	N	*r*	N	*r*	N	*r*	N	*r*	N	*r*	N	*r*	N	*r*
Language Group																		
Age	62	-.14	62	.00	62	-.20	60	.16	61	-.03	58	.21	62	.02	58	.12	58	.02
MMSE	62	.00	62	-.09	62	.07	60	.01	61	-.11	58	.04	62	-.15	58	.14	58	-.16
Neuroticism	58	.02	58	.09	58	.02	57	-.08	57	.00	55	-.13	58	.00	55	-.13	55	-.08
Extraversion	59	.01	59	-.11	59	.11	58	.06	59	-.04	56	.02	59	.23	56	.16	56	.07
Openness to Experience	60	-.05	60	-.04	60	-.03	59	.11	59	-.15	57	.03	60	-.04	57	.03	57	.06
Agreeableness	60	-.03	60	.06	60	-.18	59	.16	59	-.02	57	.14	60	-.13	57	.03	57	.09
Conscientiousness	60	.06	60	-.02	60	.04	59	.02	60	.03	57	.26	60	.29*	57	.34*	57	.37**
Percentage Adherence	60	-.13	60	.05	60	-.27*	58	.03	59	.04	56	-.06	60	-.13	56	-.12	56	-.08
Time Spent	59	.06	59	.08	59	-.09	57	.02	58	.19	55	.04	59	-.16	55	.01	55	-.16
Physical Group																		
Age	66	.02	66	.09	66	-.10	66	.00	66	.16	64	-.01	66	-.10	64	-.11	64	-.04
MMSE	66	-.02	66	.02	66	-.06	66	-.01	66	-.01	64	-.10	66	.10	64	-.14	64	.07
Neuroticism	64	-.06	64	.04	64	-.10	64	.09	64	-.09	62	.11	64	.02	62	.10	62	.10
Extraversion	63	.08	63	.10	63	.00	63	.10	63	.01	62	-.05	63	-.21	62	.09	62	-.28*
Openness to Experience	64	-.05	64	-.09	64	-.06	64	.15	64	.00	62	.12	64	.02	62	.29*	62	-.05
Agreeableness	64	.13	64	.19	64	-.01	64	.11	64	.05	63	-.14	64	-.11	63	-.29*	63	-.01
Conscientiousness	65	.03	65	.07	65	.04	65	-.05	65	-.05	63	-.21	65	-.05	63	-.33**	63	.02
Percentage Adherence	65	-.01	65	-.12	65	.00	65	.03	65	.01	63	-.12	65	.12	63	-.14	63	.11
Time Spent	63	-.13	63	-.15	63	-.12	63	.04	63	.01	61	.15	63	.10	61	.16	61	.11
Social Group																		
Age	14	-.49	14	.07	14	-.38	14	-.58*	14	-.29	12	.21	13	-.57*	12	-.21	11	-.41
MMSE	14	-.02	14	.17	14	-.29	14	.35	14	-.13	12	-.52	13	.04	12	-.51	11	.35
Neuroticism	13	.53	13	.24	13	.70**	13	.27	13	-.43	11	.20	12	.05	11	.23	10	.13
Extraversion	14	-.45	14	-.11	14	-.56*	14	-.28	14	.23	12	-.06	13	.42	12	.02	11	.47
Openness to Experience	14	.14	14	.34	14	-.05	14	.19	14	-.20	12	.44	13	.06	12	.42	11	.45
Agreeableness	14	.28	14	.35	14	.06	14	.46	14	-.19	12	.03	13	-.11	12	.02	11	-.06
Conscientiousness	14	-.53*	14	-.58*	14	-.36	14	-.41	14	.05	12	-.38	13	-.24	12	-.29	11	-.56
Percentage Adherence	14	.01	14	-.01	14	-.14	14	.14	14	.21	12	.13	13	.23	12	.22	11	.33
Time Spent	13	.23	13	.25	13	.12	13	.17	13	.00	11	.05	12	.13	11	.04	10	.39

Note. FSIQ = Full Scale IQ, VC = Verbal Comprehension, PR = Perceptual Reasoning, WM = Working Memory, PS = Processing Speed, AM = Auditory Memory, VM = Visual Memory, IM = Immediate Memory, DM = Delayed Memory.

Table 7.2

Summary of Linear Mixed Models Analysing Moderating Effect of Extraversion on Change in Perceptual Reasoning

Predictor Added to Model	No. of parameters	AIC	BIC	Log-Likelihood	χ^2	*df*	*p*
Intercept Only	3	4345.39	4358.46	-2169.69	-	-	-
Time	4	4334.81	4352.25	-2163.41	12.57	1	<0.001
Group	9	4339.52	4378.76	-2160.76	5.29	5	0.381
Extraversion	10	4336.46	4380.06	-2158.23	5.06	1	0.025
Time x Group	15	4340.87	4406.26	-2155.43	5.60	5	0.347
Time x Extraversion	16	4342.57	4412.33	-2155.29	0.29	1	0.590
Group x Extraversion	21	4350.99	4442.54	-2154.50	1.58	5	0.903
Time x Group x Extraversion	26	4346.44	4459.79	-2147.22	14.55	5	0.012

Note. 12 participants were excluded due to missing moderator data.

Table 7.3

Parameter Estimates of Full Time x Group x Extraversion Interaction Model for Perceptual Reasoning

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
(Intercept)	**122.08**	**13.04**	**346.31**	**9.36**	**<0.001**	**<0.001**
Time	-12.22	7.90	289.19	-1.55	0.123	0.421
Group (Computer)	15.06	25.79	346.31	0.58	0.560	0.705
Group (Creative)	-14.00	15.20	346.31	-0.92	0.357	0.669
Group (Language)	-2.57	16.06	346.31	-0.16	0.873	0.873
Group (Physical)	-8.92	16.31	346.31	-0.55	0.585	0.705
Group (Social)	-24.37	30.04	346.31	-0.81	0.418	0.669
Extraversion	-0.15	0.13	346.31	-1.23	0.221	0.530
Time x Group (Computer)	7.61	15.50	288.35	0.49	0.624	0.713
Time x Group (Creative)	**25.08**	**9.18**	**288.89**	**2.73**	**0.007**	**0.040**
Time x Group (Language)	7.30	9.70	288.81	0.75	0.452	0.678
Time x Group (Physical)	13.95	9.84	288.79	1.42	0.157	0.449
Time x Group (Social)	**55.83**	**18.04**	**288.27**	**3.09**	**0.002**	**0.018**
Time x Extraversion	0.13	0.08	288.88	1.71	0.089	0.356
Group (Computer) x Extraversion	-0.22	0.26	346.31	-0.84	0.399	0.669
Group (Creative) x Extraversion	0.13	0.15	346.31	0.87	0.387	0.669
Group (Language) x Extraversion	0.03	0.15	346.31	0.19	0.850	0.873
Group (Physical) x Extraversion	0.09	0.16	346.31	0.54	0.588	0.705
Group (Social) x Extraversion	0.17	0.29	346.31	0.59	0.555	0.705
Time x Group (Computer) x Extraversion	-0.06	0.15	288.25	-0.41	0.683	0.745
Time x Group (Creative) x Extraversion	-0.22	0.09	288.66	-2.55	0.011	0.054
Time x Group (Language) x Extraversion	-0.08	0.09	288.61	-0.88	0.378	0.669
Time x Group (Physical) x Extraversion	-0.13	0.09	288.58	-1.38	0.168	0.449
Time x Group (Social) x Extraversion	**-0.54**	**0.18**	**288.21**	**-3.09**	**0.002**	**0.018**

Note. **Bold** = $p_{adj} < .05$.

Table 7.4

Summary of Linear Mixed Models Analysing Moderating Effects of Openness, Agreeableness and Conscientiousness on Change in Immediate Memory

Predictor Added to Model	No. of parameters	AIC	BIC	Log-Likelihood	χ^2	*df*	*p*
Intercept Only	3	4195.64	4208.54	-2094.82	-	-	-
Time	4	4074.22	4091.43	-2033.11	123.41	1	<0.001
Group	9	4076.47	4115.17	-2029.23	7.76	5	0.170
Openness	10	4067.36	4110.37	-2023.68	11.10	1	<0.001
Agreeableness	11	4068.94	4116.25	-2023.47	0.43	1	0.513
Conscientiousness	12	4069.08	4120.69	-2022.54	1.86	1	0.173
Time x Group	17	4074.91	4148.02	-2020.45	4.17	5	0.525
Time x Openness	18	4072.21	4149.62	-2018.10	4.70	1	0.030
Time x Agreeableness	19	4071.41	4153.12	-2016.70	2.80	1	0.094
Time x Conscientiousness	20	4073.21	4159.23	-2016.61	0.19	1	0.662
Group x Openness	25	4079.36	4186.88	-2014.68	3.86	5	0.570
Group x Agreeableness	30	4086.59	4215.61	-2013.29	2.77	5	0.735
Group x Conscientiousness	35	4083.69	4234.21	-2006.84	12.90	5	0.024
Time x Group x Openness	40	4089.99	4262.02	-2004.99	3.70	5	0.593
Time x Group x Agreeableness	45	4095.21	4288.75	-2002.60	4.78	5	0.444
Time x Group x Conscientiousness	50	4090.77	4305.81	-1995.38	14.44	5	0.013

Note. 19 participants were excluded due to missing moderator data.

Table 7.5

Parameter Estimates of Full Time x Group x Openness/Agreeableness/Conscientiousness Interaction Model for Immediate Memory

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
(Intercept)	**138.61**	**21.42**	**337.67**	**6.47**	**<0.001**	**<0.001**
Time	6.09	14.02	267.26	0.43	0.665	0.886
Group (Computer)	-36.16	54.53	337.65	-0.66	0.508	0.878
Group (Creative)	-32.41	28.04	337.76	-1.16	0.249	0.878
Group (Language)	-30.67	26.21	344.02	-1.17	0.243	0.878
Group (Physical)	-74.35	28.27	337.72	-2.63	0.009	0.143
Group (Social)	-78.11	94.27	383.21	-0.83	0.408	0.878
Openness	-0.07	0.12	343.33	-0.64	0.525	0.878
Agreeableness	0.07	0.16	337.89	0.44	0.659	0.886
Conscientiousness	-0.18	0.11	341.82	-1.67	0.096	0.678
Time x Group (Computer)	-33.32	35.23	265.86	-0.95	0.345	0.878
Time x Group (Creative)	6.11	18.24	266.60	0.33	0.738	0.932
Time x Group (Language)	-11.87	17.28	268.70	-0.69	0.493	0.878
Time x Group (Physical)	10.82	18.40	266.67	0.59	0.557	0.878
Time x Group (Social)	-1.38	64.29	275.90	-0.02	0.983	0.994
Time x Openness	0.05	0.08	268.83	0.67	0.505	0.878
Time x Agreeableness	-0.05	0.10	266.55	-0.49	0.622	0.878
Time x Conscientiousness	0.00	0.07	272.97	-0.04	0.970	0.994
Group (Computer) x Openness	0.27	0.33	338.37	0.83	0.409	0.878
Group (Creative) x Openness	0.23	0.14	341.81	1.65	0.099	0.678
Group (Language) x Openness	0.28	0.15	342.55	1.91	0.057	0.550
Group (Physical) x Openness	0.21	0.15	341.38	1.42	0.158	0.878
Group (Social) x Openness	0.11	0.36	386.12	0.31	0.760	0.935
Group (Computer) x Agreeableness	0.04	0.27	337.73	0.17	0.868	0.972
Group (Creative) x Agreeableness	-0.12	0.19	337.90	-0.65	0.515	0.878
Group (Language) x Agreeableness	0.10	0.18	342.18	0.52	0.602	0.878
Group (Physical) x Agreeableness	0.03	0.19	337.84	0.14	0.888	0.972
Group (Social) x Agreeableness	0.19	0.38	358.60	0.50	0.614	0.878
Group (Computer) x Conscientiousness	-0.05	0.23	338.59	-0.24	0.810	0.972
Group (Creative) x Conscientiousness	0.16	0.13	340.79	1.21	0.226	0.878
Group (Language) x Conscientiousness	-0.19	0.15	341.22	-1.30	0.193	0.878
Group (Physical) x Conscientiousness	0.38	0.14	340.07	2.70	0.007	0.143
Group (Social) x Conscientiousness	0.29	0.27	347.47	1.06	0.291	0.878
Time x Group (Computer) x Openness	-0.08	0.21	266.02	-0.39	0.698	0.905
Time x Group (Creative) x Openness	0.00	0.09	267.95	-0.01	0.994	0.994
Time x Group (Language) x Openness	-0.06	0.10	268.28	-0.63	0.529	0.878
Time x Group (Physical) x Openness	0.07	0.10	267.78	0.69	0.493	0.878
Time x Group (Social) x Openness	0.15	0.24	276.56	0.63	0.532	0.878
Time x Group (Computer) x Agreeableness	0.15	0.17	265.94	0.90	0.369	0.878
Time x Group (Creative) x Agreeableness	0.01	0.12	266.32	0.07	0.946	0.994
Time x Group (Language) x Agreeableness	-0.02	0.12	267.53	-0.14	0.891	0.972
Time x Group (Physical) x Agreeableness	-0.06	0.12	266.35	-0.53	0.596	0.878
Time x Group (Social) x Agreeableness	-0.03	0.25	270.77	-0.14	0.889	0.972
Time x Group (Computer) x Conscientiousness	0.19	0.15	267.40	1.28	0.202	0.878
Time x Group (Creative) x Conscientiousness	-0.05	0.09	270.90	-0.60	0.551	0.878
Time x Group (Language) x Conscientiousness	0.20	0.10	271.02	2.02	0.045	0.536
Time x Group (Physical) x Conscientiousness	-0.09	0.09	270.42	-0.92	0.358	0.878
Time x Group (Social) x Conscientiousness	-0.09	0.18	269.06	-0.52	0.600	0.878

Note. **Bold** = $p_{adj} < .05$.

Table 7.6

Summary of Linear Mixed Models Analysing Moderating Effect of Conscientiousness on Change in Visual Memory

Predictor Added to Model	No. of parameters	AIC	BIC	Log-Likelihood	χ^2	*df*	*p*
Intercept Only	3	4540.07	4553.14	-2267.03	-	-	-
Time	4	4391.40	4408.83	-2191.70	150.67	1	<0.001
Group	9	4395.94	4435.16	-2188.97	5.46	5	0.362
Conscientiousness	10	4397.41	4440.98	-2188.70	0.53	1	0.466
Time x Group	15	4401.48	4466.85	-2185.74	5.93	5	0.313
Time x Conscientiousness	16	4403.48	4473.20	-2185.74	0.00	1	0.954
Group x Conscientiousness	21	4411.88	4503.39	-2184.94	1.60	5	0.901
Time x Group x Conscientiousness	26	4412.99	4526.29	-2180.49	8.89	5	0.114

Note. 10 participants were excluded due to missing moderator data.

Table 7.7

Parameter Estimates of Full Time x Group x Conscientiousness Interaction Model for Perceptual Reasoning

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
(Intercept)	**95.50**	**12.68**	**362.20**	**7.53**	**0.000**	**0.000**
Time	5.36	8.50	284.97	0.63	0.529	0.915
Group (Computer)	17.91	27.44	390.43	0.65	0.514	0.915
Group (Creative)	-6.12	15.38	362.44	-0.40	0.691	0.955
Group (Language)	16.52	17.47	362.20	0.95	0.345	0.915
Group (Physical)	-5.03	16.36	362.20	-0.31	0.759	0.955
Group (Social)	-2.06	25.70	431.26	-0.08	0.936	0.955
Conscientiousness	0.07	0.11	362.20	0.62	0.534	0.915
Time x Group (Computer)	1.41	18.92	291.57	0.07	0.941	0.955
Time x Group (Creative)	8.05	10.31	284.92	0.78	0.436	0.915
Time x Group (Language)	-18.56	11.73	285.12	-1.58	0.115	0.915
Time x Group (Physical)	7.88	10.97	285.01	0.72	0.473	0.915
Time x Group (Social)	16.88	18.44	300.14	0.92	0.361	0.915
Time x Conscientiousness	0.01	0.08	284.78	0.09	0.932	0.955
Group (Computer) x Conscientiousness	-0.18	0.24	385.84	-0.72	0.473	0.915
Group (Creative) x Conscientiousness	0.01	0.14	362.33	0.09	0.931	0.955
Group (Language) x Conscientiousness	-0.18	0.15	362.20	-1.21	0.227	0.915
Group (Physical) x Conscientiousness	0.01	0.15	362.20	0.06	0.955	0.955
Group (Social) x Conscientiousness	-0.06	0.23	422.47	-0.26	0.794	0.955
Time x Group (Computer) x Conscientiousness	-0.02	0.17	290.48	-0.12	0.907	0.955
Time x Group (Creative) x Conscientiousness	-0.06	0.09	284.77	-0.69	0.494	0.915
Time x Group (Language) x Conscientiousness	0.17	0.10	284.92	1.67	0.095	0.915
Time x Group (Physical) x Conscientiousness	-0.04	0.10	284.99	-0.38	0.701	0.955
Time x Group (Social) x Conscientiousness	-0.13	0.16	298.37	-0.83	0.409	0.915

Note. **Bold** = $p_{adj} < .05$.

Table 7.8

Summary of Linear Mixed Models Analysing Moderating Effects of Extraversion and Conscientiousness on Change in Delayed Memory

Predictor Added to Model	No. of parameters	AIC	BIC	Log-Likelihood	χ^2	*df*	*p*
Intercept Only	3	4302.54	4315.45	-2148.27	-	-	-
Time	4	4133.90	4151.12	-2062.95	170.64	1	<0.001
Group	9	4140.29	4179.03	-2061.15	3.61	5	0.607
Extraversion	10	4141.20	4184.24	-2060.60	1.10	1	0.295
Conscientiousness	11	4142.81	4190.16	-2060.40	0.39	1	0.532
Time x Group	16	4151.65	4220.52	-2059.82	1.16	5	0.949
Time x Extraversion	17	4150.79	4223.97	-2058.40	2.86	1	0.091
Time x Conscientiousness	18	4152.41	4229.89	-2058.20	0.39	1	0.533
Group x Extraversion	23	4156.20	4255.21	-2055.10	6.20	5	0.287
Group x Conscientiousness	28	4160.37	4280.90	-2052.19	5.83	5	0.323
Time x Group x Extraversion	33	4160.56	4302.61	-2047.28	9.81	5	0.081
Time x Group x Conscientiousness	38	4159.86	4323.42	-2041.93	10.70	5	0.058

Note. 10 participants were excluded due to missing moderator data.

Table 7.9

Parameter Estimates of Full Time x Group x Extraversion/Conscientiousness Interaction Model for Delayed Memory

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
(Intercept)	**136.97**	**17.56**	**327.28**	**7.80**	**0.000**	**0.000**
Time	15.67	10.61	269.35	1.48	0.141	0.634
Group (Computer)	-3.75	33.04	392.56	-0.11	0.910	0.916
Group (Creative)	-38.81	20.59	327.54	-1.88	0.060	0.341
Group (Language)	11.48	22.11	329.15	0.52	0.604	0.829
Group (Physical)	-43.05	22.76	328.55	-1.89	0.059	0.341
Group (Social)	6.37	39.97	378.36	0.16	0.873	0.916
Extraversion	-0.15	0.13	325.73	-1.18	0.238	0.677
Conscientiousness	-0.07	0.12	329.65	-0.58	0.562	0.829
Time x Group (Computer)	-39.21	21.27	277.77	-1.84	0.066	0.341
Time x Group (Creative)	3.42	12.27	268.15	0.28	0.781	0.878
Time x Group (Language)	-26.34	13.21	268.43	-1.99	0.047	0.341
Time x Group (Physical)	6.27	13.51	267.83	0.46	0.643	0.829
Time x Group (Social)	-7.89	25.12	275.29	-0.31	0.754	0.878
Time x Extraversion	-0.01	0.08	265.19	-0.12	0.908	0.916
Time x Conscientiousness	-0.07	0.07	270.09	-0.95	0.343	0.802
Group (Computer) x Extraversion	-0.28	0.38	427.80	-0.76	0.450	0.809
Group (Creative) x Extraversion	0.30	0.16	326.56	1.92	0.056	0.341
Group (Language) x Extraversion	0.08	0.16	326.63	0.48	0.632	0.829
Group (Physical) x Extraversion	0.19	0.16	329.56	1.17	0.245	0.677
Group (Social) x Extraversion	-0.16	0.33	336.90	-0.50	0.619	0.829
Group (Computer) x Conscientiousness	0.26	0.32	343.58	0.80	0.423	0.802
Group (Creative) x Conscientiousness	0.05	0.15	328.82	0.34	0.733	0.878
Group (Language) x Conscientiousness	-0.20	0.16	329.19	-1.23	0.221	0.677
Group (Physical) x Conscientiousness	0.18	0.15	328.12	1.23	0.219	0.677
Group (Social) x Conscientiousness	0.02	0.23	375.56	0.11	0.916	0.916
Time x Group (Computer) x Extraversion	0.22	0.25	281.79	0.89	0.372	0.802
Time x Group (Creative) x Extraversion	-0.07	0.09	265.06	-0.84	0.403	0.802
Time x Group (Language) x Extraversion	-0.03	0.09	265.01	-0.28	0.777	0.878
Time x Group (Physical) x Extraversion	-0.13	0.09	265.68	-1.39	0.165	0.660
Time x Group (Social) x Extraversion	0.19	0.19	266.81	0.97	0.332	0.802
Time x Group (Computer) x Conscientiousness	0.14	0.19	268.77	0.71	0.476	0.816
Time x Group (Creative) x Conscientiousness	0.04	0.09	268.25	0.46	0.645	0.829
Time x Group (Language) x Conscientiousness	0.26	0.10	268.26	2.65	0.009	0.153
Time x Group (Physical) x Conscientiousness	0.07	0.09	268.06	0.82	0.412	0.802
Time x Group (Social) x Conscientiousness	-0.09	0.15	275.15	-0.60	0.548	0.829

Note. **Bold** = $p_{adj} < .05$.

8. Shaping the Future of Cognitive Ageing Interventions

8.1. Who Uses It and Who Loses It?

The ‘use it or lose it’ theory has driven a growing body of research to identify strategies to protect against age-related cognitive decline. Such research has taken on a greater sense of urgency considering current global ageing trends. Intervention trials are a particularly important tool to test the veracity of the theory that a more engaged lifestyle can be cognitively beneficial for older adults. Considering mentally stimulating activity specifically, evidence suggests that cognitive training regimes may cause improvements in their targeted cognitive domain but transfer of improvements to other domains is less common (Ball et al., 2002; Kelly et al., 2014a; Sala et al., 2019). Training studies may also have issues with ecological validity; training conducted outside of a controlled laboratory environment (e.g., at home) may be less effective (Lampit et al., 2014). In recent years, studies have examined whether cognitive ability can be enhanced through increased engagement in mentally stimulating leisure activities. Results have suggested that activities such as volunteering or attending educational classes may be beneficial (Carlson et al., 2008; Park et al., 2014; Stine-Morrow et al., 2008). Regarding physical activity, trials have shown beneficial effects from various types of exercise, including aerobic and resistance training (Kelly et al., 2014b). Fewer studies have considered whether social or creative activities may have protective effects, but existing evidence suggests some benefits (Carlson et al., 2008; Dodge et al., 2015; Mortimer et al., 2012; Noice & Noice, 2008).

In general, the studies cited above used intervention protocols that were designed and delivered for the purposes of the studies themselves. The question of whether any cognitive benefits would persist outside of a controlled research environment remains largely unanswered. The Intervention Factory was designed to address this gap in the literature. Instead of asking participants to engage in activities in an environment that was designed and supervised by researchers, participants were allocated to attend existing classes and groups running in their local community. This community-based approach allowed the study to test the cognitive benefits of activity engagement in a more realistic context.

When designing and testing cognitive ageing interventions, it is important to also consider the possibility that individuals might not all respond in the same way. Personality traits capture individual tendencies to think, feel and behave in certain ways, and have been linked to a range of outcomes, including cognitive health in older age (Curtis et al., 2015; Luchetti et al., 2016). It is possible that individual personality traits influence the kind of activities one habitually engages in, and that this in turn influences cognitive health as people get older (Allen et al., 2019; Chamorro-Prezumic & Furnham, 2004; Ihle et al., 2016). Should this be the case, it is feasible that personality may also influence how a person approaches an activity-based intervention. In other words, it is possible that personality might influence how much a person 'uses it' (i.e., engages in a stimulating new activity), and therefore the degree to which they may 'lose it' (i.e., subsequently decline, remain unchanged, or improve in cognitive performance).

The research reported in the present thesis explored this proposition using data collected for the Intervention Factory study. In Chapter 2, baseline personality, activity engagement questionnaire, and cognitive test data from the study were used to conduct cross-sectional analyses examining whether behavioural factors, including activity engagement, mediated any personality-cognition associations in older adults. Results revealed that individuals who scored higher on the trait of Openness to Experience were more likely to engage in activities typically thought to be mentally demanding and had significantly higher levels of cognitive ability. However, activity engagement was not found to mediate the observed Openness-cognition associations. In other words, there was no evidence to suggest that more open individuals were less liable to ‘lose it’ because they tended to ‘use it’ more often in their everyday lives.

This thesis then considered the influence of personality on how individuals respond to cognitive ageing interventions. In Chapter 4, a systematic review examined whether there was any consistent evidence to suggest that personality was associated with adherence to, and efficacy of, cognitive ageing interventions. The evidence base was small; only ten studies were found that had considered the influence of personality traits. Results from three of these studies suggested that interventions using novel methods, such as training visual imagery as a mnemonic strategy, or a group-based competitive problem-solving programme, were particularly effective among those who scored higher on Openness. No published studies had examined whether personality traits predicted intervention adherence, and additional data received upon request provided no evidence of any associations.

These questions were then empirically tested in the context of the Intervention Factory’s community-based approach. As reported in Chapter 5, there was no evidence of any specific intervention-related cognitive improvements from any of the activities that were tested, but rather broad improvements were found across all participants that were indicative of a general practice effect. In Chapter 6, no consistent evidence was found to suggest that personality traits predicted adherence to the real-world activity classes or groups. Furthermore, results from Chapter 7 revealed little evidence that personality moderated cognitive changes in any activity group. Across both the wider literature and the Intervention Factory study, there is little evidence to suggest that personality traits are associated with adherence to a cognitive ageing intervention; when participants are given the opportunity to increase how much they ‘use it’ through an intervention study, personality does not appear to exert much influence. There is some evidence from the wider literature to suggest that more open individuals may respond more favourably to an intervention, and thus possibly be less likely to 'lose it' as a result (Finkel & Yesavage, 1989; Gratzinger et al., 1990; Stine-Morrow et al., 2014). However, this was not observed in the Intervention Factory, nor did any other traits moderate intervention efficacy.

Ultimately, given the lack of previous research exploring real-world activities as cognitive ageing interventions, the Intervention Factory study was intentionally exploratory. While no evidence was found that personality traits influenced cognitive health in old age via increased activity engagement, several aspects of the study design did highlight areas for future research. The remainder of this concluding chapter will reflect on some of these aspects, and how future studies could build on the presented findings.

8.2. Bridging the Gap: Methodological Issues in Real-World Cognitive Ageing Interventions

8.2.1. Study Design

The Intervention Factory revealed the difficulty of implementing an activity-based intervention within even a pseudo-randomised controlled design. It was anticipated that strict randomisation would result in poorer adherence and higher attrition due to participants being allocated to an activity they might not enjoy. Therefore, consistent with the approach taken by the Synapse study (Park et al., 2014), randomisation was relaxed to allow participants to remove up to two activity options. As discussed in Chapter 5, even with this randomisation protocol in place, some participants still refused their initial allocation, while others were unable to attend their initially allocated activity due to logistical reasons (e.g., the available dates were unsuitable). Additionally, eight participants were reallocated to a different activity after a few weeks because they found their initial activity unsuitable. Allowing such a degree of participant choice likely introduced bias to the data; certain individual characteristics may influence which activities someone is likely to exclude or refuse, leading to systematic differences between activity groups in these characteristics. There was some evidence of this in the present results; for example, those in the Social group appeared to have lower speed of processing than those in the physical group. However, ecological validity was one of the pre-designed elements of the approach, and differences due to participant choice were deemed to be preferable to the bias and loss of power caused by high levels of drop-out had participants not been allowed to change their activity.

One of the consequences of the decision to allow a degree of participant choice was that very few participants were willing to be allocated to the active control group (bingo). This is perhaps unsurprising; one could speculate that the other activities were more attractive because they offered the chance to gain new skills. Herein lies the paradox of the original Intervention Factory design: the experimental conditions were designed to offer some degree of novel engagement. Conversely, the control condition (bingo) was supposed to have low overall engagement levels while still replicating the structure of the other activities (i.e., weekly group sessions in the local community). Unfortunately, the intended low level of engagement in the bingo group appears to have contributed to making it less attractive to participants. One might suggest that this could be resolved by reverting back to a fully-randomised allocation with blinding so that participants are unaware of the other possible activities. However, this would likely introduce issues in several areas:

- Recruitment: potential participants may be wary about signing up to a study in which they have no idea what kind of activity they may be asked to do;
- Adherence: participants allocated to an activity they dislike may stop attending their group/class or refuse to attend from the outset. This seems likely based on the number of participants who refused their initial allocation in the present

study, but it is not clear the extent to which this was influenced by the knowledge of other possible activities;

- Attrition: participants allocated to an activity they dislike may withdraw from the study as a result.

The lack of an active control group was addressed in this study by recruiting an additional cohort of participants to serve as a no-contact control group. Participants were not randomly allocated to this group; the issues arising from this choice (e.g., differing participant expectations, shorter duration between assessments) were discussed previously in Chapter 5 (section 5.4.1). Because this group was recruited separately, it is not possible to say whether this type of control group would have encouraged greater uptake than bingo if adopted from the start of the study. However, as with bingo, it could be speculated that the lack of new engagement opportunities for a no-contact control group might deter some participants. Another alternative would be to use a waitlist control group (i.e., a group for whom the start of their activity was delayed while those in the experimental groups engaged in theirs). However, a waitlist control group would incur the same problems of the no-contact control group recruited for the present study. Even if not explicitly told that they were being recruited to examine improvements due to practice (as in the present study), expectations could still differ between controls and those engaging in an activity. In fact, waitlist controls might not expect to improve at all (Boot et al., 2013), and these differing expectations could confound any between-group differences in performance change. Waitlist controls may also choose to engage in activities of their own during the intervention period, which could also influence their change in cognitive performance. Going forward, randomisation and effective control/comparison groups are issues that future studies will need to consider when designing their intervention.

8.2.2. Volunteer Participants

The representativeness of volunteer research samples is an important issue when it comes to the generalisability of cognitive ageing research. Evidence suggests that participants recruited using a convenience sampling framework tend to be younger, more educated, from a higher socioeconomic background and have higher levels of cognitive ability (Brodaty et al., 2014). As discussed in earlier chapters, while the Intervention Factory study adopted a range of recruitment methods to reach a broader group of older adults, the recruited sample was, on average, towards the younger end of the age range, well-educated and lived in less deprived areas. The high-functioning status of the current sample can be observed in the obvious ceiling effect for MMSE scores. This is problematic for an intervention targeted at cognitive ageing because it suggests that those with the most to gain (i.e., those who may have already experienced some degree of cognitive decline) were being systematically under-recruited.

There is also evidence to suggest that higher cognitive ability is associated with engagement in a greater number of leisure activities in daily life among older adults (Jackson et al., 2020). Given the high-functioning status of the Intervention Factory sample, it is possible that these individuals were already engaged in a wider repertoire of activities. This is particularly problematic given that the aim of the Intervention Factory was that participants would be taking up a new activity. Indeed, many participants were already engaging in several of the activities on offer, limiting the range of activities that they could be allocated to. It is possible that those who are less active have more to gain from new engagement and may therefore show greater cognitive improvements when taking up a new activity. Understanding this possibility more fully will require the adoption of a more representative sampling method.

8.2.3. Intervention Fidelity

Another important aspect of intervention design and implementation is fidelity: the degree to which an intervention is delivered consistently and as intended for all study participants (James et al., 2017). Ensuring that an intervention is implemented correctly is important for maintaining the validity of any findings (Mars et al., 2013). In the case of activity-based interventions, previous studies have ensured a consistent approach by carefully delivering the intervention to participants in groups, under the supervision of trained facilitators. For example, in the Synapse study (Park et al., 2014) three different intervention conditions were planned, each designed to increase participants' levels of 'productive' mental engagement. These consisted of photography classes, quilting classes, or a combination of the two. Each class was delivered in the same dedicated location for all participants, by the same professional instructor. In this way, the researchers could be more confident that, within each group, participants were exposed to the same 'treatment'. This approach can, however, introduce an aspect of artificiality that may influence results. For example, given that the activities were put on specifically for the purposes of the Synapse study, participants may have felt a greater obligation to attend than they would in a real-world setting. Class members in the Synapse study were all volunteer study participants, who, as noted above, are likely to have similar characteristics to each other and may be less representative of the type of people one might interact with in a class in the real world. Other studies also incur these issues with ecological validity (e.g., Stine-Morrow et al., 2008; Vaportzis et al., 2017).

It is not possible to say with certainty that the cognitive improvements observed in the Synapse study and other interventions would persist outside the study environment. Therefore, in the Intervention Factory study a degree of researcher control over implementation was relinquished to explore whether activity engagement closer to that provided in the real world could still be cognitively beneficial. As highlighted in previous chapters, while doing so introduced a degree of realism to the study, it also introduced several issues with fidelity that could have impacted results. That said, that few cognitive benefits were observed with a more realistic level of engagement raises key questions for researchers exploring interventions in cognitive ageing, including: if the activities expected to benefit cognitive health don't provide the required degree of engagement when conducted in the real-world, what next?

Unlike previous studies, the research team had no control over the delivery of the intervention itself, which was entirely the responsibility of external providers. Therefore, individual participants within the same intervention group may have had quite different experiences when taking up their new activity, due to joining different sessions run by different instructors, and including a different set of study and non-study class members. It is important to emphasise that this was part of the design of the study; in the real world, not all computer classes will be delivered in the same way, and nor will all exercise classes, social clubs, handicraft classes or language classes. Ideally, any protective effect from activity engagement would be robust enough to persist under slight variations in the delivery of that activity. Such variations would essentially be unavoidable once an intervention was removed from a research setting and implemented as a real-world public health measure. Therefore, if reliable evidence of cognitive improvement had been found within the more heterogeneous structure of the Intervention Factory protocol, one could be more confident that this improvement was a result of the activity itself rather than an artifact of the study environment.

No strong evidence of meaningful activity-related improvements was observed. The most obvious immediate explanation for this is that the null hypothesis is true and the activities tested here are not cognitively protective. Alternatively, the activities may well be protective, but the classes or groups may not have been delivered in the most effective way. That is, and ironically, perhaps the real-world setting in which any engagement needs to occur for research to move into full application is not systemically structured or in-depth enough. Previous studies have carefully planned their intervention protocol to be mentally, physically or socially stimulating. For example, both the Senior Odyssey programme and the Experience Corps programme were carefully developed and refined through pilot studies with quantitative and qualitative empirical data collection in order to ensure that activities were mentally stimulating (Fried et al., 2004; Stine-Morrow et al., 2007). While the activities in the Intervention Factory were selected to be mentally, physically or socially demanding, the design and delivery of the classes themselves were out of the research team's control. It is possible that, within a given intervention group, some classes were highly stimulating and did cause notable cognitive improvements, but that others were less so and did not, and when combined the average improvement was not significantly greater than that of controls.

The Computer group can be used to illustrate this argument. A previous study taught a group of older adults to use tablet computers, using a pre-specified curriculum that had been deemed suitable for older adults based on feedback from focus groups (Vaportzis et al., 2017). All participants were under the tutelage of the same instructor. Results showed evidence of greater cognitive improvements in the tablet training group compared to no-contact controls. In the Intervention Factory, where participants attended a variety of computer classes under different instructors and different formats, no such improvements were evident. One explanation is that the improvements observed by Vaportzis et al. (2017) were not necessarily due to the computer lessons themselves, but rather due to a higher motivation to perform well within a supportive and supervised study environment; when this environment is removed, as in the Intervention Factory, such improvements are no longer observed. Alternatively, it may be the case that computer classes are cognitively protective, but only when they are carefully delivered following a specific curriculum designed to be cognitively engaging.

If the latter theory is true, then this is something future studies will have to contend with: how can an effective learning environment be ensured while still maintaining a degree of real world validity?

8.2.4. Future Directions

The Intervention Factory tested a novel approach to cognitive ageing interventions, one which future studies can build on to further explore the cognitive benefits of real-world, community-based activities. As highlighted above, doing so will require consideration of several key issues at the design, recruitment, and implementation stages of the study. First, researchers will need to consider the most appropriate blinding/randomisation process, and what kind of control/comparison group to utilise. Should future studies implement a fully blinded, strict RCT design, this will require careful consideration of how to reduce attrition in the case that a participant is allocated to an activity they dislike. For example, Schulz and Grimes (2002) suggest strategies such as reducing the burden on the participant to return for follow-up by offering more convenient locations for assessment, keeping time-commitment lower by using shorter measurement instruments and offering monetary reimbursement. Studies that retain the element of participant choice adopted here should expect similar variation in group size with some being more popular than others. Recruiting a larger sample will help increase power to detect effects in the subsequently smaller groups.

Selecting a control group that can be an effective placebo (i.e., not lead to differential expectations), while still having a lower level of overall engagement *and* not being seen as a less desirable option will require careful thought. Some additional empirical data collection at the design stage may be necessary. Boot et al. (2013) suggest that recruiting additional participants, presenting them with hypothetical experimental and control groups (or indeed allowing them to try the activities themselves) and then asking them to rate their expectations for improvement on given outcome measures would allow for empirical verification that expectations are not likely to differ between groups. Using this approach, researchers could also ask participants to rate expected levels of mental, physical and social engagement in order to verify that the proposed control group has low demands compared to experimental groups (as was done in the present study) and ask participants how likely they would be to discontinue the study if allocated to each activity. While such additional data collection would require increased resources, having an effective control group would help to increase confidence in the ability of any subsequent intervention to detect a true effect.

Secondly, researchers will need to give greater consideration to the recruitment of a more representative sample. The ideal approach for any study to achieve a representative sample of older adults would be to use some form of probability sampling, in which all potential participants from a given target population (or strata/clusters within that population) have an equal chance of being selected. Such an approach is often used for large-scale national cohort surveys, such as the Health Survey for England (Mindell et al., 2012). However, this approach is costly and labour intensive (Bornstein et al., 2013), meaning it may not be practical for most intervention studies. Studies using convenience samples should at the very least make greater attempts to include individuals typically underrepresented in research samples of older adults, including the oldest-old, those from lower socioeconomic backgrounds and those from ethnic minority groups (Gaertner et al., 2016; Liljas et al., 2017; Pinsky et al., 2008). One advantage of recruiting a more representative sample is that it will allow for a more robust examination of the effects of potential demographic moderator variables, such as those tested in Chapter 7. For example, recruiting a greater proportion of the oldest-old population will also allow researchers to further examine the possible moderating effect of age on intervention efficacy.

Finally, researchers should consider how to balance consistency of activity implementation with retaining real-world validity to the intervention. Future studies could elect to exercise more control over intervention delivery by only allocating participants to classes with a set number of weeks and a pre-defined curriculum, thus eliminating some of the variation in delivery between individuals. Another possibility would be to incorporate the real-world variation in intervention delivery into the design of the study, by collecting comprehensive data on pertinent features of each activity class/group. This could include practical factors (e.g., number of weeks, session duration, location, time of day, class/group content) as well as personal factors (e.g., participant enjoyment, difficulty in attending, perceived age-appropriateness of the class/group). Analyses could then examine whether these factors may have influenced the efficacy of the intervention. Examining all of these factors may involve more complex subgroup analyses, so future studies may only be able to focus on one or two.

8.3. Measuring Activity Engagement

In examining whether activity engagement is associated with cognitive health, researchers need some way to reliably measure individual levels of engagement. Self-report questionnaires offer a fast and easy option and are commonly used in the field of cognitive ageing. These questionnaires typically ask participants to indicate how frequently they engage in a list of different activities. Activities are often categorised into ‘domains’ to measure aggregate levels of engagement in different types of activity. A common approach used in cognitive ageing research is to categorise activities into the three conventional domains of mentally, physically and socially demanding activities (Small et al., 2012; Wang et al., 2013). However, the exact items used to measure these domains vary from study to study. In particular, the specific activities used to measure engagement in the mental domain are notably idiosyncratic. For example, Wang et al. (2013) included activities such as sewing or attending the opera, while Schinka et al.

(2005) included items such as managing investments and gardening. This lack of consensus on the most appropriate way to measure engagement limits the ability to generalise results across studies.

Several findings in the present thesis suggest that these three domains may not be the optimal way to categorise activities. In Chapter 2, a data-driven approach was used to determine the domains measured by a modified version of the Victoria Longitudinal Study-Activity Lifestyle Questionnaire. This questionnaire asked participants to indicate how frequently they engaged in 62 activities. An exploratory factor analysis indicated the presence of six latent factors that explained variance among 22 of these activities: Manual, Intellectual, Games, Religious, Exercise and Social. Engagement in these domains was associated with cognitive ability in different ways. For example, engagement in Intellectual activities was positively correlated with verbal ability only, while engagement in Manual activities was positively correlated with both verbal and visuospatial ability. Both the Intellectual and Manual domains incorporated activities that could be conceived of as mentally demanding. The differences between these narrower domains suggest that categorising activities as being broadly mentally demanding might mask more nuanced activity-cognition associations.

Furthermore, categorising activities in this way ignores the multifaceted nature of some activities. For example, activities typically categorised as physical or social may also involve significant mental demands (e.g., navigating social cues when socialising with others or strategic planning in sport; Bielak, 2010). In the Intervention Factory, both language and handicraft classes were specifically selected to have mixed mental-social and mental-physical demands respectively. This was supported by the subjective ratings of demand collected from study participants. For example, the Language group had significantly higher average ratings of both mental and social demands compared to other groups, suggesting that, as intended, participants tended to find this activity both mentally and socially stimulating. Also as anticipated, the Creative group reported significantly higher average ratings of both mental and physical demands than some other groups. It is also important to note that ratings of demands varied between individuals; while average ratings of physical demand in the physical group were high, some participants still provided low ratings. Such findings highlight the subjective nature of categorising activities based on how demanding they are: what is highly demanding for one person may not be so for another.

Overall, these findings highlight the fact that activities in the real world are unlikely to be purely mentally, physically or socially demanding, but rather some combination of these. Furthermore, the demands of an activity are inherently subjective. The subjective, multidimensional nature of activity engagement is effectively ignored when categorising activities into the discrete domains of mental, physical and social. There is, however, no current consensus on what the most appropriate alternative domains of activity engagement are. A review into the measurement of activity engagement in older age found that, across 42 studies, the number of domains measured varied considerably, ranging from one to thirteen (Adams et al., 2011). The six activity domains identified in Chapter 2 may offer a useful way for future studies to measure activity engagement. However, the analysis used to identify these domains was exploratory, and thus further validation is necessary. It is also important to note that activity engagement is likely to be influenced by geographic, cultural and socioeconomic factors (Bielak, 2010). Therefore, future studies should examine whether the factors identified here are replicated in larger, more diverse samples.

Ultimately, achieving a generalisable framework for measuring activity engagement will enable greater synthesis of results across studies, and thus identify what types of activity, if any, are most beneficial for cognitive health. This in turn could help to identify the most effective activities for future intervention studies.

8.4. The Benefits of Keeping an Open Mind

Previously observed associations between the personality trait of Openness to Experience and both activity engagement and cognitive ability in older age are the foundation of the investment theory. This theory suggests a causal pathway in which Openness enhances cognitive ability through increased levels of engagement in mentally stimulating activities (Chamorro-Prezumic & Furnham, 2004; Soubelet & Salthouse, 2010). In other words, those who are more open to experience are more likely to ‘use it,’ and thus less liable to ‘lose it’. Furthermore, evidence from intervention studies suggests that more open individuals may experience greater cognitive benefits (Finkel & Yesavage, 1989; Gratzinger et al., 1990; Stine-Morrow et al., 2014). To take the investment analogy further, these findings suggest that more open individuals may also show greater investment in an intervention setting, and thus see greater returns on their investment in the form of larger performance improvements. The Intervention Factory study provided the opportunity to explore the investment theory, both cross-sectionally and in the context of an intervention study.

In the cross-sectional study, there was some evidence that scores on the trait of Openness to Experience were positively correlated with everyday engagement in several of the activity domains measured, suggesting that more open individuals may well lead a more active lifestyle. Openness was also positively associated with performance in several cognitive domains. However, there was no evidence that activity engagement (particularly engagement in mentally stimulating activities) mediated any of the observed associations between Openness and cognitive ability. In other words, there was little evidence that the higher level of cognitive ability in more open individuals could be accounted for by a more mentally engaged lifestyle.

Interestingly, given that more open individuals appear to be more mentally active in their everyday lives, evidence regarding whether these individuals were more active during the intervention was mixed. A positive association between Openness and Time Spent across all intervention groups was observed, suggesting that more open individuals spent more time engaging in all kinds of activity, not just those that were highly mentally demanding. In fact, Openness did not appear to be related to adherence to those activities that were rated as more mentally stimulating on average (Creative and Language). As noted above, however, ratings were subjective and variable, so it may be that these activities were not mentally engaging enough to engender higher adherence among more open individuals. It should also be noted that analyses considering intervention across all groups had greater statistical power than the sub-group analyses, which may explain why no group-specific associations between Openness and adherence were found.

It is also possible that the causal direction of previously reported cross-sectional Openness-engagement associations have been misinterpreted. In other words, Openness does not cause higher levels of engagement in mentally stimulating activity, but rather higher levels of mental stimulation cause higher levels of Openness. This would explain why activity engagement did not mediate the association between Openness and cognition, because this model assumes that Openness is the causal factor affecting engagement. This would also explain why baseline levels of Openness did not predict subsequent adherence to those activities that were rated as more mentally demanding in the intervention. Under this alternative theory, one might expect that an intervention designed to be mentally engaging would cause an increase in scores on the trait of Openness to Experience. Indeed, there is some evidence that a cognitive training intervention can lead to an increase in Openness to Experience among older adults (Jackson et al., 2012). Personality change was not assessed in the present study, so the theory could not be empirically tested, but this remains an area for further research.

8.5. Conclusion

The idea that the brain can be kept healthy by maintaining an active, engaged lifestyle is an appealing one, suggesting that loss of memory or thinking skills in older age is not inevitable but a process that we can control by changing the way we behave. The idea is also far from novel: as far back as the 1st century BCE, the Roman philosopher Cicero may well have been the earliest scholar to espouse support for the 'use it or lose it' theory:

> But it is our duty, my young friends, to resist old age; to compensate for its defects by a watchful care; to fight against it as we would fight against disease; to adopt a regimen of health; to practise moderate exercise; and to take just enough of food and drink to restore our strength and not to overburden it. Nor, indeed, are we to give our attention solely to the body; much greater care is due to the mind and soul; for they, too, like lamps, grow dim with time, unless we keep them supplied with oil. Moreover, exercise causes the body to become heavy with fatigue, but intellectual activity gives buoyancy to the mind. (Cicero, 44 B.C.E./1923, p. 45)

There is now a growing body of scientific evidence to suggest that many of the strategies espoused by Cicero, including staying physically and mentally engaged, are indeed associated with better cognitive health in later life (Blondell et al., 2014; Hertzog et al., 2008). In fact, these strategies are now among those recommended by the Global Council on Brain Health, alongside staying socially active and maintaining a healthy diet (2016, 2017a, 2017b, 2018).

Such recommendations are supported by results from a range of intervention studies showing that increased levels of mental, physical and/or social activity can lead to cognitive improvements in older adults. However, whether these interventions remain effective once translated out of the research environment and into the real-world remains unconfirmed. It is also possible that individual factors, particularly personality traits, might influence how effective interventions actually are. Given current global ageing trends, identifying effective strategies to protect cognitive health in older adults is imperative. Tailored approaches that account for individual differences will help to ensure these strategies are implemented as effectively and efficiently as possible.

Ultimately, there was no evidence that the real-world, community-based activities tested in the Intervention Factory study caused meaningful cognitive improvement in a sample of older adults compared to a no-contact control group. Furthermore, there was little evidence to suggest that intervention effects were moderated by personality traits. In other words, regardless of individual differences in personality, taking up a new activity in the local community was not found to be cognitively beneficial. Such findings raise questions about whether activity engagement can be an effective cognitive intervention when translated out of a more controlled, experimental environment.

As of now, it is not possible to make any concrete recommendations about how the findings of this study could be applied in the real world. It is important to note, however, that while the results do not support meaningful cognitive improvement as a result of trying a new activity, this should not discourage older adults from seeking out opportunities for new learning and engagement. Activity-based interventions in older age can have benefits beyond cognition, including improvements in mental wellbeing and physical health (Krzeczkowska et al., 2021; Netz et al., 2005). The Intervention Factory collected data on numerous other health-related outcomes, including quality of life, anxiety and depression, sleep quality, physical function and cardiovascular health. These data are beyond the scope of the present thesis but planned future analysis will examine any intervention-related changes in these outcomes.

It is important to note that this study was the first to test the potential of such community-based activities as an intervention for age-related cognitive decline. In doing so, several challenges were identified that could have influenced results, such as maintaining pseudo-random group allocation, or selecting an effective control group. Identifying solutions to these challenges and adapting the intervention protocol for further testing will allow future studies to achieve a greater understanding of the true effects of real-world activity engagement. That is, if these 'real' real-world activities don't provide benefits, how can we modify their delivery, while still being within our communities, to do so?

It is hoped that the research presented within this thesis will form part of a larger, ongoing effort to understand who benefits most from different intervention strategies. A growing body of evidence suggests that a one-size-fits-all approach may not be the best way to protect cognitive health in older age. By considering the importance of individual factors such as personality traits when it comes to intervention design, future researchers will hopefully be better able to identify the most effective way to help older adults to keep 'using it' and, in turn, avoid 'losing it'.

References

Aartsen, M. J., Smits, C. H., van Tilburg, T., Knipscheer, K. C., & Deeg, D. J. (2002). Activity in older adults: cause or consequence of cognitive functioning? A longitudinal study on everyday activities and cognitive performance in older adults. *J Gerontol B Psychol Sci Soc Sci*, *57*(2), P153-162.

Adams, K. B., Leibbrandt, S., & Moon, H. (2011). A critical review of the literature on social and leisure activity and wellbeing in later life. *Ageing and Society*, *31*(4), 683-712. https://doi.org/10.1017/S0144686X10001091

Adler, G., & Rottunda, S. (2006). Older adults' perspectives on driving cessation. *Journal of Aging Studies*, *20*(3), 227-235. https://doi.org/https://doi.org/10.1016/j.jaging.2005.09.003

Age UK. (2018). *All the Lonely People: Loneliness in Later Life*. https://www.ageuk.org.uk/globalassets/age-uk/documents/reports-and-publications/reports-and-briefings/loneliness/loneliness-report.pdf

Agrell, B., & Dehlin, O. (1998). The clock-drawing test. *Age and ageing*, *27*(3), 399-403.

Aiken-Morgan, A. T., Bichsel, J., Allaire, J. C., Savla, J., Edwards, C. L., & Whitfield, K. E. (2012). Personality as a Source of Individual Differences in Cognition among Older African Americans. *J Res Pers*, *46*(5), 465-471. https://doi.org/10.1016/j.jrp.2012.04.006

Allen, M. S., Laborde, S., & Walter, E. E. (2019). Health-Related Behavior Mediates the Association Between Personality and Memory Performance in Older Adults. *J Appl Gerontol*, *38*(2), 232-252. https://doi.org/10.1177/0733464817698816

Alvarez, J. A., & Emory, E. (2006). Executive function and the frontal lobes: a meta-analytic review. *Neuropsychology review*, *16*(1), 17-42.

Alzheimer's Research UK. (2019). *Dementia Attitudes Monitor: Wave 1 2018*. https://www.dementiastatistics.org/wp-content/uploads/2019/02/Dementia-Attitudes-Monitor-Wave-1-Report.pdf#zoom=100

Anderson, L. A., Day, K. L., Beard, R. L., Reed, P. S., & Wu, B. (2009). The public's perceptions about cognitive health and Alzheimer's disease among the US population: a national review. *The Gerontologist*, *49*(S1), S3-S11.

Anstey, K. J., Horswill, M. S., Wood, J. M., & Hatherly, C. (2012). The role of cognitive and visual abilities as predictors in the Multifactorial Model of Driving Safety. *Accident Analysis & Prevention*, *45*, 766-774.

Anstey, K. J., von Sanden, C., Salim, A., & O'Kearney, R. (2007). Smoking as a risk factor for dementia and cognitive decline: a meta-analysis of prospective studies. *American journal of epidemiology*, *166*(4), 367-378.

Antoniou, M., Gunasekera, G. M., & Wong, P. C. M. (2013). Foreign language training as cognitive therapy for age-related cognitive decline: A hypothesis for future research. *Neuroscience & Biobehavioral Reviews*, *37*(10, Part 2), 2689-2698. https://doi.org/https://doi.org/10.1016/j.neubiorev.2013.09.004

Ashton, M. C., & Lee, K. (2007). Empirical, Theoretical, and Practical Advantages of the HEXACO Model of Personality Structure. *Personality and Social Psychology Review*, *11*(2), 150-166. https://doi.org/10.1177/1088868306294907

Austin, E. J., Deary, I. J., Whiteman, M. C., Fowkes, F. G. R., Pedersen, N. L., Rabbitt, P., . . . McInnes, L. (2002). Relationships between ability and personality: does intelligence contribute positively to personal and social adjustment? *Personality and Individual Differences*, *32*(8), 1391-1411.

Baer, L. H., Tabri, N., Blair, M., Bye, D., Li, K. Z., & Pushkar, D. (2012). Longitudinal associations of need for cognition, cognitive activity, and depressive symptomatology with cognitive function in recent retirees. *Journals of*

Gerontology Series B: Psychological Sciences and Social Sciences, *68*(5), 655-664.

Bagby, R. M., Quilty, L. C., Segal, Z. V., McBride, C. C., Kennedy, S. H., & Costa, P. T. (2008). Personality and Differential Treatment Response in Major Depression: A Randomized Controlled Trial Comparing Cognitive-Behavioural Therapy and Pharmacotherapy. *The Canadian Journal of Psychiatry*, *53*(6), 361-370.

Bagwell, D. K., & West, R. L. (2008). Assessing compliance: active versus inactive trainees in a memory intervention. *Clinical interventions in aging*, *3*(2), 371-382. https://doi.org/10.2147/cia.s1413

Baker, T. J., & Bichsel, J. (2006). Personality predictors of intelligence: Differences between young and cognitively healthy older adults. *Personality and Individual Differences*, *41*(5), 861-871. https://doi.org/10.1016/j.paid.2006.02.017

Ball, K., Berch, D. B., Helmers, K. F., Jobe, J. B., Leveck, M. D., Marsiske, M., . . . Willis, S. L. (2002). Effects of Cognitive Training Interventions With Older Adults: A Randomized Controlled Trial. *JAMA*, *288*(18), 2271-2281.

Balogun, J., Akindele, K., Nihinlola, J., & Marzouk, D. (1994). Age-related changes in balance performance. *Disabil Rehabil*, *16*(2), 58-62.

Barnes, D. E., Yaffe, K., Satariano, W. A., & Tager, I. B. (2003). A longitudinal study of cardiorespiratory fitness and cognitive function in healthy older adults. *Journal of the American Geriatrics Society*, *51*(4), 459-465.

Barnes, L. L. B., Harp, D., & Jung, W. S. (2002). Reliability Generalization of Scores on the Spielberger State-Trait Anxiety Inventory. *Educational and Psychological Measurement*, *62*(4), 603-618. https://doi.org/10.1177/0013164402062004005

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*(1), 1-48. https://doi.org/10.18637/jss.v067.i01

Beard, J. R., Officer, A., de Carvalho, I. A., Sadana, R., Pot, A. M., Michel, J.-P., . . . Chatterji, S. (2016). The World report on ageing and health: a policy framework for healthy ageing. *The Lancet*, *387*(10033), 2145-2154. https://doi.org/https://doi.org/10.1016/S0140-6736(15)00516-4

Belleville, S., Hudon, C., Bier, N., Brodeur, C., Gilbert, B., Grenier, S., . . . Gauthier, S. (2018). MEMO+: Efficacy, Durability and Effect of Cognitive Training and Psychosocial Intervention in Individuals with Mild Cognitive Impairment. *J Am Geriatr Soc*, *66*(4), 655-663. https://doi.org/10.1111/jgs.15192

Bennett, J. E., Li, G., Foreman, K., Best, N., Kontis, V., Pearson, C., . . . Ezzati, M. (2015). The future of life expectancy and life expectancy inequalities in England and Wales: Bayesian spatiotemporal forecasting. *The Lancet*, *386*(9989), 163-170.

Berchtold, N. C., & Cotman, C. W. (1998). Evolution in the Conceptualization of Dementia and Alzheimer's Disease: Greco-Roman Period to the 1960s. *Neurobiol Aging*, *19*(3), 173-189.

Berggren, R., Nilsson, J., Brehmer, Y., Schmiedek, F., & Lövdén, M. (2020). Foreign language learning in older age does not improve memory or intelligence: Evidence from a randomized controlled study. *Psychology and Aging*, *35*(2), 212-219. https://doi.org/10.1037/pag0000439

Bielak, A. A., Anstey, K. J., Christensen, H., & Windsor, T. D. (2012). Activity engagement is related to level, but not change in cognitive ability across adulthood. *Psychol Aging*, *27*(1), 219-228. https://doi.org/10.1037/a0024667

Bielak, A. A. M. (2010). How can we not 'lose it'if we still don't understand how to 'use it'? Unanswered questions about the influence of activity participation on cognitive performance in older age–a mini-review. *Gerontology, 56*(5), 507-519. https://doi.org/10.1159/000264918

Bier, N., Grenier, S., Brodeur, C., Gauthier, S., Gilbert, B., Hudon, C., . . . Belleville, S. (2015). Measuring the impact of cognitive and psychosocial interventions in persons with mild cognitive impairment with a randomized single-blind controlled trial: rationale and design of the MEMO plus study. *International Psychogeriatrics*, *27*(3), 511-525. https://doi.org/10.1017/s1041610214001902

Bierman, E., Comijs, H., Jonker, C., & Beekman, A. (2007). Symptoms of anxiety and depression in the course of cognitive decline. *Dementia and Geriatric Cognitive Disorders*, *24*(3), 213-219.

Bink, M. L., & Marsh, R. L. (2000). Cognitive regularities in creative activity. *Review of General Psychology*, *4*(1), 59-78.

Birns, J., & Kalra, L. (2009). Cognitive function and hypertension. *Journal of human hypertension*, *23*(2), 86-96.

Bissig, D., & Lustig, C. (2007). Who benefits from memory training? *Psychological Science*, *18*(8), 720-726.

Black, S. A., & Rush, R. D. (2002). Cognitive and Functional Decline in Adults Aged 75 and Older. *Journal of the American Geriatrics Society*, *50*(12), 1978-1986.

Bless, H., Wänke, M., Bohner, G., Fellhauer, R. F., & Schwarz, N. (1994). Need for cognition: eine Skala zur Erfassung von Engagement und Freude bei Denkaufgaben: need for cognition: a scale measuring engagement and happiness in cognitive tasks. *Zeitschrift für Sozialpsychologie*, *25*.

Blondell, S. J., Hammersley-Mather, R., & Veerman, J. L. (2014). Does physical activity prevent cognitive decline and dementia?: A systematic review and meta-analysis of longitudinal studies. *BMC public health*, *14*(1), 510.

Boehme, A. K., Esenwa, C., & Elkind, M. S. (2017). Stroke Risk Factors, Genetics, and Prevention. *Circ Res*, *120*(3), 472-495. https://doi.org/10.1161/CIRCRESAHA.116.308398

Bogg, T., & Roberts, B. W. (2004). Conscientiousness and health-related behaviors: a meta-analysis of the leading behavioral contributors to mortality. *Psychol Bull*, *130*(6), 887-919. https://doi.org/10.1037/0033-2909.130.6.887

Bohannon, R. W. (1997). Comfortable and maximum walking speed of adults aged 20—79 years: reference values and determinants. *Age Ageing*, *26*(1), 15-19.

Boot, W. R., Simons, D. J., Stothart, C., & Stutts, C. (2013). The Pervasive Problem With Placebos in Psychology: Why Active Control Groups Are Not Sufficient to Rule Out Placebo Effects. *Perspectives on Psychological Science*, *8*(4), 445-454. https://doi.org/10.1177/1745691613491271

Booth, J. E., Schinka, J. A., Brown, L. M., Mortimer, J. A., & Borenstein, A. R. (2006). Five-factor personality dimensions, mood states, and cognitive performance in older adults. *J Clin Exp Neuropsychol*, *28*(5), 676-683. https://doi.org/10.1080/13803390590954209

Booth, T., Mottus, R., Corley, J., Gow, A. J., Henderson, R. D., Maniega, S. M., . . . Deary, I. J. (2014). Personality, health, and brain integrity: the Lothian birth cohort study 1936. *Health Psychol*, *33*(12), 1477-1486. https://doi.org/10.1037/hea0000012

Booth-Kewley, S., & Vickers Jr, R. R. (1994). Associations between Major Domains of Personality and Health Behavior. *Journal of Personality*, *62*(3), 281-298. https://doi.org/10.1111/j.1467-6494.1994.tb00298.x

Bopp, K. L., & Verhaeghen, P. (2005). Aging and verbal memory span: A meta-analysis. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *60*(5), P223-P233.

Borella, E., Carretti, B., Cantarella, A., Riboldi, F., Zavagnin, M., & De Beni, R. (2014). Benefits of training visuospatial working memory in young–old and old–old. *Developmental Psychology*, *50*(3), 714-727. https://doi.org/10.1037/a0034293

Borella, E., Carretti, B., Riboldi, F., & De Beni, R. (2010). Working memory training in older adults: evidence of transfer and maintenance effects. *Psychol Aging*, *25*(4), 767-778. https://doi.org/10.1037/a0020683

Bornstein, M. H., Jager, J., & Putnick, D. L. (2013). Sampling in developmental science: Situations, shortcomings, solutions, and standards. *Developmental Review*, *33*(4), 357-370. https://doi.org/https://doi.org/10.1016/j.dr.2013.08.003

Bottiroli, S., & Cavallini, E. (2009). Can computer familiarity regulate the benefits of computer-based memory training in normal aging? A study with an Italian sample of older adults. *Aging, Neuropsychology, and Cognition*, *16*(4), 401-418.

Bowen, N. K., & Guo, S. (2011). *Structural Equation Modeling*. Oxford University Press.

Boyle, P. A., Yu, L., Wilson, R. S., Segawa, E., Buchman, A. S., & Bennett, D. A. (2013). Cognitive decline impairs financial and health literacy among community-based older persons without dementia. *Psychology and Aging*, *28*(3), 614.

Brodaty, H., Mothakunnel, A., de Vel-Palumbo, M., Ames, D., Ellis, K. A., Reppermund, S., . . . Sachdev, P. S. (2014). Influence of population versus convenience sampling on sample characteristics in studies of cognitive aging.

Annals of Epidemiology, *24*(1), 63-71. https://doi.org/https://doi.org/10.1016/j.annepidem.2013.10.005

Browne, M. W., & Cudeck, R. (1992). Alternative Ways of Assessing Model Fit. *Sociological Methods & Research*, *21*(2), 230-258. https://doi.org/10.1177/0049124192021002005

Bugos, J. A., Perlstein, W. M., McCrae, C. S., Brophy, T. S., & Bedenbaugh, P. H. (2007). Individualized piano instruction enhances executive functioning and working memory in older adults. *Aging and mental health*, *11*(4), 464-471.

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology*, *42*(1), 116-131. https://doi.org/10.1037/0022-3514.42.1.116

Cacioppo, J. T., Petty, R. E., & Feng Kao, C. (1984). The efficient assessment of need for cognition. *Journal of Personality Assessment*, *48*(3), 306-307.

Calamia, M., Markon, K., & Tranel, D. (2012). Scoring Higher the Second Time Around: Meta-Analyses of Practice Effects in Neuropsychological Assessment. *The Clinical Neuropsychologist*, *26*(4), 543-570. https://doi.org/10.1080/13854046.2012.680913

Carlson, M. C., Parisi, J. M., Xia, J., Xue, Q.-L., Rebok, G. W., Bandeen-Roche, K., & Fried, L. P. (2012). Lifestyle Activities and Memory: Variety May Be the Spice of Life. The Women's Health and Aging Study II. *Journal of the International Neuropsychological Society*, *18*(2), 286-294. https://doi.org/10.1017/S135561771100169X

Carlson, M. C., Saczynski, J. S., Rebok, G. W., Seeman, T., Glass, T. A., McGill, S., . . . Fried, L. P. (2008). Exploring the Effects of an ‘‘Everyday’’ Activity Program on Executive Function and Memory in Older Adults: Experience Corps. *The Gerontologist*, *48*(6), 793-801.

Carretti, B., Borella, E., Zavagnin, M., & De Beni, R. (2011). Impact of metacognition and motivation on the efficacy of strategic memory training in older adults: analysis of specific, transfer and maintenance effects. *Arch Gerontol Geriatr*, *52*(3), e192-197. https://doi.org/10.1016/j.archger.2010.11.004

Carretti, B., Borella, E., Zavagnin, M., & de Beni, R. (2013). Gains in language comprehension relating to working memory training in healthy older adults. *International journal of geriatric psychiatry*, *28*(5), 539-546.

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. Cambridge University Press.

Cattell, H. E. P., & Mead, A. D. (2008). The Sixteen Personality Factor Questionnaire (16PF). In *The SAGE handbook of personality theory and assessment, Vol 2: Personality measurement and testing.* (pp. 135-159). Sage Publications, Inc. https://doi.org/10.4135/9781849200479.n7

Cattell, R. B. (1943). The measurement of adult intelligence. *Psychological bulletin*, *40*(3), 153.

Cavallini, E., Dunlosky, J., Bottiroli, S., Hertzog, C., & Vecchi, T. (2010). Promoting transfer in memory training for older adults. *Aging clinical and experimental research*, *22*(4), 314-323.

Cerino, E. S., Hooker, K., Goodrich, E., & Dodge, H. H. (2020). Personality Moderates Intervention Effects on Cognitive Function: A 6-Week Conversation-Based Intervention. *The Gerontologist*, *60*(5), 958-967. https://doi.org/10.1093/geront/gnz063

Chambon, C., & Alescio-Lautier, B. (2019). Improved executive functioning in healthy older adults after multifactorial cognitive training targeting controlled processes. *Journal of Systems and Integrative Neuroscience*, *6*.

Chamorro-Premuzic, T., Furnham, A., & Petrides, K. (2006). Personality and intelligence: The relationship of Eysenck's Giant Three with verbal and numerical ability. *Journal of Individual Differences*, *27*(3), 147-150. https://doi.org/10.1027/1614-0001.27.3.147

Chamorro-Prezumic, T., & Furnham, A. (2004). A possible model for understanding the personality–intelligence interface. *British Journal of Psychology*, *95*(2), 249-264.

Chan, M. Y., Haber, S., Drew, L. M., & Park, D. C. (2016). Training Older Adults to Use Tablet Computers: Does It Enhance Cognitive Function? *Gerontologist*, *56*(3), 475-484. https://doi.org/10.1093/geront/gnu057

Chang, W. (n.d.). *Plotting means and error bars (ggplot2)*. Retrieved October 28, 2021 from http://www.cookbook-r.com/Graphs/Plotting_means_and_error_bars_(ggplot2)/

Chapman, B., Duberstein, P., Tindle, H. A., Sink, K. M., Robbins, J., Tancredi, D. J., . . . Investigators, G. E. o. M. S. (2012). Personality predicts cognitive function over 7 years in older persons. *The American Journal of Geriatric Psychiatry*, *20*(7), 612-621.

Chapman, B. P., Benedict, R. H., Lin, F., Roy, S., Federoff, H. J., & Mapstone, M. (2017). Personality and Performance in Specific Neurocognitive Domains Among Older Persons. *The American journal of geriatric psychiatry : official journal of the American Association for Geriatric Psychiatry*, *25*(8), 900-908. https://doi.org/10.1016/j.jagp.2017.03.006

Chapman, B. P., Hampson, S., & Clarkin, J. (2014). Personality-informed interventions for healthy aging: conclusions from a National Institute on Aging work group. *Dev Psychol*, *50*(5), 1426-1441. https://doi.org/10.1037/a0034135

Chapman, B. P., Roberts, B., & Duberstein, P. (2011). Personality and longevity: knowns, unknowns, and implications for public health and personalized medicine. *J Aging Res*, *2011*, 759170. https://doi.org/10.4061/2011/759170

Cheng, Y., Wu, W., Feng, W., Wang, J., Chen, Y., Shen, Y., . . . Li, C. (2012). The effects of multi-domain versus single-domain cognitive training in non-demented older people: a randomized controlled trial. *BMC medicine*, *10*(1), 30.

Christensen, A. J., & Smith, T. W. (1995). Personality and patient adherence: correlates of the five-factor model in renal dialysis. *Journal of behavioral medicine*, *18*(3), 305-313.

Christensen, H., Mackinnon, A. J., Korten, A., Jorm, A. F., Henderson, A., Jacomb, P., & Rodgers, B. (1999). An analysis of diversity in the cognitive performance of elderly community dwellers: individual differences in change scores as a function of age. *Psychology and aging*, *14*(3), 365.

Cicero. (1923). On Old Age. On Friendship. On Divination (W. A. Falconer, Trans.). In (Vol. Loeb Classical Library 154). Cambridge, MA: Harvard University Press. (Original work published 44 B.C.E.)

Coley, N., Ngandu, T., Lehtisalo, J., Soininen, H., Vellas, B., Richard, E., . . . Coley, N. (2019). Adherence to multidomain interventions for dementia prevention: Data from the FINGER and MAPT trials. *Alzheimer's & Dementia*, *15*(6), 729-741. https://doi.org/https://doi.org/10.1016/j.jalz.2019.03.005

Collins, L. M., Schafer, J. L., & Kam, C.-M. (2001). A comparison of inclusive and restrictive strategies in modern missing data procedures. *Psychological methods*, *6*(4), 330.

Collins, N., Sachs-Ericsson, N., Preacher, K. J., Sheffield, K. M., & Markides, K. (2009). Smoking increases risk for cognitive decline among community-dwelling older Mexican Americans. *The American Journal of Geriatric Psychiatry*, *17*(11), 934-942. https://doi.org/10.1097/JGP.0b013e3181b0f8df

Corley, J., Gow, A. J., Starr, J. M., & Deary, I. J. (2012). Smoking, childhood IQ, and cognitive function in old age. *Journal of Psychosomatic Research*, *73*(2), 132-138. https://doi.org/https://doi.org/10.1016/j.jpsychores.2012.03.006

Corley, J., Starr, J. M., McNeill, G., & Deary, I. J. (2013). Do dietary patterns influence cognitive function in old age? *International psychogeriatrics*, *25*(9), 1393-1407.

Corner, L., & Bond, J. (2004). Being at risk of dementia: Fears and anxieties of older adults. *Journal of aging studies*, *18*(2), 143-155.

Cornwell, B. (2011). Age Trends in Daily Social Contact Patterns. *Res Aging*, *33*(5), 598-631. https://doi.org/10.1177/0164027511409442

Costa, P., & McCrae, R. (1985). *Manual for the NEO Personality Inventory*. Psychological Assessment Resources.

Costa, P. T., Jr., Fozard, J. L., McCrae, R. R., & Bossé, R. (1976). Relations of Age and Personality Dimensions to Cognitive Ability Factors. *Journal of Gerontology*, *31*(6), 663-669. https://doi.org/10.1093/geronj/31.6.663

Costa, P. T., & McCrae, R. R. (1992a). *Manual for the Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI)*. Psychological Assessment Resources.

Costa, P. T., & McCrae, R. R. (1992b). Normal personality assessment in clinical practice: The NEO Personality Inventory. *Psychological assessment*, *4*(1), 5.

Coubard, O. A., Duretz, S., Lefebvre, V., Lapalus, P., & Ferrufino, L. (2011). Practice of contemporary dance improves cognitive flexibility in aging. *Frontiers in aging neuroscience*, *3*, 13.

Courtin, E., & Knapp, M. (2017). Social isolation, loneliness and health in old age: a scoping review. *Health Soc Care Community*, *25*(3), 799-812. https://doi.org/10.1111/hsc.12311

Craig, C. L., Marshall, A. L., Sjorstrom, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., . . . Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise*, *35*(8), 1381-1395. https://doi.org/10.1249/01.MSS.0000078924.61453.FB

Craik, F. I., & Bialystok, E. (2006). Cognition through the lifespan: mechanisms of change. *Trends Cogn Sci*, *10*(3), 131-138. https://doi.org/10.1016/j.tics.2006.01.007

Craik, F. I., Winocur, G., Palmer, H., Binns, M. A., Edwards, M., Bridges, K., . . . Stuss, D. T. (2007). Cognitive rehabilitation in the elderly: effects on memory. *Journal of the International Neuropsychological Society*, *13*(1), 132-142.

Crum, R. M., Anthony, J. C., Bassett, S. S., & Folstein, M. F. (1993). Population-Based Norms for the Mini-Mental State Examination by Age and Educational Level. *JAMA*, *269*(18), 2386-2391. https://doi.org/10.1001/jama.1993.03500180078038

Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychological methods*, *1*(1), 16.

Curtis, R. G., Windsor, T. D., & Soubelet, A. (2015). The relationship between Big-5 personality traits and cognitive ability in older adults - a review. *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn*, *22*(1), 42-71. https://doi.org/10.1080/13825585.2014.888392

De Buyser, S. L., Petrovic, M., Taes, Y. E., Vetrano, D. L., & Onder, G. (2014). A multicomponent approach to identify predictors of hospital outcomes in older in-patients: a multicentre, observational study. *PloS one*, *9*(12).

Deary, I. J., Corley, J., Gow, A. J., Harris, S. E., Houlihan, L. M., Marioni, R. E., . . . Starr, J. M. (2009). Age-associated cognitive decline. *British Medical Bulletin*, *92*(1), 135-152.

Deary, I. J., Gow, A. J., Pattie, A., & Starr, J. M. (2012). Cohort profile: the Lothian Birth Cohorts of 1921 and 1936. *International journal of epidemiology*, *41*(6), 1576-1584.

Deary, I. J., Johnson, W., & Houlihan, L. M. (2009). Genetic foundations of human intelligence. *Human genetics*, *126*(1), 215-232.

Deary, I. J., Whalley, L. J., Batty, G. D., & Starr, J. M. (2006). Physical fitness and lifetime cognitive change. *Neurology*, *67*(7), 1195-1200. https://doi.org/10.1212/01.wnl.0000238520.06958.6a

Deary, I. J., Whiteman, M. C., Starr, J. M., Whalley, L. J., & Fox, H. C. (2004). The impact of childhood intelligence on later life: following up the Scottish mental surveys of 1932 and 1947. *Journal of personality and social psychology*, *86*(1), 130.

Deary, I. J., Wright, A. F., Harris, S. E., Whalley, L. J., & Starr, J. M. (2004). Searching for genetic influences on normal cognitive ageing. *Trends in cognitive sciences*, *8*(4), 178-184.

Der, G., & Deary, I. J. (2006). Age and sex differences in reaction time in adulthood: results from the United Kingdom Health and Lifestyle Survey. *Psychology and aging*, *21*(1), 62.

Derwinger, A., Stigsdotter Neely, A., & Backman, L. (2005). Design your own memory strategies! Self-generated strategy training versus mnemonic training in old age: an 8-month follow-up. *Neuropsychol Rehabil*, *15*(1), 37-54. https://doi.org/10.1080/09602010343000336

DeYoung, C. G., Quilty, L. C., Peterson, J. B., & Gray, J. R. (2014). Openness to Experience, Intellect, and Cognitive Ability. *Journal of Personality Assessment, 96*(1), 46-52. https://doi.org/10.1080/00223891.2013.806327

Dodge, H. H., Zhu, J., Mattek, N. C., Bowman, M., Ybarra, O., Wild, K. V., . . . Kaye, J. A. (2015). Web-enabled conversational interactions as a method to improve cognitive functions: Results of a 6-week randomized controlled trial. *Alzheimer's & Dementia: Translational Research & Clinical Interventions*, *1*(1), 1-12.

Double, K. S., & Birney, D. P. (2016). The effects of personality and metacognitive beliefs on cognitive training adherence and performance. *Personality and Individual Differences*, *102*, 7-12. https://doi.org/10.1016/j.paid.2016.04.101

Dufouil, C., Fuhrer, R., Dartigues, J.-F., & Alpérovitch, A. (1996). Longitudinal analysis of the association between depressive symptomatology and cognitive deterioration. *American Journal of Epidemiology*, *144*(7), 634-641.

Edwards, J. D., Wadley, V., Vance, D., Wood, K., Roenker, D., & Ball, K. (2005). The impact of speed of processing training on cognitive and everyday performance. *Aging & mental health, 9*(3), 262-271.

Edwards, J. D., Wadley, V. G., Myers, R. S., Roenker, D. L., Cissell, G. M., & Ball, K. K. (2002). Transfer of a speed of processing intervention to near and far cognitive functions. *Genrontology*, *48*(5), 329-340.

Eekhout, I., de Vet, H. C. W., Twisk, J. W. R., Brand, J. P. L., de Boer, M. R., & Heymans, M. W. (2014). Missing data in a multi-item instrument were best handled by multiple imputation at the item score level. *Journal of Clinical Epidemiology*, *67*(3), 335-342. https://doi.org/https://doi.org/10.1016/j.jclinepi.2013.09.009

Egan, V., Deary, I., & Austin, E. (2000). The NEO-FFI: emerging British norms and an item-level analysis suggest N, A and C are more reliable than O and E. *Personality and Individual Differences*, *29*(5), 907-920. https://doi.org/https://doi.org/10.1016/S0191-8869(99)00242-1

Emerson, J. L., Johnson, A. M., Dawson, J. D., Uc, E. Y., Anderson, S. W., & Rizzo, M. (2012). Predictors of driving outcomes in advancing age. *Psychology and aging*, *27*(3), 550.

Enders, C. K. (2010). *Applied Missing Data Analysis*. The Guildford Press.

Eysenck, H. J. (1968). *Eysenck Personality Inventory Manual*. Educational and Industrial Testing Service.

Eysenck, H. J. (1990). Biological dimensions of personality. In *Handbook of personality: Theory and research.* (pp. 244-276). The Guilford Press.

Farrer, L. A., Cupples, L. A., Haines, J. L., Hyman, B., Kukull, W. A., Mayeux, R., . . . Van Duijn, C. M. (1997). Effects of age, sex, and ethnicity on the association between apolipoprotein E genotype and Alzheimer disease: a meta-analysis. *Jama*, *278*(16), 1349-1356.

Fillenbaum, G., Hughes, D., Heyman, A., George, L., & Blazer, D. (1988). Relationship of health and demographic characteristics to Mini-Mental State Examination score among community residents. *Psychological medicine*, *18*(3), 719-726.

Finkel, S. I., & Yesavage, J. A. (1989). Learning mnemonics: a preliminary evaluation of a computer-aided instruction package for the elderly. *Exp Aging Res*, *15*(3-4), 199-201. https://doi.org/10.1080/03610738908259776

Finney, S. J., & DiStefano, C. (2006). Non-normal and Categorical Data in Structural Equation Modeling. In G. R. Hancock & R. O. Mueller (Eds.), *Structural Equation Modeling: A Second Course* (pp. 269-314). Information Age Publishing.

Fleming, K. A., Heintzelman, S. J., & Bartholow, B. D. (2016). Specifying Associations Between Conscientiousness and Executive Functioning: Mental Set Shifting, Not Prepotent Response Inhibition or Working Memory Updating. *Journal of personality*, *84*(3), 348-360. https://doi.org/10.1111/jopy.12163

Floyd, F. J., & Widaman, K. F. (1995). Factor analysis in the development and refinement of clinical assessment instruments. *Psychological assessment*, *7*(3), 286.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. *Journal of psychiatric research*, *12*(3), 189-198.

Fonda, S. J., Wallace, R. B., & Herzog, A. R. (2001). Changes in Driving Patterns and Worsening Depressive Symptoms Among Older Adults. *The Journals of Gerontology: Series B*, *56*(6), S343-S351. https://doi.org/10.1093/geronb/56.6.S343

Friebel, R. (2018). *Trends in the number of English NHS hospital admissions, 2006 to 2016*. The Health Foundation. https://www.health.org.uk/chart/chart-trends-in-the-number-of-english-nhs-hospital-admissions-2006-to-2016

Fried, L. P., Carlson, M. C., Freedman, M., Frick, K. D., Glass, T. A., Hill, J., . . . Zeger, S. (2004). A social model for health promotion for an aging population: Initial evidence on the experience corps model. *Journal of Urban Health*, *81*(1), 64-78. https://doi.org/10.1093/jurban/jth094

Friedman, H. S. (2000). Long-term relations of personality and health: Dynamisms, mechanisms, tropisms. *Journal of personality*, *68*(6), 1089-1107.

Friedman, H. S., & Kern, M. L. (2014). Personality, Well-Being, and Health. *Annual Review of Psychology*, *65*(1), 719-742. https://doi.org/10.1146/annurev-psych-010213-115123

Gabrys, J. B. (1982). Validity and Reliability of the Eysenck Personality Inventory with Outpatients. *Psychological Reports*, *51*(2), 541-542. https://doi.org/10.2466/pr0.1982.51.2.541

Gaertner, B., Seitz, I., Fuchs, J., Busch, M. A., Holzhausen, M., Martus, P., & Scheidt-Nave, C. (2016). Baseline participation in a health examination survey of the population 65 years and older: who is missed and why? *BMC Geriatrics*, *16*(1), 21. https://doi.org/10.1186/s12877-016-0185-6

Gajewski, P. D., & Falkenstein, M. (2012). Training-induced improvement of response selection and error detection in aging assessed by task switching: Effects of cognitive, physical, and relaxation training. *Frontiers in Human Neuroscience*, *6*, 18. https://doi.org/http://dx.doi.org/10.3389/fnhum.2012.00130

Gallagher, K. M., & Updegraff, J. A. (2012). Health message framing effects on attitudes, intentions, and behavior: a meta-analytic review. *Ann Behav Med*, *43*(1), 101-116. https://doi.org/10.1007/s12160-011-9308-7

Ganguli, M., Vander Bilt, J., Saxton, J., Shen, C., & Dodge, H. (2005). Alcohol consumption and cognitive function in late life: a longitudinal community study. *Neurology*, *65*(8), 1210-1217.

Gee, E. M. (2002). Misconceptions and misapprehensions about population ageing. *International Journal of Epidemiology*, *31*(4), 750-753.

Ghisletta, P., Bickel, J.-F., & Lövdén, M. (2006). Does activity engagement protect against cognitive decline in old age? Methodological and analytical considerations. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *61*(5), 253-261. https://doi.org/10.1093/geronb/61.5.P253

Ginet, A., & Py, J. (2000). Need for cognition: A French scale for children and its consequences on a sociocognitive level. *Année Psychologique*, *100*(4), 585-628.

Global Council on Brain Health. (2016). *The Brain-Body Connection: GCBH Recommendations on Physical Activity and Brain Health*. https://www.aarp.org/content/dam/aarp/health/brain_health/2016/05/gcbh-the-brain-body-connection.pdf

Global Council on Brain Health. (2017a). *Engage Your Brain: GCBH Recommendations on Cognitively Stimulating Activities*. https://www.aarp.org/content/dam/aarp/health/brain_health/2017/07/gcbh-cognitively-stimulating-activities-report-english-aarp.doi.10.26419%252Fpia.00001.001.pdf

Global Council on Brain Health. (2017b). *The Brain and Social Connectedness: GCBH Recommendations on Social Engagement and Brain Health*. https://www.aarp.org/content/dam/aarp/health/brain_health/2017/02/gcbh-social-engagement-report-english-aarp.doi.10.26419%252Fpia.00015.001.pdf

Global Council on Brain Health. (2018). *Brain Food: GCBH Recommendations on Nourishing Your Brain Health*. https://www.aarp.org/content/dam/aarp/health/brain_health/2018/01/gcbh-recommendations-on-nourishing-your-brain-health.doi.10.26419%252Fpia.00019.001.pdf

Goghari, V. M., & Lawlor-Savage, L. (2017). Comparison of cognitive change after working memory training and logic and planning training in healthy older adults. *Frontiers in aging neuroscience*, *9*, 39.

Goldberg, L. R. (1999). A broad-bandwidth, public domain, personality inventory measuring the lower-level facets of several five-factor models. In I. Mervielde, I. J. Deary, F. D. Fruyt, & F. Ostendorf (Eds.), *Personality Psychology in Europe* (Vol. 7, pp. 7-28). Tilburg University Press.

Gorbach, T., Pudas, S., Lundquist, A., Orädd, G., Josefsson, M., Salami, A., . . . Nyberg, L. (2017). Longitudinal association between hippocampus atrophy and episodic-memory decline. *Neurobiology of Aging*, *51*, 167-176. https://doi.org/https://doi.org/10.1016/j.neurobiolaging.2016.12.002

Goretzko, D., Heumann, C., & Bühner, M. (2019). Investigating Parallel Analysis in the Context of Missing Data: A Simulation Study Comparing Six Missing Data Methods. *Educational and Psychological Measurement*, *80*(4), 756-774. https://doi.org/10.1177/0013164419893413

Gothe, N. P., Kramer, A. F., & McAuley, E. (2014). The effects of an 8-week Hatha yoga intervention on executive function in older adults. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, *69*(9), 1109-1116.

Government Office for Science. (2016). *Future of an ageing population*. UK Retrieved from https://www.gov.uk/government/publications/future-of-an-ageing-population

Gow, A. J., Corley, J., Starr, J. M., & Deary, I. J. (2012). Reverse causation in activity-cognitive ability associations: the Lothian Birth Cohort 1936. *Psychol Aging*, *27*(1), 250-255. https://doi.org/10.1037/a0024144

Gow, A. J., Pattie, A., & Deary, I. J. (2017). Lifecourse Activity Participation From Early, Mid, and Later Adulthood as Determinants of Cognitive Aging: The Lothian Birth Cohort 1921. *J Gerontol B Psychol Sci Soc Sci*, *72*(1), 25-37. https://doi.org/10.1093/geronb/gbw124

Gow, A. J., Whiteman, M. C., Pattie, A., & Deary, I. J. (2005a). Goldberg's 'IPIP' Big-Five factor markers: Internal consistency and concurrent validation in Scotland. *Personality and Individual Differences*, *39*(2), 317-329. https://doi.org/https://doi.org/10.1016/j.paid.2005.01.011

Gow, A. J., Whiteman, M. C., Pattie, A., & Deary, I. J. (2005b). The personality–intelligence interface: insights from an ageing cohort. *Personality and Individual Differences*, *39*(4), 751-761. https://doi.org/10.1016/j.paid.2005.01.028

Gow, J., & Gilhooly, M. (2003). *Risk Factors for Dementia and Cognitive Decline*. Glasgow: NHS Health Scotland

Graham, E. K., Rutsohn, J. P., Turiano, N. A., Bendayan, R., Batterham, P. J., Gerstorf, D., . . . Mroczek, D. K. (2017). Personality Predicts Mortality Risk: An Integrative Data Analysis of 15 International Longitudinal Studies. *Journal of research in personality*, *70*, 174-186. https://doi.org/10.1016/j.jrp.2017.07.005

Graham, J. M., Guthrie, A. C., & Thompson, B. (2003). Consequences of Not Interpreting Structure Coefficients in Published CFA Research: A Reminder. *Structural Equation Modeling: A Multidisciplinary Journal*, *10*(1), 142-153. https://doi.org/10.1207/S15328007SEM1001_7

Gratzinger, P., Sheikh, J. I., Friedman, L., & Yesavage, J. A. (1990). Cognitive interventions to improve face-name recall: The role of personality trait differences. *Developmental Psychology, 26*(6), 889-893. https://doi.org/http://dx.doi.org/10.1037/0012-1649.26.6.889

Gray, R., & Gow, A. J. (2020). How is musical activity associated with cognitive ability in later life? *Aging, Neuropsychology, and Cognition*, *27*(4), 617-635.

Graziano, W. G., & Eisenberg, N. (1997). Agreeableness: A dimension of personality. In *Handbook of personality psychology* (pp. 795-824). Elsevier.

Graziano, W. G., Habashi, M. M., Sheese, B. E., & Tobin, R. M. (2007). Agreeableness, empathy, and helping: A person × situation perspective. *Journal of Personality and Social Psychology, 93*(4), 583-599. https://doi.org/10.1037/0022-3514.93.4.583

Greiner, P. A., Snowdon, D. A., & Schmitt, F. A. (1996). The loss of independence in activities of daily living: the role of low normal cognitive function in elderly nuns. *American Journal of Public Health*, *86*(1), 62-66.

Gunning-Dixon, F. M., & Raz, N. (2003). Neuroanatomical correlates of selected executive functions in middle-aged and older adults: a prospective MRI study. *Neuropsychologia*, *41*(14), 1929-1941.

Guralnik, J. M., Simonsick, E. M., Ferrucci, L., Glynn, R. J., Berkman, L. F., Blazer, D. G., . . . Wallace, R. B. (1994). A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *Journal of gerontology*, *49*(2), M85-M94.

Guye, S., De Simoni, C., & von Bastian, C. C. (2017). Do Individual Differences Predict Change in Cognitive Training Performance? A Latent Growth Curve Modeling Approach. *Journal of Cognitive Enhancement*, *1*(4), 374-393.

Guye, S., & von Bastian, C. C. (2017). Working memory training in older adults: Bayesian evidence supporting the absence of transfer. *Psychology and Aging*, *32*(8), 732-746. https://doi.org/http://dx.doi.org/10.1037/pag0000206

Gómez-Pinilla, F. (2008). Brain foods: the effects of nutrients on brain function. *Nature reviews neuroscience*, *9*(7), 568-578.

Hajjar, I., & Kotchen, T. A. (2003). Trends in Prevalence, Awareness, Treatment, and Control of Hypertension in the United States, 1988-2000. *Jama*, *290*(2), 199-206.

Hamburg, M. A., & Collins, F. S. (2010). The path to personalized medicine. *New England Journal of Medicine*, *363*(4), 301-304.

Hanna-Pladdy, B., & Gajewski, B. (2012). Recent and past musical activity predicts cognitive aging variability: direct comparison with general lifestyle activities. *Frontiers in Human Neuroscience*, *6*, 198.

Hanna-Pladdy, B., & MacKay, A. (2011). The relation between instrumental musical activity and cognitive aging. *Neuropsychology*, *25*(3), 378.

Hansson, I., Berg, A. I., & Thorvaldsson, V. (2018). Can personality predict longitudinal study attrition? Evidence from a population-based sample of older adults. *Journal of Research in Personality*, *77*, 133-136. https://doi.org/https://doi.org/10.1016/j.jrp.2018.10.002

Harrison, A., & Ragland, D. R. (2003). Consequences of driving reduction or cessation for older adults. *Transportation Research Record*, *1843*(1), 96-104.

Harrison, E., Drake, T., & Ots, R. (2020). finalfit: Quickly Create Elegant Regression Results Tables and Plots when Modelling. R package version 1.0.1. https://CRAN.R-project.org/package=finalfit

Hartshorne, J. K., & Germine, L. T. (2015). When does cognitive functioning peak? The asynchronous rise and fall of different cognitive abilities across the life span. *Psychological science*, *26*(4), 433-443.

Hendrie, H. C., Albert, M. S., Butters, M. A., Gao, S., Knopman, D. S., Launer, L. J., . . . Wagster, M. V. (2006). The NIH Cognitive and Emotional Health Project. Report of the Critical Evaluation Study Committee. *Alzheimers Dement*, *2*(1), 12-32. https://doi.org/10.1016/j.jalz.2005.11.004

Hering, A., Meuleman, B., Bürki, C., Borella, E., & Kliegel, M. (2017). Improving Older Adults' Working Memory: the Influence of Age and Crystallized Intelligence on Training Outcomes. *Journal of Cognitive Enhancement*, *1*(4), 358-373.

Hertzog, C., Kramer, A. F., Wilson, R. S., & Lindenberger, U. (2008). Enrichment Effects on Adult Cognitive Development: Can the Functional Capacity of Older Adults Be Preserved and Enhanced? *Psychol Sci Public Interest*, *9*(1), 1-65. https://doi.org/10.1111/j.1539-6053.2009.01034.x

Higgins, J. P. T., & Altman, D. G. (2008). Assessing risk of bias in included studies. In J. P. T. Higgins & S. Green (Eds.), *Cochrane handbook for systematic reviews of interventions* (pp. 187-241). Wiley.

Higgins, J. P. T., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., . . . Sterne, J. A. C. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*, *343*, d5928.

Hilbert, S., Stadler, M., Lindl, A., Naumann, F., & Bühner, M. (2019). ANALYZING LONGITUDINAL INTERVENTION STUDIES WITH LINEAR MIXED MODELS. *TPM: Testing, Psychometrics, Methodology in Applied Psychology*, *26*(1), 101-119. https://doi.org/10.4473/TPM26.1.6

Hill, P. L., & Payne, B. R. (2016). Don’t forget the person when promoting healthy cognitive aging: Comment on Smith (2016). *American Psychologist*, *72*(4), 390-392.

Hill, P. L., & Roberts, B. W. (2011). The role of adherence in the relationship between conscientiousness and perceived health. *Health Psychol*, *30*(6), 797-804. https://doi.org/10.1037/a0023860

Hill, R. D., Yesavage, J. A., Sheikh, J., & Friedman, L. (1989). Mental status as a predictor of response to memory training in older adults. *Educational Gerontology*, *15*(6), 633-639. https://doi.org/10.1080/0380127890150607

Hochstenbach, J., Mulder, T., van Limbeek, J., Donders, R., & Schoonderwaldt, H. (1998). Cognitive decline following stroke: a comprehensive study of cognitive decline following stroke. *Journal of clinical and experimental neuropsychology*, *20*(4), 503-517.

Hofmann, R. J. (1978). Complexity And Simplicity As Objective Indices Descriptive Of Factor Solutions. *Multivariate Behavioral Research*, *13*(2), 247-250. https://doi.org/10.1207/s15327906mbr1302_9

Hogan, M. J. (2003). Divided Attention in Older But Not Younger Adults Is Impaired by Anxiety. *Experimental Aging Research*, *29*(2), 111-136. https://doi.org/10.1080/03610730303712

Hogan, M. J., Staff, R. T., Bunting, B. P., Deary, I. J., & Whalley, L. J. (2012). Openness to experience and activity engagement facilitate the maintenance of verbal ability in older adults. *Psychology and Aging*, *27*(4), 849.

Horn, J. L. (1965). A rationale and test for the number of factors in factor analysis. *Psychometrika*, *30*(2), 179-185. https://doi.org/10.1007/BF02289447

Horn, J. L., & Cattell, R. B. (1967). Age differences in fluid and crystallized intelligence. *Acta psychologica*, *26*, 107-129.

Hoyer, W. J., Stawski, R. S., Wasylyshyn, C., & Verhaeghen, P. (2004). Adult age and digit symbol substitution performance: a meta-analysis. *Psychology and aging*, *19*(1), 211.

Hu, L. t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1-55. https://doi.org/10.1080/10705519909540118

Hultsch, D. F., Hammer, M., & Small, B. J. (1993). Age Differences in Cognitive Performance in Later Life: Relationships to Self-Reported Health and Activity Life Style. *Journal of Gerontology*, *48*(1), P1-P11. https://doi.org/10.1093/geronj/48.1.P1

Hultsch, D. F., Hertzog, C., Small, B. J., & Dixon, R. A. (1999). Use it or lose it: engaged lifestyle as a buffer of cognitive decline in aging? *Psychol Aging*, *14*(2), 245-263.

Ihle, A., Oris, M., Fagot, D., Maggiori, C., & Kliegel, M. (2016). The association of educational attainment, cognitive level of job, and leisure activities during the course of adulthood with cognitive performance in old age: the role of openness to experience. *Int Psychogeriatr*, *28*(5), 733-740. https://doi.org/10.1017/s1041610215001933

Ihle, A., Zuber, S., Gouveia, É. R., Gouveia, B. R., Mella, N., Desrichard, O., . . . Kliegel, M. (2019). Cognitive Reserve Mediates the Relation between Openness to Experience and Smaller Decline in Executive Functioning. *Dementia and Geriatric Cognitive Disorders*, *48*(1-2), 39-44. https://doi.org/10.1159/000501822

Izaks, G. J., Gussekloo, J., Dermout, K., Heeren, T., & Ligthart, G. (1995). Three-year follow-up of Mini-Mental State Examination score in community residents aged 85 and over. *Psychological medicine*, *25*(4), 841-848.

Jackson, J. J., Hill, P. L., Payne, B. R., Parisi, J. M., & Stine-Morrow, E. A. L. (2020). Linking openness to cognitive ability in older adulthood: The role of activity diversity. *Aging & Mental Health*, *24*(7), 1079-1087. https://doi.org/10.1080/13607863.2019.1655705

Jackson, J. J., Hill, P. L., Payne, B. R., Roberts, B. W., & Stine-Morrow, E. A. L. (2012). Can An Old Dog Learn (and Want To Experience) New Tricks? Cognitive Training Increases Openness to Experience in Older Adults. *Psychology and Aging*, *27*(2), 286-292. https://doi.org/10.1037/a0025918

Jacqmin-Gadda, H., Fabrigoule, C., Commenges, D., & Dartigues, J.-F. (1997). A 5-year longitudinal study of the Mini-Mental State Examination in normal aging. *American journal of epidemiology*, *145*(6), 498-506.

James, B. D., Wilson, R. S., Barnes, L. L., & Bennett, D. A. (2011). Late-Life Social Activity and Cognitive Decline in Old Age. *Journal of the International Neuropsychological Society*, *17*(6), 998-1005. https://doi.org/10.1017/s1355617711000531

James, K., Quirk, A., Patterson, S., Brennan, G., & Stewart, D. (2017). Quality of intervention delivery in a cluster randomised controlled trial: a qualitative observational study with lessons for fidelity. *Trials*, *18*(1), 548. https://doi.org/10.1186/s13063-017-2189-8

Jerant, A., Chapman, B., Duberstein, P., Robbins, J., & Franks, P. (2011). Personality and medication non-adherence among older adults enrolled in a six-year trial. *Br J Health Psychol*, *16*(Pt 1), 151-169. https://doi.org/10.1348/135910710X524219

John, O. P., Angleitner, A., & Ostendorf, F. (1988). The lexical approach to personality: A historical review of trait taxonomic research. *European Journal of Personality*, *2*(3), 171-203. https://doi.org/10.1002/per.2410020302

John, O. P., & Srivastava, S. (1999). The Big Five Trait Taxonomy: History, Measurement, and Theoretical Perspectives. In L. A. Pervin & O. P. John (Eds.), *Handbook of Personality: Theory and Research* (2nd ed., pp. 102-138). The Guildford Press.

Johnson, J. K., Lui, L.-Y., & Yaffe, K. (2007). Executive function, more than global cognition, predicts functional decline and mortality in elderly women. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *62*(10), 1134-1141.

Jolijn Hendriks, A. A., Perugini, M., Angleitner, A., Ostendorf, F., Johnson, J. A., De Fruyt, F., . . . Ruisel, I. (2003). The five-factor personality inventory: cross-cultural generalizability across 13 countries. *European Journal of Personality*, *17*(5), 347-373. https://doi.org/10.1002/per.491

Jonasson, L. S., Nyberg, L., Kramer, A. F., Lundquist, A., Riklund, K., & Boraxbekk, C.-J. (2017). Aerobic exercise intervention, cognitive performance, and brain structure: results from the physical influences on brain in aging (PHIBRA) study. *Frontiers in aging neuroscience*, *8*, 336.

Jopp, D. S., & Hertzog, C. (2007). Activities, self-referent memory beliefs, and cognitive performance: Evidence for direct and mediated relations. *Psychology and Aging*, *22*(4), 811-825. https://doi.org/10.1037/0882-7974.22.4.811

Jopp, D. S., & Hertzog, C. (2010). Assessing adult leisure activities: an extension of a self-report activity questionnaire. *Psychol Assess*, *22*(1), 108-120. https://doi.org/10.1037/a0017662

Jorgensen, T. D., Pornprasertmanit, S., Schoemann, A. M., & Rosseel, Y. (2020). *semTools: Useful tools for structural equation modelling*. In (Version 0.5-3) https://CRAN.R-project.org/package=semTools

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika*, *39*(1), 31-36. https://doi.org/10.1007/BF02291575

Karlamangla, A. S., Miller-Martinez, D., Aneshensel, C. S., Seeman, T. E., Wight, R. G., & Chodosh, J. (2009). Trajectories of cognitive function in late life in the United States: demographic and socioeconomic predictors. *American journal of epidemiology*, *170*(3), 331-342.

Katz, S., & Akpom, C. A. (1976). A measure of primary sociobiological functions. *International journal of health services*, *6*(3), 493-508.

Keller, J. N. (2006). Age-related neuropathology, cognitive decline, and Alzheimer's disease. *Ageing Research Reviews*, *5*(1), 1-13. https://doi.org/https://doi.org/10.1016/j.arr.2005.06.002

Kelley, K. (2020). *MBESS: The MBESS R Package*. In (Version 4.7.0) https://CRAN.R-project.org/package=MBESS

Kelly, M. E., Loughrey, D., Lawlor, B. A., Robertson, I. H., Walsh, C., & Brennan, S. (2014a). The impact of cognitive training and mental stimulation on cognitive and everyday functioning of healthy older adults: A systematic review and meta-analysis. *Ageing Research Reviews*, *15*, 28-43.

Kelly, M. E., Loughrey, D., Lawlor, B. A., Robertson, I. H., Walsh, C., & Brennan, S. (2014b). The impact of exercise on the cognitive functioning of healthy older adults: a systematic review and meta-analysis. *Ageing Res Rev*, *16*, 12-31. https://doi.org/10.1016/j.arr.2014.05.002

Kessler, E.-M., Bowen, C. E., Baer, M., Froelich, L., & Wahl, H.-W. (2012). Dementia worry: a psychological examination of an unexplored phenomenon. *European Journal of Ageing*, *9*(4), 275-284.

Klaming, R., Veltman, D. J., & Comijs, H. C. (2017). The impact of personality on memory function in older adults-results from the Longitudinal Aging Study Amsterdam. *Int J Geriatr Psychiatry*, *32*(7), 798-804. https://doi.org/10.1002/gps.4527

Klusmann, V., Evers, A., Schwarzer, R., Schlattmann, P., Reischies, F. M., Heuser, I., & Dimeo, F. C. (2010). Complex mental and physical activity in older women and cognitive performance: a 6-month randomized controlled trial. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, *65*(6), 680-688.

Kramer, A. F., Bherer, L., Colcombe, S. J., Dong, W., & Greenough, W. T. (2004). Environmental Influences on Cognitive and Brain Plasticity During Aging. *Journal of Gerontology: Medical Sciences*, *59A*(9), 940-957.

Kramer, A. F., Colcombe, S. J., McAuley, E., Scalf, P. E., & Erickson, K. I. (2005). Fitness, aging and neurocognitive function. *Neurobiology of aging*, *26*(1), 124-127.

Kramer, J. H., Mungas, D., Reed, B. R., Wetzel, M. E., Burnett, M. M., Miller, B. L., . . . Chui, H. C. (2007). Longitudinal MRI and cognitive change in healthy elderly. *Neuropsychology*, *21*(4), 412-418. https://doi.org/10.1037/0894-4105.21.4.412

Krueger, K. R., Wilson, R. S., Kamenetsky, J. M., Barnes, L. L., Bienias, J. L., & Bennett, D. A. (2009). Social engagement and cognitive function in old age. *Experimental aging research*, *35*(1), 45-60.

Krzeczkowska, A., Spalding, D. M., McGeown, W. J., Gow, A. J., Carlson, M. C., & Nicholls, L. A. B. (2021). A systematic review of the impacts of intergenerational engagement on older adults' cognitive, social, and health outcomes. *Ageing Research Reviews*, *71*, 101400. https://doi.org/https://doi.org/10.1016/j.arr.2021.101400

Kuiper, J. S., Zuidersma, M., Zuidema, S. U., Burgerhof, J. G., Stolk, R. P., Oude Voshaar, R. C., & Smidt, N. (2016). Social relationships and cognitive decline: a systematic review and meta-analysis of longitudinal cohort studies. *International journal of epidemiology*, *45*(4), 1169-1206. https://doi.org/10.1093/ije/dyw089

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software*, *82*(13), 1-26. https://doi.org/10.18637/jss.v082.i13

Kuznetsova, K. A., Maniega, S. M., Ritchie, S. J., Cox, S. R., Storkey, A. J., Starr, J. M., . . . Bastin, M. E. (2016). Brain white matter structure and information processing speed in healthy older age. *Brain Structure and Function, 221*(6), 3223-3235.

Kåreholt, I., Lennartsson, C., Gatz, M., & Parker, M. G. (2011). Baseline leisure time activity and cognition more than two decades later. *International journal of geriatric psychiatry, 26*(1), 65-74.

Küper, K., Gajewski, P. D., Frieg, C., & Falkenstein, M. (2017). A randomized controlled erp study on the effects of multi-domain cognitive training and task difficulty on task switching performance in older adults. *Frontiers in human neuroscience, 11*, 184.

Laditka, J. N., Laditka, S. B., Liu, R., Price, A. E., Wu, B., Friedman, D. B., . . . Hunter, R. (2011). Older adults' concerns about cognitive health: commonalities and differences among six United States ethnic groups. *Ageing & Society, 31*(7), 1202-1228.

Lahey, B. B. (2009). Public health significance of neuroticism. *The American psychologist, 64*(4), 241-256. https://doi.org/10.1037/a0015309

Lam, L. C.-w., Chan, W. C., Leung, T., Fung, A. W.-t., & Leung, E. M.-f. (2015). Would Older Adults with Mild Cognitive Impairment Adhere to and Benefit from a Structured Lifestyle Activity Intervention to Enhance Cognition?: A Cluster Randomized Controlled Trial. *PLOS ONE, 10*(3), e0118173. https://doi.org/10.1371/journal.pone.0118173

Lampit, A., Hallock, H., & Valenzuela, M. (2014). Computerized cognitive training in cognitively healthy older adults: a systematic review and meta-analysis of effect modifiers. *PLoS medicine, 11*(11), e1001756.

Lang, F. R., & Carstensen, L. L. (1994). Close emotional relationships in late life: further support for proactive aging in the social domain. *Psychol Aging*, *9*(2), 315-324. https://doi.org/10.1037//0882-7974.9.2.315

Langbaum, J. B., Rebok, G. W., Bandeen-Roche, K., & Carlson, M. C. (2009). Predicting memory training response patterns: results from ACTIVE. *J Gerontol B Psychol Sci Soc Sci*, *64*(1), 14-23. https://doi.org/10.1093/geronb/gbn026

Lange, S., & Süß, H. M. (2015). Experimental evaluation of near- and far-transfer effects of an adaptive multicomponent working memory training. *Applied Cognitive Psychology*, *29*(4), 502-514. https://doi.org/http://dx.doi.org/10.1002/acp.3126

Larsson, L., Grimby, G., & Karlsson, J. (1979). Muscle strength and speed of movement in relation to age and muscle morphology. *Journal of Applied Physiology*, *46*(3), 451-456.

Lawton, M. P., & Brody, E. M. (1969). Assessment of older people: self-maintaining and instrumental activities of daily living. *The gerontologist*, *9*(3_Part_1), 179-186.

Leanos, S., Kürüm, E., Strickland-Hughes, C. M., Ditta, A. S., Nguyen, G., Felix, M., . . . Wu, R. (2019). The Impact of Learning Multiple Real-World Skills on Cognitive Abilities and Functional Independence in Healthy Older Adults. *The Journals of Gerontology: Series B*. https://doi.org/10.1093/geronb/gbz084

Lee, Y., Back, J. H., Kim, J., Kim, S. H., Na, D. L., Cheong, H. K., . . . Kim, Y. G. (2010). Systematic review of health behavioral risks and cognitive health in older adults. *Int Psychogeriatr*, *22*(2), 174-187. https://doi.org/10.1017/S1041610209991189

Liljas, A. E. M., Walters, K., Jovicic, A., Iliffe, S., Manthorpe, J., Goodman, C., & Kharicha, K. (2017). Strategies to improve engagement of 'hard to reach' older people in research on health promotion: a systematic review. *BMC Public Health*, *17*(1), 349. https://doi.org/10.1186/s12889-017-4241-8

Lloret-Segura, S., Ferreres-Traver, A., Hernandez-Baeza, A., & Tomas-Marco, I. (2014). Exploratory item factor analysis: A practical guide revised and updated. *Anales de Psicología*, *30*(3), 1151-1169. https://doi.org/10.6018/analesps.30.3.199361

Luchetti, M., Terracciano, A., Stephan, Y., & Sutin, A. R. (2016). Personality and Cognitive Decline in Older Adults: Data From a Longitudinal Sample and Meta-Analysis. *J Gerontol B Psychol Sci Soc Sci*, *71*(4), 591-601. https://doi.org/10.1093/geronb/gbu184

Lugtig, P. (2014). Panel Attrition: Separating Stayers, Fast Attriters, Gradual Attriters, and Lurkers. *Sociological Methods & Research*, *43*(4), 699-723. https://doi.org/10.1177/0049124113520305

Lundgren, A. S., & Ljuslinder, K. (2012). The baby-boom is over and the ageing shock awaits: populist media imagery in news-press representations of population ageing. *International Journal of Ageing and Later Life*, *6*(2), 39-71. https://doi.org/10.3384/ijal.1652-8670.116233

Lupien, S. J., Maheu, F., Tu, M., Fiocco, A., & Schramek, T. E. (2007). The effects of stress and stress hormones on human cognition: Implications for the field of brain and cognition. *Brain Cogn*, *65*(3), 209-237. https://doi.org/10.1016/j.bandc.2007.02.007

Lusardi, A., & Mitchell, O. S. (2007). Baby Boomer retirement security: The roles of planning, financial literacy, and housing wealth. *Journal of Monetary Economics*, *54*(1), 205-224. https://doi.org/https://doi.org/10.1016/j.jmoneco.2006.12.001

Lyketsos, C. G., Chen, L.-S., & Anthony, J. C. (1999). Cognitive decline in adulthood: an 11.5-year follow-up of the Baltimore Epidemiologic Catchment Area study. *American Journal of Psychiatry, 156*(1), 58-65.

Lövdén, M., Brehmer, Y., Li, S.-C., & Lindenberger, U. (2012). Training-induced compensation versus magnification of individual differences in memory performance [10.3389/fnhum.2012.00141]. *Frontiers in Human Neuroscience*, *6*, 141.

Lövdén, M., Ghisletta, P., & Lindenberger, U. (2005). Social participation attenuates decline in perceptual speed in old and very old age. *Psychology and aging*, *20*(3), 423.

Maki, Y., Ura, C., Yamaguchi, T., Murai, T., Isahai, M., Kaiho, A., . . . Sugiyama, M. (2012). Effects of intervention using a community-based walking program for prevention of mental decline: A randomized controlled trial. *Journal of the American Geriatrics Society*, *60*(3), 505-510.

Marr, C., Vaportzis, E., Dewar, M., & Gow, A. J. (2020). Investigating associations between personality and the efficacy of interventions for cognitive ageing: A systematic review. *Archives of Gerontology and Geriatrics*, *87*, 103992. https://doi.org/https://doi.org/10.1016/j.archger.2019.103992

Marr, C., Vaportzis, E., Niechcial, M. A., Dewar, M., & Gow, A. J. (2021). Measuring activity engagement in old age: An exploratory factor analysis. *PLOS ONE*, *16*(12), e0260996. https://doi.org/10.1371/journal.pone.0260996

Mars, T., Ellard, D., Carnes, D., Homer, K., Underwood, M., & Taylor, S. J. C. (2013). Fidelity in complex behaviour change interventions: a standardised approach to evaluate intervention integrity. *BMJ Open*, *3*(11), e003555. https://doi.org/10.1136/bmjopen-2013-003555

Martin, K. A., & Sinden, A. R. (2001). Who Will Stay and Who Will Go? A Review of Older Adults' Adherence to Randomized Controlled Trials of Exercise. *Journal of Aging and Physical Activity*, *9*(2), 91-114. https://doi.org/10.1123/japa.9.2.91 10.1123/japa.9.2.91

Martin, P., Baenziger, J., Macdonald, M., Siegler, I. C., & Poon, L. W. (2009). Engaged Lifestyle, Personality, and Mental Status Among Centenarians. *J Adult Dev*, *16*(4), 199-208. https://doi.org/10.1007/s10804-009-9066-y

Matysiak, O., Kroemeke, A., & Brzezicka, A. (2019). Working Memory Capacity as a Predictor of Cognitive Training Efficacy in the Elderly Population [10.3389/fnagi.2019.00126]. *Frontiers in Aging Neuroscience*, *11*, 126.

McArdle, J. J., & Prindle, J. J. (2008). A latent change score analysis of a randomized clinical trial in reasoning training. *Psychology and Aging*, *23*(4), 702-719. https://doi.org/http://dx.doi.org/10.1037/a0014349

McCrae, R. R. (1994). Openness to Experience: expanding the boundaries of Factor V. *European Journal of Personality*, *8*(4), 251-272.

McCrae, R. R., & Costa, P. T. (1987). Validation of the five-factor model of personality across instruments and observers. *Journal of personality and social psychology*, *52*(1), 81.

McCrae, R. R., Costa, P. T., & Lord, W. (2015). *NEO Personality Inventory - 3 (UK Edition) Manual*. Hogrefe Ltd.

McCrae, R. R., & John, O. P. (1992). An Introduction to the Five-Factor Model and Its Applications. *Journal of Personality*, *60*(2), 175-215.

McCrae, R. R., & Terracciano, A. (2005). Universal features of personality traits from the observer's perspective: data from 50 cultures. *Journal of personality and social psychology*, *88*(3), 547.

McDaniel, S. A. (1987). Demographic Aging as a Guiding Paradigm in Canada's Welfare State. *Canadian Public Policy / Analyse de Politiques*, *13*(3). https://doi.org/10.2307/3550909

McDougall, G. J., Jr., Becker, H., Pituch, K., Acee, T. W., Vaughan, P. W., & Delville, C. L. (2010). The SeniorWISE study: improving everyday memory in older adults. *Arch Psychiatr Nurs*, *24*(5), 291-306. https://doi.org/10.1016/j.apnu.2009.11.001

McDougall, S., & House, B. (2012). Brain training in older adults: evidence of transfer to memory span performance and pseudo-Matthew effects. *Aging, Neuropsychology, and Cognition*, *19*(1-2), 195-221.

McGrew, K. S. (2009). CHC theory and the human cognitive abilities project: Standing on the shoulders of the giants of psychometric intelligence research. In: Elsevier.

McKnight, A. J., & McKnight, A. S. (1999). Multivariate analysis of age-related driver ability and performance deficits. *Accident Analysis & Prevention*, *31*(5), 445-454.

McNeish, D. (2018). Thanks coefficient alpha, we'll take it from here. *Psychological Methods*, *23*(3), 412-433. https://doi.org/10.1037/met0000144

Meier, B., Perrig-Chiello, P., & Perrig, W. (2002). Personality and memory in old age. *Aging, Neuropsychology, and Cognition*, *9*(2), 135-144.

Mein, G., Johal, S., Grant, R. L., Seale, C., Ashcroft, R., & Tinker, A. (2012). Predictors of two forms of attrition in a longitudinal health study involving ageing participants: an analysis based on the Whitehall II study. *BMC medical research methodology*, *12*(1), 164.

Mercuri, G., & Holtzer, R. (2020). Engagement in Cognitively Stimulating Activities Mediates the Relationship between Openness and Attention/Executive

Functions, but Not Memory in Older Adults. *Archives of Clinical Neuropsychology*. https://doi.org/10.1093/arclin/acaa066

Miller, G. A., & Chapman, J. P. (2001). Misunderstanding Analysis of Covariance. *Journal of Abnormal Psychology*, *110*(1), 40-48. https://doi.org/10.1037//0021-843X.110.1.40

Mindell, J., Biddulph, J. P., Hirani, V., Stamatakis, E., Craig, R., Nunn, S., & Shelton, N. (2012). Cohort Profile: The Health Survey for England. *International Journal of Epidemiology*, *41*(6), 1585-1593. https://doi.org/10.1093/ije/dyr199

Moffat, S. D., Zonderman, A. B., & Resnick, S. M. (2001). Age differences in spatial memory in a virtual environment navigation task. *Neurobiology of aging*, *22*(5), 787-796.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine*, *151*(4), 264-269.

Molloy, G. J., O'Carroll, R. E., & Ferguson, E. (2014). Conscientiousness and Medication Adherence: A Meta-analysis. *Annals of Behavioral Medicine*, *47*(1), 92-101. https://doi.org/10.1007/s12160-013-9524-4

Moreland, J. D., Richardson, J. A., Goldsmith, C. H., & Clase, C. M. (2004). Muscle Weakness and Falls in Older Adults: A Systematic Review and Meta-Analysis. *J Am Geriatr Soc*, *52*(7), 1121-1129. https://doi.org/10.1111/j.1532-5415.2004.52310.x

Morey, R. D. (2008). Confidence Intervals from Normalized Data: A correction to Cousineau (2005). *Tutorials in Quantitative Methods for Psychology*, *4*(2), 61-64. https://doi.org/10.20982/tqmp.04.2.p061 (IN FILE)

Mortensen, E. L., Flensborg-Madsen, T., Molbo, D., Christensen, U., Osler, M., Avlund, K., & Lund, R. (2014). Personality in late midlife: associations with demographic factors and cognitive ability. *J Aging Health*, *26*(1), 21-36. https://doi.org/10.1177/0898264313519317

Mortimer, J. A., Ding, D., Borenstein, A. R., DeCarli, C., Guo, Q., Wu, Y., . . . Chu, S. (2012). Changes in brain volume and cognition in a randomized trial of exercise and social interaction in a community-based sample of non-demented Chinese elders. *Journal of Alzheimer's disease : JAD*, *30*(4), 757-766. https://doi.org/10.3233/JAD-2012-120079

Mozaffarian, D., Benjamin, E. J., Go, A. S., Arnett, D. K., Blaha, M. J., Cushman, M., . . . Stroke Statistics, S. (2016). Executive Summary: Heart Disease and Stroke Statistics--2016 Update: A Report From the American Heart Association. *Circulation*, *133*(4), 447-454. https://doi.org/10.1161/CIR.0000000000000366

Mozolic, J. L., Long, A. B., Morgan, A. R., Rawley-Payne, M., & Laurienti, P. J. (2011). A cognitive training intervention improves modality-specific attention in a randomized controlled trial of healthy older adults. *Neurobiology of aging*, *32*(4), 655-668.

Muir, S. W., Berg, K., Chesworth, B., Klar, N., & Speechley, M. (2010). Quantifying the magnitude of risk for balance impairment on falls in community-dwelling older adults: a systematic review and meta-analysis. *J Clin Epidemiol*, *63*(4), 389-406. https://doi.org/https://doi.org/10.1016/j.jclinepi.2009.06.010

Mõttus, R., McNeill, G., Jia, X., Craig, L. C. A., Starr, J. M., & Deary, I. J. (2013). The associations between personality, diet and body mass index in older people. *Health Psychology*, *32*(4), 353-360. https://doi.org/10.1037/a0025537

Nagamatsu, L. S., Handy, T. C., Hsu, C. L., Voss, M., & Liu-Ambrose, T. (2012). Resistance Training Promotes Cognitive and Functional Brain Plasticity in Seniors With Probable Mild Cognitive Impairment. *Archives of Internal Medicine*, *172*(8), 666-668.

Nassiri, V., Lovik, A., Molenberghs, G., & Verbeke, G. (2018). On using multiple imputation for exploratory factor analysis of incomplete data. *Behavior Research Methods, 50*(2), 501-517. https://doi.org/10.3758/s13428-017-1013-4

National Records of Scotland. (2019a). Centenarians in Scotland, 2008 to 2018.

National Records of Scotland. (2019b). *Mid-Year Population Estimates Scotland, Mid-2018*. Retrieved from https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-estimates/mid-year-population-estimates/mid-2018

Netz, Y., Wu, M. J., Becker, B. J., & Tenenbaum, G. (2005). Physical activity and psychological well-being in advanced age: a meta-analysis of intervention studies. *Psychol Aging, 20*(2), 272-284. https://doi.org/10.1037/0882-7974.20.2.272

Ngandu, T., Lehtisalo, J., Solomon, A., Levälahti, E., Ahtiluoto, S., Antikainen, R., . . . Kivipelto, M. (2015). A 2 year multidomain intervention of diet, exercise, cognitive training, and vascular risk monitoring versus control to prevent cognitive decline in at-risk elderly people (FINGER): a randomised controlled trial. *The Lancet, 385*(9984), 2255-2263. https://doi.org/https://doi.org/10.1016/S0140-6736(15)60461-5

Nguyen, L., Murphy, K., & Andrews, G. (2019). Immediate and long-term efficacy of executive functions cognitive training in older adults: A systematic review and meta-analysis. *Psychological bulletin, 145*(7), 698-733.

Niechcial, M. A., Vaportzis, E., & Gow, A. J. (2019). People’s views on preserving thinking skills in old age. *Educational Gerontology, 45*(5), 341-352. https://doi.org/10.1080/03601277.2019.1627054

NIH. (2011). *Conscientiousness and Healthy Ageing*. https://www.nia.nih.gov/sites/default/files/d7/meeting-report_rev3-29-13.pdf

Nisbett, R. E., Aronson, J., Blair, C., Dickens, W., Flynn, J., Halpern, D. F., & Turkheimer, E. (2012). Intelligence: new findings and theoretical developments. *American psychologist*, *67*(2), 130.

Njegovan, V., Man-Son-Hing, M., Mitchell, S. L., & Molnar, F. J. (2001). The hierarchy of functional loss associated with cognitive decline in older persons. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *56*(10), M638-M643.

Noack, H., Lövdén, M., & Schmiedek, F. (2014). On the validity and generality of transfer effects in cognitive training research. *Psychological research*, *78*(6), 773-789.

Noice, H., & Noice, T. (2008). An arts intervention for older adults living in subsidized retirement homes. *Aging, Neuropsychology, and Cognition*, *16*(1), 56-79.

Noice, T., Noice, H., & Kramer, A. F. (2014). Participatory arts for older adults: a review of benefits and challenges. *Gerontologist*, *54*(5), 741-753. https://doi.org/10.1093/geront/gnt138

Nooyens, A. C., van Gelder, B. M., & Verschuren, W. M. (2008). Smoking and cognitive decline among middle-aged men and women: the Doetinchem Cohort Study. *American Journal of Public Health*, *98*(12), 2244-2250.

Nouchi, R., Taki, Y., Takeuchi, H., Hashizume, H., Akitsuki, Y., Shigemune, Y., . . . Yomogida, Y. (2012). Brain training game improves executive functions and processing speed in the elderly: a randomized controlled trial. *PloS one*, *7*(1).

O'Carroll, R. E., Chambers, J. A., Dennis, M., Sudlow, C., & Johnston, M. (2013). Improving Adherence to Medication in Stroke Survivors: A Pilot Randomised Controlled Trial. *Annals of Behavioral Medicine*, *46*(3), 358-368. https://doi.org/10.1007/s12160-013-9515-5

O'Hara, R., Brooks, J. O., 3rd, Friedman, L., Schroder, C. M., Morgan, K. S., & Kraemer, H. C. (2007). Long-term effects of mnemonic training in community-dwelling older adults. *J Psychiatr Res, 41*(7), 585-590. https://doi.org/10.1016/j.jpsychires.2006.04.010

Office for National Statistics. (2018). *Living longer: how our population is changing and why it matters*. Retrieved from https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/ageing/articles/livinglongerhowourpopulationischangingandwhyitmatters/2018-08-13

Office for National Statistics. (2019). *Overview of the UK population: August 2019*. Retrieved from https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/articles/overviewoftheukpopulation/august2019

Okonkwo, O. C., Cohen, R. A., Gunstad, J., Tremont, G., Alosco, M. L., & Poppas, A. (2010). Longitudinal trajectories of cognitive decline among older adults with cardiovascular disease. *Cerebrovascular diseases*, *30*(4), 362-373.

Old, S. R., & Naveh-Benjamin, M. (2008). Differential effects of age on item and associative measures of memory: a meta-analysis. *Psychology and aging*, *23*(1), 104.

Opdebeeck, C., Martyr, A., & Clare, L. (2016). Cognitive reserve and cognitive function in healthy older people: a meta-analysis. *Aging, Neuropsychology, and Cognition*, *23*(1), 40-60. https://doi.org/10.1080/13825585.2015.1041450

Ormel, J., Rijsdijk, F. V., Sullivan, M., van Sonderen, E., & Kempen, G. I. J. M. (2002). Temporal and Reciprocal Relationship Between IADL/ADL Disability and Depressive Symptoms in Late Life. *The Journals of Gerontology: Series B*, *57*(4), P338-P347. https://doi.org/10.1093/geronb/57.4.P338

Owen, A. M., Hampshire, A., Grahn, J. A., Stenton, R., Dajani, S., Burns, A. S., . . . Ballard, C. G. (2010). Putting brain training to the test. *Nature, 465*(7299), 775-778. https://doi.org/10.1038/nature09042

Park, D., & Gutchess, A. (2006). The cognitive neuroscience of aging and culture. *Current directions in psychological science*, *15*(3), 105-108.

Park, D. C., Gutchess, A. H., Meade, M. L., & Stine-Morrow, E. A. L. (2007). Improving cognitive function in older adults: Nontraditional approaches. *Journals of Gerontology Series B-Psychological Sciences and Social Sciences*, *62,* 45-52. https://doi.org/10.1093/geronb/62.special_issue_1.45

Park, D. C., Lodi-Smith, J., Drew, L., Haber, S., Hebrank, A., Bischof, G. N., & Aamodt, W. (2014). The impact of sustained engagement on cognitive function in older adults: the Synapse Project. *Psychol Sci*, *25*(1), 103-112. https://doi.org/10.1177/0956797613499592

Parrott, M. D., & Greenwood, C. E. (2007). Dietary influences on cognitive function with aging: from high-fat diets to healthful eating. *Annals of the New York Academy of Sciences*, *1114*(1), 389-397.

Parslow, R. A., Jorm, A. F., Christensen, H., & Mackinnon, A. (2006). An instrument to measure engagement in life: factor analysis and associations with sociodemographic, health and cognition measures. *Gerontology*, *52*(3), 188-198. https://doi.org/10.1159/000091829

Payne, B. R., Jackson, J. J., Hill, P. L., Gao, X., Roberts, B. W., & Stine-Morrow, E. A. (2012). Memory self-efficacy predicts responsiveness to inductive reasoning training in older adults. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *67*(1), 27-35.

Payne, B. R., & Stine-Morrow, E. A. (2017). The effects of home-based cognitive training on verbal working memory and language comprehension in older adulthood. *Frontiers in aging neuroscience, 9*, 256.

Pearson. (n.d.). *Q-interactive*. Retrieved June 1, 2020 from https://www.pearsonclinical.co.uk/q-interactive/q-interactive.aspx

Perrino, T., Mason, C. A., Brown, S. C., Spokane, A., & Szapocznik, J. (2008). Longitudinal relationships between cognitive functioning and depressive symptoms among Hispanic older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *63*(5), P309-P317.

Pinsky, P. F., Ford, M., Gamito, E., Higgins, D., Jenkins, V., Lamerato, L., . . . Gohagan, J. K. (2008). Enrollment of Racial and Ethnic Minorities in the Prostate, Lung, Colorectal and Ovarian Cancer Screening Trial. *Journal of the National Medical Association*, *100*(3), 291-298. https://doi.org/https://doi.org/10.1016/S0027-9684(15)31241-4

Pitkala, K. H., Routasalo, P., Kautiainen, H., Sintonen, H., & Tilvis, R. S. (2011). Effects of Socially Stimulating Group Intervention on Lonely, Older People's Cognition: A Randomized, Controlled Trial. *The American Journal of Geriatric Psychiatry*, *19*(7), 654-663.

Plassman, B. L., Williams, J. W., Burke, J. R., Holsinger, T., & Benjamin, S. (2010). Systematic review: factors associated with risk for and possible prevention of cognitive decline in later life. *Annals of internal medicine*, *153*(3), 182-193.

Preacher, K. J., & Selig, J. P. (2012). Advantages of Monte Carlo Confidence Intervals for Indirect Effects. *Communication Methods and Measures*, *6*(2), 77-98. https://doi.org/10.1080/19312458.2012.679848

Pushkar Gold, D., Andres, D., Etezadi, J., Arbuckle, T., Schwartzman, A., & Chaikelson, J. (1995). Structural Equation Model of Intellectual Change and

Continuity and Predictors of Intelligence in Older Men. *Psychology and Aging*, *10*(2), 294-303.

Pusswald, G., Tropper, E., Kryspin-Exner, I., Moser, D., Klug, S., Auff, E., . . . Lehrner, J. (2015). Health-related quality of life in patients with subjective cognitive decline and mild cognitive impairment and its relation to activities of daily living. *Journal of Alzheimer's Disease*, *47*(2), 479-486.

R Core Team. (2020). *R: A language and environment for statistical computing*. In R Foundation for Statistical Computing. https://www.R-project.org/

Rabin, J. S., Perea, R. D., Buckley, R. F., Neal, T. E., Buckner, R. L., Johnson, K. A., . . . Hedden, T. (2019). Global White Matter Diffusion Characteristics Predict Longitudinal Cognitive Change Independently of Amyloid Status in Clinically Normal Older Adults. *Cerebral Cortex*, *29*(3), 1251-1262. https://doi.org/10.1093/cercor/bhy031

Rafnsson, S. B., Deary, I. J., Smith, F. B., Whiteman, M. C., & Fowkes, F. G. R. (2007). Cardiovascular diseases and decline in cognitive function in an elderly community population: the Edinburgh Artery Study. *Psychosomatic Medicine*, *69*(5), 425-434.

Raz, N., & Rodrigue, K. M. (2006). Differential aging of the brain: patterns, cognitive correlates and modifiers. *Neuroscience & Biobehavioral Reviews, 30*(6), 730-748.

Rebok, G. W., Ball, K., Guey, L. T., Jones, R. N., Kim, H. Y., King, J. W., . . . Group, A. S. (2014). Ten-year effects of the advanced cognitive training for independent and vital elderly cognitive training trial on cognition and everyday functioning in older adults. *J Am Geriatr Soc, 62*(1), 16-24. https://doi.org/10.1111/jgs.12607

Reese, H. W., Lee, L.-J., Cohen, S. H., & Puckett Jr, J. M. (2001). Effects of intellectual variables, age, and gender on divergent thinking in adulthood. *International Journal of Behavioral Development*, *25*(6), 491-500.

Reeve, A., Simcox, E., & Turnbull, D. (2014). Ageing and Parkinson's disease: Why is advancing age the biggest risk factor? *Ageing Research Reviews*, *14*, 19-30. https://doi.org/https://doi.org/10.1016/j.arr.2014.01.004

Revelle, W. (2019). *psych: Procedures for Personality and Psychological Research*. In (Version 1.9.12) https://CRAN.R-project.org/package=psych

Rhodes, R. E., & Smith, N. E. (2006). Personality correlates of physical activity: a review and meta-analysis. *Br J Sports Med*, *40*(12), 958-965. https://doi.org/10.1136/bjsm.2006.028860

Richmond, L. L., Morrison, A. B., Chein, J. M., & Olson, I. R. (2011). Working memory training and transfer in older adults. *Psychology and aging*, *26*(4), 813.

Richter, D., Körtner, J. L., & Saßenroth, D. (2014). Personality has minor effects on panel attrition. *Journal of Research in Personality*, *53*, 31-35. https://doi.org/https://doi.org/10.1016/j.jrp.2014.08.001

Roberts, B. W., Chernyshenko, O. S., Stark, S., & Goldberg, L. R. (2005). The Structure of Conscientiousness: An Empirical Investigation Based on Seven Major Personality Questionnaires [https://doi.org/10.1111/j.1744-6570.2005.00301.x]. *Personnel Psychology*, *58*(1), 103-139. https://doi.org/https://doi.org/10.1111/j.1744-6570.2005.00301.x

Roberts, R. O., Cha, R. H., Mielke, M. M., Geda, Y. E., Boeve, B. F., Machulda, M. M., . . . Petersen, R. C. (2015). Risk and protective factors for cognitive impairment in persons aged 85 years and older. *Neurology*, *84*(18), 1854-1861.

Robertson, A. (1990). The politics of Alzheimer's disease: A case study in apocalyptic demography. *International Journal of Health Services*, *20*(3), 429-442.

Robitzsch, A., & Grund, S. (2020). *miceadds: Some Additional Multiple Imputation Functions, Especially for 'mice'*. In (Version 3.9-14) https://CRAN.R-project.org/package=miceadds

Roheger, M., Meyer, J., Kessler, J., & Kalbe, E. (2020). Predicting short- and long-term cognitive training success in healthy older adults: who benefits? *Aging, Neuropsychology, and Cognition*, *27*(3), 351-369. https://doi.org/10.1080/13825585.2019.1617396

Román, G. C. (1999). A Historical Review of the Concept of Vasular Demetia: Lessons from the Past for the Future. *Alzheimer Dis Assoc Disord*, *13*(S3), 54-58.

Routasalo, P. E., Tilvis, R. S., Kautiainen, H., & Pitkala, K. H. (2009). Effects of psychosocial group rehabilitation on social functioning, loneliness and well-being of lonely, older people: randomized controlled trial. *J Adv Nurs*, *65*(2), 297-305. https://doi.org/10.1111/j.1365-2648.2008.04837.x

Rozanova, J. (2006). Newspaper portrayals of health and illness among Canadian seniors: Who ages healthily and at what cost? *International Journal of Ageing and Later Life*, *1*(2), 111-139.

Rubin, D. R. (2004). *Multiple Imputation for Nonresponse in Surveys* (Wiley Classics Library ed.). John Wiley & Sons. (1987)

Sala, G., Aksayli, N. D., Tatlidil, K. S., Gondo, Y., & Gobet, F. (2019). Working memory training does not enhance older adults' cognitive skills: A comprehensive meta-analysis. *Intelligence*, *77*, 101386.

Salthouse, T. (2010). *Major Issues in Cognitive Aging*. Oxford University Press.

Salthouse, T. A. (2004a). Localizing age-related individual differences in a hierarchical structure. *Intelligence*, *32*(6). https://doi.org/10.1016/j.intell.2004.07.003

Salthouse, T. A. (2004b). What and When of Cognitive Aging. *Current Directions in Psychological Science*, *13*(4), 140-144.

Salthouse, T. A. (2006). Mental exercise and mental aging: Evaluating the validity of the "use it or lose it" hypothesis. *Perspectives on Psychological Science, 1*(1), 68-87.

Salthouse, T. A. (2009a). Decomposing age correlations on neuropsychological and cognitive variables. *Journal of the International Neuropsychological Society*, *15*(5), 650-661.

Salthouse, T. A. (2009b). When does age-related cognitive decline begin? *Neurobiology of aging*, *30*(4), 507-514.

Salthouse, T. A. (2014). Selectivity of Attrition in Longitudinal Studies of Cognitive Functioning. *The Journals of Gerontology: Series B*, *69*(4), 567-574. https://doi.org/10.1093/geronb/gbt046

Salthouse, T. A., Babcock, R. L., Skovronek, E., Mitchell, D. R. D., & Palmon, R. (1990). Age and experience effects in spatial visualization. *Developmental Psychology*, *26*(1), 128.

Salthouse, T. A., & Ferrer-Caja, E. (2003). What needs to be explained to account for age-related effects on multiple cognitive variables? *Psychology and aging*, *18*(1), 91.

Satherley, N., Milojev, P., Greaves, L. M., Huang, Y., Osborne, D., Bulbulia, J., & Sibley, C. G. (2015). Demographic and Psychological Predictors of Panel Attrition: Evidence from the New Zealand Attitudes and Values Study. *PLOS ONE*, *10*(3), e0121950. https://doi.org/10.1371/journal.pone.0121950

Schafer, J. L. (1999). Multiple imputation: a primer. *Statistical Methods in Medical Research*, *8*(1), 3-15. https://doi.org/10.1177/096228029900800102

Schaie, K. W. (1989). The hazards of cognitive aging. *The Gerontologist, 29*(4), 484-493.

Schaie, K. W. (2013). *Developmental Influences on Adult Intelligence: The Seattle Longitudinal Study* (2nd ed.). Oxford University Press.

Scherr, P. A., Albert, M. S., Funkenstein, H. H., Cook, N. R., Hennekens, C. H., Branch, L. G., . . . Evans, D. A. (1988). Correlates of cognitive function in an elderly community population. *American Journal of Epidemiology*, *128*(5), 1084-1101.

Schiepers, O., Harris, S., Gow, A., Pattie, A., Brett, C., Starr, J., & Deary, I. (2012). APOE E4 status predicts age-related cognitive decline in the ninth decade: longitudinal follow-up of the Lothian Birth Cohort 1921. *Molecular psychiatry*, *17*(3), 315-324.

Schinka, J. A., McBride, A., Vanderploeg, R. D., Tennyson, K., Borenstein, A. R., & Mortimer, J. A. (2005). Florida Cognitive Activities Scale: initial development and validation. *Journal of the International Neuropsychological Society*, *11*(1), 108-116. https://doi.org/10.1017/S1355617705050125

Schooler, C., & Mulatu, M. S. (2001). The reciprocal effects of leisure time activities and intellectual functioning in older people: a longitudinal analysis. *Psychology and aging*, *16*(3), 466.

Schulz, K. F., & Grimes, D. A. (2002). Sample size slippages in randomised trials: exclusions and the lost and wayward. *The Lancet*, *359*(9308), 781-785. https://doi.org/https://doi.org/10.1016/S0140-6736(02)07882-0

Scottish Government. (2016). *The Scottish Index of Multiple Deprivation 2016*. https://www2.gov.scot/Topics/Statistics/SIMD

Shankar, A., McMunn, A., Demakakos, P., Hamer, M., & Steptoe, A. (2017). Social isolation and loneliness: Prospective associations with functional status in older adults. *Health Psychol*, *36*(2), 179.

Sharp, E. S., Reynolds, C. A., Pedersen, N. L., & Gatz, M. (2010). Cognitive engagement and cognitive aging: is openness protective? *Psychol Aging*, *25*(1), 60-73. https://doi.org/10.1037/a0018748

Sharpe, C., Holup, A. A., Hansen, K. E., & Edwards, J. D. (2014). Does self-efficacy affect responsiveness to cognitive speed of processing training? *Journal of Aging and Health*, *26*(5), 786-806. https://doi.org/http://dx.doi.org/10.1177/0898264314531615

Shaw, B. A., Krause, N., Liang, J., & Bennett, J. (2007). Tracking Changes in Social Relations Throughout Late Life. *Journal of Gerontology: Social Sciences*, *62B*(2), S90-S99.

Shua-Haim, J., Koppuzha, G., & Gross, J. (1996). A Simple Scoring System for Clock Drawing in Patients with Alzheimer's Disease. *Journal of the American Geriatrics Society*, *44*(3), 335-335. https://doi.org/10.1111/j.1532-5415.1996.tb00931.x

Simon, S. S., Lee, S., & Stern, Y. (2020). Personality-cognition associations across the adult life span and potential moderators: Results from two cohorts [https://doi.org/10.1111/jopy.12548]. *Journal of Personality, 88*(5), 1025-1039. https://doi.org/https://doi.org/10.1111/jopy.12548

Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z., & Stine-Morrow, E. A. (2016). Do “brain-training” programs work? *Psychological Science in the Public Interest*, *17*(3), 103-186.

Singal, A. G., Higgins, P. D. R., & Waljee, A. K. (2014). A primer on effectiveness and efficacy trials. *Clinical and translational gastroenterology*, *5*(1), e45-e45. https://doi.org/10.1038/ctg.2013.13

Singer, T., Verhaeghen, P., Ghisletta, P., Lindenberger, U., & Baltes, P. B. (2003). The fate of cognition in very old age: Six-year longitudinal findings in the Berlin Aging Study (BASE). *Psychology and aging, 18*(2), 318.

Singh-Manoux, A., Kivimaki, M., Glymour, M. M., Elbaz, A., Berr, C., Ebmeier, K. P., . . . Dugravot, A. (2012). Timing of onset of cognitive decline: results from Whitehall II prospective cohort study. *Bmj, 344*, d7622.

Sinharay, S., Stern, H. S., & Russell, D. (2001). The use of multiple imputation for the analysis of missing data. *Psychological Methods*, *6*(4), 317-329. https://doi.org/10.1037/1082-989X.6.4.317

Sink, K. M., Espeland, M. A., Castro, C. M., Church, T., Cohen, R., Dodson, J. A., . . . Investigators, L. S. (2015). Effect of a 24-Month Physical Activity Intervention vs Health Education on Cognitive Outcomes in Sedentary Older Adults: The LIFE Randomized Trial. *JAMA*, *314*(8), 781-790. https://doi.org/10.1001/jama.2015.9617

Slegers, K., van Boxtel, M., & Jolles, J. (2009). Effects of computer training and internet usage on cognitive abilities in older adults: a randomized controlled study. *Aging clinical and experimental research*, *21*(1), 43-54.

Small, B. J., Dixon, R. A., McArdle, J. J., & Grimm, K. J. (2012). Do changes in lifestyle engagement moderate cognitive decline in normal aging? Evidence from the Victoria Longitudinal Study. *Neuropsychology*, *26*(2), 144. https://doi.org/10.1037/a0026579

Small, B. J., Rosnick, C. B., Fratiglioni, L., & Bäckman, L. (2004). Apolipoprotein E and cognitive performance: a meta-analysis. *Psychology and aging*, *19*(4), 592.

Smith, T. W., & Spiro III, A. (2002). Personality, health, and aging: Prolegomenon for the next generation. *Journal of Research in Personality*, *36*(4), 363-394.

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: a meta-analysis of prospective studies. *Journal of internal medicine*, *269*(1), 107-117.

Solomon, A., Turunen, H., Ngandu, T., Peltonen, M., Levalahti, E., Helisalmi, S., . . . Kivipelto, M. (2018). Effect of the Apolipoprotein E Genotype on Cognitive Change During a Multidomain Lifestyle Intervention: A Subgroup Analysis of a Randomized Clinical Trial. *JAMA Neurol*, *75*(4), 462-470. https://doi.org/10.1001/jamaneurol.2017.4365

Soubelet, A. (2011). Age-cognition relations and the personality trait of Conscientiousness. *Journal of Research in Personality*, *45*(6), 529-534. https://doi.org/https://doi.org/10.1016/j.jrp.2011.06.007

Soubelet, A., & Salthouse, T. (2010). The role of activity engagement in the relations between Openness/Intellect and cognition. *Pers Individ Dif*, *49*(8), 896-901. https://doi.org/10.1016/j.paid.2010.07.026

Soubelet, A., & Salthouse, T. A. (2011). Personality-cognition relations across adulthood. *Developmental psychology*, *47*(2), 303-310. https://doi.org/10.1037/a0021816

Spearman, C. (1904). "General Intelligence," objectively determined and measured. *American Journal of Psychology*, *15*, 201-293.

Spector, W. D., & Fleishman, J. A. (1998). Combining activities of daily living with instrumental activities of daily living to measure functional disability. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *53*(1), S46-S57.

Spector, W. D., Katz, S., Murphy, J. B., & Fulton, J. P. (1987). The hierarchical relationship between activities of daily living and instrumental activities of daily living. *Journal of chronic diseases*, *40*(6), 481-489.

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). *Manual for the State-Trait Anxiety Inventory (Self-Evaluation Questionnaire)*. Consulting Psychologists Press.

Starr, J. M., Deary, I. J., Fox, H. C., & Whalley, L. J. (2007). Smoking and cognitive change from age 11 to 66 years: A confirmatory investigation. *Addictive Behaviors*, *32*(1), 63-68. https://doi.org/https://doi.org/10.1016/j.addbeh.2006.03.020

Stephan, Y., Boiché, J., Canada, B., & Terracciano, A. (2014). Association of personality with physical, social, and mental activities across the lifespan: Findings from US and French samples. *British Journal of Psychology*, *105*(4), 564-580.

Steptoe, A., Breeze, E., Banks, J., & Nazroo, J. (2013). Cohort Profile: The English Longitudinal Study of Ageing. *International Journal of Epidemiology*, *42*(6), 1640-1648. https://doi.org/10.1093/ije/dys168

Stine-Morrow, E. A., Parisi, J. M., Morrow, D. G., & Park, D. C. (2008). The effects of an engaged lifestyle on cognitive vitality: a field experiment. *Psychol Aging*, *23*(4), 778-786. https://doi.org/10.1037/a0014341

Stine-Morrow, E. A., Payne, B. R., Roberts, B. W., Kramer, A. F., Morrow, D. G., Payne, L., . . . Parisi, J. M. (2014). Training versus engagement as paths to cognitive enrichment with aging. *Psychol Aging*, *29*(4), 891-906. https://doi.org/10.1037/a0038244

Stine-Morrow, E. A. L., Parisi, J. M., Morrow, D. G., Greene, J., & Park, D. C. (2007). An Engagement Model of Cognitive Optimization Through Adulthood. *The Journals of Gerontology: Series B*, *62*(Special_Issue_1), 62-69. https://doi.org/10.1093/geronb/62.special_issue_1.62

Studer-Luethi, B., Jaeggi, S. M., Buschkuehl, M., & Perrig, W. J. (2012). Influence of neuroticism and conscientiousness on working memory training outcome. *Personality and Individual Differences*, *53*(1), 44-49.

Sutin, A. R., Stephan, Y., Damian, R. I., Luchetti, M., Strickhouser, J. E., & Terracciano, A. (2019). Five-factor model personality traits and verbal fluency in 10 cohorts. *Psychol Aging*, *34*(3), 362-373. https://doi.org/10.1037/pag0000351

Sutin, A. R., Stephan, Y., Luchetti, M., & Terracciano, A. (2019). Five-factor model personality traits and cognitive function in five domains in older adulthood. *BMC Geriatrics*, *19*(1), 343. https://doi.org/10.1186/s12877-019-1362-1

Tabachnick, B. G., & Fidell, L. S. (2001). *Using Multivariate Statistics* (4th ed.). Allyn and Bacon.

Techentin, C., Voyer, D., & Voyer, S. D. (2014). Spatial abilities and aging: A meta-analysis. *Experimental aging research*, *40*(4), 395-425.

Tennstedt, S. L., & Unverzagt, F. W. (2013). The ACTIVE study: Study overview and major findings. *Journal of Aging and Health*, *25*(8S), 3S-20S.

Terracciano, A., & Costa Jr, P. T. (2004). Smoking and the Five-Factor Model of personality. *Addiction*, *99*(4), 472-481. https://doi.org/10.1111/j.1360-0443.2004.00687.x

Terracciano, A., Sutin, A. R., An, Y., O'Brien, R. J., Ferrucci, L., Zonderman, A. B., & Resnick, S. M. (2014). Personality and risk of Alzheimer's disease: new data and meta-analysis. *Alzheimers Dement*, *10*(2), 179-186. https://doi.org/10.1016/j.jalz.2013.03.002

Tetlow, A. M., & Edwards, J. D. (2017). Systematic literature review and meta-analysis of commercially available computerized cognitive training among older adults. *Journal of Cognitive Enhancement*, *1*(4), 559-575.

Tombaugh, T. N., & McIntyre, N. J. (1992). The mini-mental state examination: a comprehensive review. *Journal of the American Geriatrics Society, 40*(9), 922-935.

Tomioka, K., Kurumatani, N., & Hosoi, H. (2016). Association between social participation and instrumental activities of daily living among community-dwelling older adults. *Journal of epidemiology*, JE20150253.

Toril, P., Reales, J. M., & Ballesteros, S. (2014). Video game training enhances cognition of older adults: A meta-analytic study. *Psychology and Aging, 29*(3), 706-716. https://doi.org/10.1037/a0037507

Tranter, L. J., & Koutstaal, W. (2008). Age and flexible thinking: an experimental demonstration of the beneficial effects of increased cognitively stimulating activity on fluid intelligence in healthy older adults. *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn*, *15*(2), 184-207. https://doi.org/10.1080/13825580701322163

Turunen, M., Hokkanen, L., Bäckman, L., Stigsdotter-Neely, A., Hänninen, T., Paajanen, T., . . . Ngandu, T. (2019). Computer-based cognitive training for older adults: Determinants of adherence. *PLOS ONE, 14*(7), e0219541. https://doi.org/10.1371/journal.pone.0219541

United Nations. (1999). *The World at Six Billion*. Retrieved from http://www.subdude-site.com/WebPages_Local/RefInfo/eDocs/Environment_edocs/docs/worldPop_dataTables_forecastGraphs_UNpopDiv_11pgs_circa2000.pdf

United Nations. (2002). *Political Declaration and Madrid International Plan of Action on Ageing*. New York

United Nations. (2019). *World Population Prospects 2019: Highlights*. New York: United Nations

Unsworth, N., Miller, J. D., Lakey, C. E., Young, D. L., Meeks, J. T., Campbell, W. K., & Goodie, A. S. (2009). Exploring the Relations Among Executive Functions, Fluid Intelligence, and Personality. *Journal of Individual Differences*, *30*(4), 194-200. https://doi.org/10.1027/1614-0001.30.4.194

van Buuren, S., & Groothuis-Oudshoorn, K. (2011). mice: Multivariate Imputation by Chained Equations in R. *Journal of Statistical Software*, *45*(3), 1-68. https://doi.org/10.18637/jss.v045.i03

Van Dyk, K., & Sano, M. (2007). The impact of nutrition on cognition in the elderly. *Neurochemical research*, *32*(4-5), 893-904.

Vaportzis, E., & Gow, A. J. (2018). People's Beliefs and Expectations About How Cognitive Skills Change with Age: Evidence From a U.K.-Wide Aging Survey. *The American Journal of Geriatric Psychiatry*, *26*(7), 797-805. https://doi.org/10.1016/j.jagp.2018.03.016

Vaportzis, E., Martin, M., & Gow, A. J. (2017). A Tablet for Healthy Ageing: The Effect of a Tablet Computer Training Intervention on Cognitive Abilities in Older Adults. *Am J Geriatr Psychiatry*, *25*(8), 841-851. https://doi.org/10.1016/j.jagp.2016.11.015

Vaportzis, E., Niechcial, M. A., & Gow, A. J. (2019). A Systematic Literature Review and Meta-analysis of Real-World Interventions for Cognitive Ageing in Healthy Older Adults. *Ageing Research Reviews*. https://doi.org/https://doi.org/10.1016/j.arr.2019.01.006

Velicer, W. F. (1976). Determining the number of components from the matrix of partial correlations. *Psychometrika*, *41*(3), 321-327. https://doi.org/10.1007/BF02293557

Vellas, B., Carrie, I., Gillette-Guyonnet, S., Touchon, J., Dantoine, T., Dartigues, J. F., . . . Andrieu, S. (2014). MAPT STUDY: A MULTIDOMAIN APPROACH FOR

PREVENTING ALZHEIMER'S DISEASE: DESIGN AND BASELINE DATA. *The journal of prevention of Alzheimer's disease*, *1*(1), 13-22.

Vemuri, P., Lesnick, T. G., Przybelski, S. A., Machulda, M., Knopman, D. S., Mielke, M. M., . . . Jack, C. R., Jr. (2014). Association of lifetime intellectual enrichment with cognitive decline in the older population. *JAMA Neurol*, *71*(8), 1017-1024. https://doi.org/10.1001/jamaneurol.2014.963

Verghese, J., LeValley, A., Derby, C., Kuslansky, G., Katz, M., Hall, C., . . . Lipton, R. B. (2006). Leisure activities and the risk of amnestic mild cognitive impairment in the elderly. *Neurology*, *66*(6), 821. https://doi.org/10.1212/01.wnl.0000202520.68987.48

Verhaeghen, P. (2003). Aging and vocabulary score: A meta-analysis. *Psychology and aging*, *18*(2), 332.

Verhaeghen, P., Marcoen, A., & Goossens, L. (1992). Improving memory performance in the aged through mnemonic training: a meta-analytic study. *Psychol Aging*, *7*(2), 242-251.

Verhaeghen, P., & Salthouse, T. A. (1997). Meta-analyses of age–cognition relations in adulthood: Estimates of linear and nonlinear age effects and structural models. *Psychological bulletin*, *122*(3), 231.

Verhaeghen, P., Steitz, D. W., Sliwinski, M. J., & Cerella, J. (2003). Aging and dual-task performance: a meta-analysis. *Psychology and aging*, *18*(3), 443.

Vinkers, D., Stek, M., Van der Mast, R., De Craen, A., Le Cessie, S., Jolles, J., . . . Gussekloo, J. (2005). Generalized atherosclerosis, cognitive decline, and depressive symptoms in old age. *Neurology*, *65*(1), 107-112.

Vozikaki, M., Papadaki, A., Linardakis, M., & Philalithis, A. (2018). Loneliness among older European adults: results from the survey of health, aging and retirement in

Europe. *Journal of Public Health, 26*(6), 613-624. https://doi.org/10.1007/s10389-018-0916-6

Vranic, A., Spanic, A. M., Carretti, B., & Borella, E. (2013). The efficacy of a multifactorial memory training in older adults living in residential care settings. *Int Psychogeriatr, 25*(11), 1885-1897. https://doi.org/10.1017/s1041610213001154

Waggel, S. E., Lipnicki, D. M., Delbaere, K., Kochan, N. A., Draper, B., Andrews, G., . . . Brodaty, H. (2015). Neuroticism scores increase with late-life cognitive decline. *Int J Geriatr Psychiatry, 30*(9), 985-993. https://doi.org/10.1002/gps.4251

Waldstein, S. R., Snow, J., Muldoon, M. F., & Katzel, L. I. (2001). Neuropsychological consequences of cardiovascular disease. In R. E. Tarter, M. A. Butters, & S. R. Beers (Eds.), *Medical Neuropsychology* (2nd ed., pp. 51-83). Springer.

Wang, H.-X., Jin, Y., Hendrie, H. C., Liang, C., Yang, L., Cheng, Y., . . . Murrell, J. R. (2013). Late life leisure activities and risk of cognitive decline. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, *68*(2), 205-213.

Wang, R., Lagakos, S. W., Ware, J. H., Hunter, D. J., & Drazen, J. M. (2007). Statistics in medicine—reporting of subgroup analyses in clinical trials. *New England Journal of Medicine*, *357*(21), 2189-2194.

Waris, O., Soveri, A., Lukasik, K. M., Lehtonen, M., & Laine, M. (2018). Working memory and the Big Five. *Personality and Individual Differences, 130*, 26-35. https://doi.org/10.1016/j.paid.2018.03.027

Wechsler, D. (2010a). *Wechsler Adult Intelligence Scale - Fourth UK Edition (WAIS-IV UK)*. Pearson.

Wechsler, D. (2010b). *Wechsler Memory Scale - Fourth UK Edition (WMS-IV UK)*. Pearson.

Weinstein, G., Elran Barak, R., Schnaider Beeri, M., & Ravona-Springer, R. (2019). Personality traits and cognitive function in old-adults with type-2 diabetes. *Aging & Mental Health*, *23*(10), 1317-1325. https://doi.org/10.1080/13607863.2018.1493720

Weiss, S. (2019, October 6). Brain training apps don't really work. So why do we love them? *Wired UK*. https://www.wired.co.uk/article/nintendo-brain-training-switch

Weston, S. J., Hill, P. L., & Jackson, J. J. (2014). Personality Traits Predict the Onset of Disease. *Social Psychological and Personality Science*, *6*(3), 309-317. https://doi.org/10.1177/1948550614553248

Weuve, J., Kang, J. H., Manson, J. E., Breteler, M. M., Ware, J. H., & Grodstein, F. (2004). Physical activity, including walking, and cognitive function in older women. *Jama*, *292*(12), 1454-1461.

White, I. R., Royston, P., & Wood, A. M. (2011). Multiple imputation using chained equations: Issues and guidance for practice. *Statistics in Medicine*, *30*(4), 377-399. https://doi.org/10.1002/sim.4067

Whitley, E., Deary, I. J., Ritchie, S. J., Batty, G. D., Kumari, M., & Benzeval, M. (2016). Variations in cognitive abilities across the life course: Cross-sectional evidence from Understanding Society: The UK Household Longitudinal Study. *Intelligence*, *59*, 39-50.

Wild, S., Roglic, G., Green, A., Sicree, R., & King, H. (2004). Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes care*, *27*(5), 1047-1053.

Williams, P. G., Suchy, Y., & Kraybill, M. L. (2010). Five-Factor Model personality traits and executive functioning among older adults. *Journal of Research in Personality*, *44*(4), 485-491. https://doi.org/10.1016/j.jrp.2010.06.002

Wilson, K. E., & Dishman, R. K. (2015). Personality and physical activity: A systematic review and meta-analysis. *Personality and Individual Differences*, *72*, 230-242. https://doi.org/10.1016/j.paid.2014.08.023

Wilson, R. S., Barnes, L. L., & Bennett, D. A. (2003). Assessment of Lifetime Participation in Cognitively Stimulating Activities. *Journal of Clinical and Experimental Neuropsychology*, *25*(5), 634-642.

Wilson, R. S., Beckett, L. A., Barnes, L. L., Schneider, J. A., Bach, J., Evans, D. A., & Bennett, D. A. (2002). Individual differences in rates of change in cognitive abilities of older persons. *Psychology and Aging*, *17*(2), 179-193. https://doi.org/10.1037/0882-7974.17.2.179

Wisdom, N. M., Callahan, J. L., & Hawkins, K. A. (2011). The effects of apolipoprotein E on non-impaired cognitive functioning: a meta-analysis. *Neurobiology of aging*, *32*(1), 63-74.

Wolf, M. B., & Ackerman, P. L. (2005). Extraversion and intelligence: A meta-analytic investigation. *Personality and Individual Differences*, *39*(3), 531-542. https://doi.org/https://doi.org/10.1016/j.paid.2005.02.020

World Health Organization. (2017). *Global strategy and action plan on ageing and health*. Geneva: World Health Organization

Yong, A. G., & Pearce, S. (2013). A Beginner's Guide to Factor Analysis: Focusing on Exploratory Factor Analysis. *Tutorials in Quantitative Methods for Psychology*, *9*(2), 79-94. https://doi.org/10.20982/tqmp.09.2.p079 (IN FILE)

Yusuf, S., Wittes, J., Probstfield, J., & Tyroler, H. A. (1991). Analysis and interpretation of treatment effects in subgroups of patients in randomized clinical trials. *Jama*, *266*(1), 93-98.

Zhang, C., & Pierce, B. L. (2014). Genetic susceptibility to accelerated cognitive decline in the US Health and Retirement Study. *Neurobiology of Aging*, *35*(6), 1512.e1511-1512.e1518. https://doi.org/https://doi.org/10.1016/j.neurobiolaging.2013.12.021

Zigmond, A. S., & Snaith, R. P. (1983). The hospital anxiety and depression scale. *Acta psychiatrica scandinavica*, *67*(6), 361-370.

Zimmermann, K., von Bastian, C. C., Röcke, C., Martin, M., & Eschen, A. (2016). Transfer after process-based object-location memory training in healthy older adults. *Psychology and Aging*, *31*(7), 798-814. https://doi.org/http://dx.doi.org/10.1037/pag0000123

Zinke, K., Zeintl, M., Rose, N. S., Putzmann, J., Pydde, A., & Kliegel, M. (2014). Working memory training and transfer in older adults: Effects of age, baseline performance, and training gains. *Developmental Psychology*, *50*(1), 304-315. https://doi.org/10.1037/a0032982

Appendices

Appendix A

Analyses Comparing Demographic, Cognitive and Health Measures Between Those With and Without Missing Data for Each Study Outcome in Chapter 2

Independent Variable[a]	Dependent Variable	N not missing (%)	N missing (%)	Not Missing Mean (SD)	Missing Mean (SD)	*p*
Working Memory	Age			71.3 (5.3)	75.0 (6.6)	0.073
	Gender (Male)	102 (31.0)	0 (0.0)			0.177
	Gender (Female)	227 (69.0)	7 (100.0)			
	Education			15.9 (3.5)	13.9 (3.0)	0.124
	SIMD16 Vigintile			16.2 (4.6)	19.3 (1.0)	0.073
	MMSE			28.9 (1.2)	28.1 (1.3)	0.12
	Verbal Comprehension			108.6 (11.8)	100.1 (10.7)	0.061
	Perceptual Reasoning			104.4 (13.5)	94.1 (9.6)	0.047
	Processing Speed			104.9 (12.7)	96.7 (7.2)	0.09
	Auditory Memory			117.3 (14.9)	109.2 (11.0)	0.231
	Visual Memory			98.9 (14.1)	83.7 (13.8)	0.005
	Alcohol			11.2 (13.7)	1.1 (1.6)	0.052
	Diet			0.6 (0.9)	0.6 (1.1)	0.978
	Pack Years			8.4 (16.5)	7.7 (19.8)	0.915
	IPAQ			2686.6 (2391.6)	1373.9 (958.8)	0.149
	Self-Rated Health			3.7 (0.9)	3.4 (0.8)	0.423
Auditory Memory	Age			71.3 (5.3)	73.6 (6.4)	0.103
	Gender (Male)	98 (30.5)	4 (26.7)			0.975
	Gender (Female)	223 (69.5)	11 (73.3)			
	Education			15.9 (3.5)	14.6 (3.3)	0.16
	SIMD16 Vigintile			16.2 (4.6)	16.5 (4.1)	0.842
	MMSE			28.9 (1.2)	28.1 (1.0)	0.019
	Verbal Comprehension			108.8 (11.6)	100.0 (12.9)	0.005
	Perceptual Reasoning			104.5 (13.3)	97.1 (15.5)	0.039
	Working Memory			111.2 (13.7)	103.2 (11.4)	0.039
	Processing Speed			105.0 (12.5)	100.0 (16.0)	0.137
	Visual Memory			99.0 (13.9)	88.4 (16.7)	0.005
	Alcohol			11.4 (13.8)	3.7 (4.9)	0.034
	Diet			0.6 (0.8)	0.7 (1.1)	0.69
	Pack Years			8.4 (16.6)	6.3 (15.3)	0.624
	IPAQ			2654.2 (2406.0)	2708.9 (1689.6)	0.933
	Self-Rated Health			3.7 (0.9)	3.7 (0.9)	0.877
Visual Memory	Age			71.4 (5.4)	70.2 (1.3)	0.673
	Gender (Male)	101 (30.4)	1 (25.0)			1
	Gender (Female)	231 (69.6)	3 (75.0)			
	Education			15.9 (3.5)	16.2 (3.2)	0.831
	SIMD16 Vigintile			16.2 (4.6)	19.8 (0.5)	0.12
	MMSE			28.9 (1.2)	27.5 (2.5)	0.026
	Verbal Comprehension			108.5 (11.8)	101.8 (10.3)	0.257
	Perceptual Reasoning			104.1 (13.5)	109.0 (19.9)	0.473
	Working Memory			111.0 (13.7)	102.8 (14.2)	0.23
	Processing Speed			104.7 (12.7)	108.2 (15.0)	0.58
	Auditory Memory			117.2 (14.9)	107.5 (9.1)	0.194
	Alcohol			11.1 (13.7)	8.3 (11.5)	0.689
	Diet			0.6 (0.9)	0.8 (1.0)	0.691
	Pack Years			8.4 (16.6)	3.0 (6.0)	0.517
	IPAQ			2639.9 (2358.7)	3931.5 (3692.6)	0.281
	Self-Rated Health			3.7 (0.9)	2.8 (1.0)	0.035

Independent Variable[a]	Dependent Variable	N not missing (%)	N missing (%)	Not Missing Mean (SD)	Missing Mean (SD)	*p*
Pack Years	Age			71.4 (5.3)	70.9 (7.7)	0.78
	Gender (Male)	97 (29.7)	5 (55.6)			0.194
	Gender (Female)	230 (70.3)	4 (44.4)			
	Education			15.9 (3.5)	15.2 (3.8)	0.571
	SIMD16 Vigintile			16.2 (4.6)	17.3 (3.8)	0.465
	MMSE			28.9 (1.2)	28.6 (1.1)	0.453
	Verbal Comprehension			108.3 (11.5)	111.9 (21.0)	0.368
	Perceptual Reasoning			104.1 (13.5)	105.6 (14.4)	0.757
	Working Memory			110.9 (13.7)	110.2 (15.7)	0.876
	Processing Speed			104.9 (12.7)	100.7 (9.8)	0.327
	Auditory Memory			117.2 (14.9)	113.6 (15.3)	0.467
	Visual Memory			98.7 (13.9)	92.0 (22.6)	0.162
	Alcohol			10.8 (13.6)	18.6 (11.8)	0.092
	Diet			0.6 (0.9)	0.3 (0.7)	0.381
	IPAQ			2625.4 (2351.3)	3697.9 (3075.3)	0.183
	Self-Rated Health			3.7 (0.9)	3.7 (0.7)	0.905
IPAQ	Age			71.2 (5.2)	73.2 (6.6)	0.06
	Gender (Male)	91 (29.5)	11 (39.3)			0.391
	Gender (Female)	217 (70.5)	17 (60.7)			
	Education			16.1 (3.4)	13.8 (3.8)	0.001
	SIMD16 Vigintile			16.4 (4.4)	14.6 (6.0)	0.047
	MMSE			28.9 (1.1)	28.1 (1.8)	<0.001
	Verbal Comprehension			108.9 (11.4)	102.9 (14.3)	0.01
	Perceptual Reasoning			104.8 (13.5)	97.0 (11.7)	0.003
	Working Memory			111.4 (12.8)	106.1 (20.8)	0.051
	Processing Speed			105.3 (12.4)	98.6 (14.5)	0.007
	Auditory Memory			118.0 (14.2)	107.7 (18.9)	0.001
	Visual Memory			98.8 (13.9)	95.6 (17.4)	0.254
	Alcohol			11.3 (13.6)	7.9 (14.0)	0.209
	Diet			0.6 (0.9)	0.5 (0.6)	0.455
	Pack Years			7.9 (15.9)	13.5 (22.3)	0.085
	Self-Rated Health			3.7 (0.9)	3.6 (0.9)	0.719
VLS	Age			71.2 (5.3)	72.4 (6.3)	0.204
	Gender (Male)	93 (31.4)	9 (22.5)			0.333
	Gender (Female)	203 (68.6)	31 (77.5)			
	Education			15.9 (3.5)	15.5 (3.9)	0.455
	SIMD16 Vigintile			16.4 (4.5)	15.1 (4.7)	0.085
	MMSE			28.9 (1.2)	28.4 (1.7)	0.008
	Verbal Comprehension			108.7 (11.5)	106.4 (13.4)	0.254
	Perceptual Reasoning			104.6 (13.4)	100.8 (14.0)	0.092
	Working Memory			111.4 (12.8)	107.3 (18.8)	0.072
	Processing Speed			105.2 (12.4)	101.2 (14.1)	0.055
	Auditory Memory			117.4 (14.0)	115.3 (20.6)	0.417
	Visual Memory			98.4 (13.5)	99.5 (18.7)	0.64
	Alcohol			11.0 (13.3)	11.5 (16.0)	0.81
	Diet			0.6 (0.9)	0.6 (0.7)	0.966
	Pack Years			7.9 (16.0)	11.1 (19.8)	0.256
	IPAQ			2580.3 (2299.6)	3603.3 (3083.4)	0.047
	Self-Rated Health			3.7 (0.9)	3.5 (1.0)	0.19
NEO	Age			71.3 (5.2)	71.8 (6.9)	0.654
	Gender (Male)	90 (29.9)	12 (34.3)			0.734
	Gender (Female)	211 (70.1)	23 (65.7)			
	Education			16.1 (3.4)	14.0 (3.5)	0.001
	SIMD16 Vigintile			16.3 (4.5)	15.5 (4.7)	0.32
	MMSE			28.9 (1.2)	28.5 (1.5)	0.041
	Verbal Comprehension			109.0 (11.4)	103.3 (14.1)	0.007
	Processing Speed			105.0 (13.5)	97.3 (11.3)	0.001
	Working Memory			111.3 (13.7)	108.1 (13.6)	0.198
	Processing Speed			105.4 (12.6)	98.9 (11.8)	0.004
	Auditory Memory			118.0 (14.4)	109.6 (17.3)	0.002
	Visual Memory			98.9 (13.8)	95.1 (17.3)	0.135
	Alcohol			10.8 (13.1)	13.0 (17.5)	0.372
	Diet			0.6 (0.8)	0.7 (1.1)	0.236
	Pack Years			7.8 (16.2)	12.6 (19.3)	0.116
	IPAQ			2692.2 (2425.2)	2339.2 (1883.0)	0.434
	Self-Rated Health			3.7 (0.9)	3.4 (1.0)	0.06

Note. Comparisons were conducted in R with the missing_compare() function from the finalfit package (version 1.0.1; Harrison et al., 2020), which compares continuous variables with a Kruskal-Wallis test (due to often vastly differing group sizes) and categorical variables with a chi-squared test.

[a] The independent variable in this case is a binary categorical variable (missing or not missing the relevant variable).

Appendix B

Table B1

Three-Factor Model Pattern Matrix

Item	Factor 1.	2.	3.	h^2
Household repairs	-0.03	**0.84**	0.00	0.70
Repair mechanical device	0.06	**0.73**	0.00	0.55
Purchase new item requiring set-up	-0.03	**0.62**	0.06	0.39
Creative writing	**0.49**	0.18	-0.08	0.29
Card games	0.01	-0.02	**0.46**	0.21
Board games	0.06	0.09	**0.60**	0.40
Knowledge games	0.02	0.03	**0.65**	0.43
Word games	-0.05	-0.05	**0.66**	0.41
Read for career/education	**0.37**	0.11	0.02	0.17
Go to galleries/museums	**0.41**	-0.06	0.11	0.20
Attend public talk	**0.61**	-0.05	0.06	0.38
Attend religious services	**0.37**	-0.10	-0.01	0.13
Engage in prayer/meditation	**0.38**	-0.06	0.05	0.15
Attend club meetings	**0.50**	-0.09	0.05	0.26
Attend organised social events	**0.46**	-0.12	0.01	0.22
Engage in political activities	**0.41**	0.14	-0.02	0.20
Give public talk	**0.45**	0.12	-0.11	0.22

Note. **Bold** = loading > .3; h^2 = communality. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table B2

Three-Factor Model Structure Matrix

Item	Factor 1.	Factor 2.	Factor 3.
Household repairs	0.09	**0.84**	0.08
Repair mechanical device	0.16	**0.74**	0.08
Purchase new item requiring set-up	0.07	**0.63**	0.11
Creative writing	**0.50**	0.24	0.05
Card games	0.11	0.02	**0.46**
Board games	0.21	0.15	**0.62**
Knowledge games	0.17	0.10	**0.65**
Word games	0.09	0.01	**0.64**
Read for career/education	**0.39**	0.17	0.11
Go to galleries/museums	**0.43**	0.00	0.20
Attend public talk	**0.61**	0.04	0.19
Attend religious services	**0.35**	-0.05	0.06
Engage in prayer/meditation	**0.38**	0.00	0.12
Attend club meetings	**0.50**	-0.02	0.15
Attend organised social events	**0.45**	-0.06	0.10
Engage in political activities	**0.42**	0.19	0.08
Give public talk	**0.45**	0.17	0.00

Note. **Bold** = loading > .3. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table B3

Four-Factor Model Pattern Matrix

Item	Factor 1.	2.	3.	4.	h^2
Household repairs	-0.03	**0.86**	0.00	0.01	0.73
Repair mechanical device	0.06	**0.72**	0.00	0.00	0.54
Purchase new item requiring set-up	-0.02	**0.62**	0.06	0.00	0.39
Creative writing	**0.45**	0.16	-0.07	0.07	0.26
Aerobics (cardiovascular, fitness training etc.)	**0.32**	0.10	0.03	-0.05	0.12
Flexibility training (stretching, yoga etc.)	**0.36**	-0.05	0.11	-0.03	0.15
Weight lifting, strength training etc.	**0.36**	0.09	-0.04	-0.15	0.15
Card games	-0.01	-0.02	**0.46**	0.04	0.22
Board games	0.06	0.08	**0.61**	-0.01	0.41
Knowledge games	0.01	0.03	**0.64**	0.00	0.42
Word games	-0.05	-0.05	**0.65**	-0.01	0.41
Read for career/education	**0.47**	0.07	0.01	-0.11	0.22
Go to galleries/museums	**0.49**	-0.10	0.10	-0.06	0.25
Attend public talk	**0.60**	-0.08	0.05	0.07	0.39
Attend religious services	-0.06	0.01	-0.01	**0.86**	0.73
Engage in prayer/meditation	0.11	0.01	0.05	**0.55**	0.35
Attend club meetings	**0.42**	-0.08	0.06	0.17	0.25
Attend organised social events	0.20	-0.06	0.02	**0.49**	0.33
Engage in political activities	**0.43**	0.11	-0.03	-0.01	0.21
Give public talk	**0.45**	0.10	-0.12	0.05	0.22

Note. **Bold** = loading > .3; h^2 = communality. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table B4

Four-Factor Model Structure Matrix

Item	Factor 1.	2.	3.	4.
Household repairs	0.12	**0.85**	0.08	-0.03
Repair mechanical device	0.18	**0.73**	0.08	-0.01
Purchase new item requiring set-up	0.10	**0.62**	0.11	-0.02
Creative writing	**0.48**	0.23	0.05	0.16
Aerobics (cardiovascular, fitness training etc.)	**0.33**	0.15	0.11	0.03
Flexibility training (stretching, yoga etc.)	**0.37**	0.02	0.18	0.06
Weight lifting, strength training etc.	**0.34**	0.15	0.04	-0.08
Card games	0.11	0.03	**0.46**	0.08
Board games	0.21	0.15	**0.63**	0.06
Knowledge games	0.17	0.10	**0.65**	0.06
Word games	0.09	0.01	**0.63**	0.04
Read for career/education	**0.46**	0.15	0.11	0.00
Go to galleries/museums	**0.48**	-0.01	0.20	0.06
Attend public talk	**0.61**	0.02	0.19	0.21
Attend religious services	0.14	-0.03	0.05	**0.85**
Engage in prayer/meditation	0.25	0.02	0.13	**0.58**
Attend club meetings	**0.46**	-0.02	0.16	0.27
Attend organised social events	**0.31**	-0.04	0.10	**0.54**
Engage in political activities	**0.44**	0.18	0.08	0.08
Give public talk	**0.45**	0.16	0.00	0.13

Note. **Bold** = loading > .3. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table B5

Five-Factor Model Pattern Matrix

Item	Factor 1.	2.	3.	4.	5.	h^2
Household repairs	**0.86**	-0.02	0.00	0.00	0.02	0.73
Repair mechanical device	**0.71**	0.09	0.00	0.00	0.00	0.54
Purchase new item requiring set-up	**0.62**	-0.02	0.06	0.00	0.00	0.39
Creative writing	0.12	**0.57**	-0.06	0.05	-0.08	0.35
Aerobics (cardiovascular, fitness training etc.)	0.05	-0.02	0.02	0.05	**0.65**	0.43
Flexibility training (stretching, yoga etc.)	-0.09	0.07	0.12	0.05	**0.49**	0.29
Weight lifting, strength training etc.	0.03	-0.01	-0.06	-0.05	**0.76**	0.59
Card games	-0.02	-0.05	**0.46**	0.05	0.06	0.22
Board games	0.09	0.03	**0.62**	-0.01	0.01	0.41
Knowledge games	0.03	0.03	**0.65**	0.00	-0.03	0.43
Word games	-0.04	-0.04	**0.65**	-0.01	-0.03	0.40
Read for career/education	0.02	**0.55**	0.03	-0.11	-0.01	0.30
Go to galleries/museums	-0.14	**0.44**	0.12	-0.03	0.10	0.25
Attend public talk	-0.11	**0.53**	0.09	0.09	0.07	0.35
Attend religious services	0.01	-0.03	-0.02	**0.90**	-0.04	0.79
Engage in prayer/meditation	-0.01	0.08	0.06	**0.55**	0.11	0.35
Attend organised social events	-0.06	0.13	0.04	**0.48**	0.05	0.28
Engage in political activities	0.08	**0.46**	0.00	-0.01	0.02	0.23
Give public talk	0.06	**0.50**	-0.10	0.05	0.00	0.26

Note. **Bold** = loading > .3; h^2 = communality. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table B6

Five-Factor Model Structure Matrix

Item	Factor 1.	2.	3.	4.	5.
Household repairs	**0.86**	0.15	0.08	-0.02	0.14
Repair mechanical device	**0.73**	0.23	0.08	-0.01	0.13
Purchase new item requiring set-up	**0.62**	0.11	0.11	-0.02	0.09
Creative writing	0.22	**0.57**	0.06	0.15	0.08
Aerobics (cardiovascular, fitness training etc.)	0.14	0.18	0.10	0.05	**0.65**
Flexibility training (stretching, yoga etc.)	0.01	0.21	0.19	0.08	**0.51**
Weight lifting, strength training etc.	0.14	0.18	0.02	-0.06	**0.76**
Card games	0.02	0.06	**0.46**	0.09	0.10
Board games	0.15	0.17	**0.63**	0.05	0.11
Knowledge games	0.09	0.16	**0.65**	0.06	0.06
Word games	0.01	0.08	**0.63**	0.04	0.02
Read for career/education	0.14	**0.54**	0.13	0.00	0.14
Go to galleries/museums	-0.02	**0.46**	0.21	0.06	0.21
Attend public talk	0.01	**0.57**	0.21	0.20	0.21
Attend religious services	-0.03	0.13	0.06	**0.89**	-0.05
Engage in prayer/meditation	0.01	0.22	0.13	**0.57**	0.13
Attend organised social events	-0.04	0.23	0.11	**0.51**	0.08
Engage in political activities	0.17	**0.48**	0.10	0.07	0.16
Give public talk	0.15	**0.50**	0.01	0.13	0.13

Note. **Bold** = loading > .3. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table B7

Seven-Factor Model Pattern Matrix

Item	Factor 1.	2.	3.	4.	5.	6.	7.	h^2
Household repairs	**0.86**	-0.03	0.00	0.01	0.02	0.02	0.01	0.74
Repair mechanical device	**0.71**	0.08	0.01	0.00	0.01	0.02	-0.05	0.54
Purchase new item requiring set-up	**0.60**	-0.01	0.06	0.00	-0.01	-0.07	0.11	0.41
Creative writing	0.13	**0.58**	-0.04	0.04	-0.06	0.04	-0.11	0.38
Aerobics (cardiovascular, fitness training etc.)	0.04	-0.01	0.02	0.05	**0.63**	-0.03	0.06	0.43
Flexibility training (stretching, yoga etc.)	-0.08	0.06	0.12	0.05	**0.49**	0.02	-0.01	0.29
Weight lifting, strength training etc.	0.03	-0.01	-0.06	-0.06	**0.77**	0.00	0.00	0.60
Card games	-0.02	-0.05	**0.46**	0.05	0.05	0.00	0.05	0.22
Board games	0.08	0.02	**0.65**	-0.01	0.02	-0.04	-0.07	0.43
Knowledge games	0.02	0.03	**0.64**	-0.01	-0.04	0.00	0.08	0.43
Word games	-0.04	-0.04	**0.63**	-0.01	-0.04	0.05	0.01	0.39
Read for career/education	0.01	**0.56**	0.02	-0.10	-0.01	0.00	0.11	0.32
Go to galleries/museums	-0.12	**0.41**	0.12	-0.03	0.11	0.11	-0.02	0.25
Attend public talk	-0.11	**0.52**	0.10	0.09	0.08	-0.01	0.02	0.34
Talk on phone to friends/relatives	-0.11	-0.03	0.08	0.13	0.03	**0.34**	0.05	0.18
Visit relatives/friends	0.01	0.00	-0.01	-0.01	-0.01	**1.00**	0.01	1.00
Attend religious services	0.01	-0.03	-0.02	**0.91**	-0.04	-0.02	0.04	0.83
Engage in prayer/meditation	0.01	0.07	0.08	**0.54**	0.13	0.01	-0.15	0.37
Attend organised social events	-0.05	0.12	0.02	**0.47**	0.06	0.13	-0.02	0.29
Engage in political activities	0.08	**0.45**	0.02	-0.02	0.04	0.00	-0.08	0.24
Give public talk	0.03	**0.52**	-0.10	0.05	0.00	-0.09	0.12	0.30
Travel outside region	0.00	0.02	0.03	0.02	0.00	0.02	**0.70**	0.50
Travel outside town	0.04	0.00	-0.01	-0.02	0.06	0.02	**0.61**	0.40

Note. **Bold** = loading > .3; h^2 = communality. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table B8

Seven-Factor Model Structure Matrix

Item	Factor						
	1.	2.	3.	4.	5.	6.	7.
Household repairs	**0.86**	0.15	0.08	-0.02	0.14	-0.06	0.10
Repair mechanical device	**0.73**	0.23	0.09	-0.01	0.13	-0.04	0.03
Purchase new item requiring set-up	**0.62**	0.11	0.12	-0.02	0.09	-0.11	0.17
Creative writing	0.22	**0.59**	0.07	0.14	0.08	0.06	-0.09
Aerobics (cardiovascular, fitness training etc.)	0.14	0.17	0.10	0.05	**0.65**	-0.01	0.14
Flexibility training (stretching, yoga etc.)	0.01	0.20	0.19	0.07	**0.51**	0.06	0.05
Weight lifting, strength training etc.	0.14	0.16	0.02	-0.06	**0.77**	0.00	0.09
Card games	0.02	0.05	**0.46**	0.08	0.10	0.07	0.11
Board games	0.15	0.16	**0.64**	0.05	0.11	0.04	0.01
Knowledge games	0.09	0.15	**0.65**	0.06	0.06	0.09	0.15
Word games	0.00	0.07	**0.62**	0.04	0.02	0.13	0.08
Read for career/education	0.13	**0.54**	0.13	0.00	0.14	0.04	0.12
Go to galleries/museums	-0.02	**0.44**	0.21	0.06	0.21	0.16	0.00
Attend public talk	0.01	**0.55**	0.21	0.20	0.21	0.06	0.04
Talk on phone to friends/relatives	-0.13	0.02	0.13	0.15	0.03	**0.37**	0.08
Visit relatives/friends	-0.08	0.07	0.13	0.04	0.02	**1.00**	0.08
Attend religious services	-0.03	0.13	0.06	**0.91**	-0.05	0.02	0.02
Engage in prayer/meditation	0.01	0.21	0.14	**0.56**	0.14	0.04	-0.13
Attend organised social events	-0.04	0.22	0.11	**0.50**	0.08	0.17	-0.01
Engage in political activities	0.17	**0.47**	0.11	0.06	0.16	0.02	-0.06
Give public talk	0.15	**0.52**	0.01	0.13	0.13	-0.05	0.11
Travel outside region	0.08	0.04	0.12	0.02	0.09	0.08	**0.71**
Travel outside town	0.11	0.03	0.08	-0.02	0.14	0.07	**0.62**

Note. **Bold** = loading > .3. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table B9

Eight-Factor Model Pattern Matrix

Item	Factor 1.	2.	3.	4.	5.	6.	7.	8.	h^2
Household repairs	**0.87**	-0.02	-0.01	0.00	0.02	0.02	0.01	-0.02	0.74
Repair mechanical device	**0.69**	0.08	0.01	0.00	0.02	0.02	-0.06	0.15	0.57
Purchase new item requiring set-up	**0.62**	0.00	0.04	0.00	-0.03	-0.07	0.13	-0.11	0.42
Creative writing	0.14	**0.58**	-0.05	0.04	-0.07	0.03	-0.10	-0.05	0.38
Aerobics (cardiovascular, fitness training etc.)	0.01	-0.01	0.02	0.05	**0.67**	-0.03	0.06	0.10	0.47
Flexibility training (stretching, yoga etc.)	-0.04	0.07	0.09	0.04	**0.49**	0.02	0.00	-0.28	0.37
Weight lifting, strength training etc.	0.03	0.00	-0.06	-0.06	**0.75**	0.00	0.00	0.02	0.56
Card games	0.01	-0.05	**0.43**	0.05	0.04	0.01	0.06	-0.14	0.23
Board games	0.10	0.03	**0.63**	-0.01	0.02	-0.04	-0.07	-0.10	0.42
Knowledge games	-0.02	0.03	**0.70**	0.00	-0.02	0.00	0.06	0.18	0.53
Word games	-0.03	-0.04	**0.62**	-0.01	-0.04	0.05	0.00	-0.04	0.38
Read for career/education	0.01	**0.55**	0.03	-0.10	-0.02	0.00	0.11	0.00	0.31
Go to galleries/museums	-0.09	**0.43**	0.11	-0.04	0.08	0.10	-0.02	-0.16	0.27
Attend public talk	-0.11	**0.53**	0.10	0.09	0.08	-0.01	0.02	-0.02	0.35
Attend sports events	0.12	0.02	0.13	0.01	0.10	0.03	-0.07	**0.52**	0.34
Talk on phone to friends/relatives	-0.13	-0.02	0.08	0.13	0.04	**0.35**	0.05	0.07	0.18
Visit relatives/friends	0.01	-0.01	-0.01	-0.01	0.00	**1.00**	0.00	0.00	1.00
Go out with friends	-0.15	0.09	0.00	-0.01	-0.06	**0.33**	0.10	-0.04	0.17
Attend religious services	0.00	-0.03	-0.02	**0.92**	-0.04	-0.02	0.03	0.03	0.84
Engage in prayer/meditation	0.03	0.08	0.07	**0.54**	0.11	0.01	-0.14	-0.14	0.38
Attend organised social events	-0.04	0.12	0.02	**0.46**	0.05	0.14	-0.02	-0.02	0.29
Engage in political activities	0.09	**0.44**	0.02	-0.02	0.05	0.00	-0.09	0.00	0.24
Give public talk	0.00	**0.53**	-0.09	0.06	0.02	-0.08	0.10	0.19	0.34
Travel outside region	0.02	0.02	0.03	0.02	0.00	0.02	**0.72**	-0.04	0.53
Travel outside town	0.05	0.00	-0.01	-0.02	0.07	0.03	**0.59**	0.01	0.38

Note. **Bold** = loading > .3; h^2 = communality. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table B10

Eight-Factor Model Structure Matrix

Item	Factor							
	1.	2.	3.	4.	5.	6.	7.	8.
Household repairs	**0.86**	0.15	0.08	-0.02	0.15	-0.06	0.08	0.12
Repair mechanical device	**0.73**	0.22	0.10	-0.01	0.14	-0.04	0.01	0.26
Purchase new item requiring set-up	**0.62**	0.11	0.11	-0.01	0.09	-0.11	0.17	0.01
Creative writing	0.22	**0.59**	0.06	0.14	0.08	0.06	-0.09	-0.02
Aerobics (cardiovascular, fitness training etc.)	0.14	0.17	0.11	0.05	**0.67**	-0.01	0.13	0.08
Flexibility training (stretching, yoga etc.)	0.01	0.20	0.17	0.07	**0.52**	0.07	0.06	-0.30
Weight lifting, strength training etc.	0.14	0.17	0.03	-0.06	**0.74**	0.00	0.07	0.00
Card games	0.03	0.05	**0.44**	0.08	0.10	0.07	0.11	-0.15
Board games	0.15	0.16	**0.63**	0.05	0.11	0.04	0.01	-0.09
Knowledge games	0.09	0.15	**0.70**	0.06	0.07	0.09	0.15	0.18
Word games	0.01	0.06	**0.61**	0.04	0.03	0.13	0.07	-0.05
Read for career/education	0.13	**0.54**	0.13	0.00	0.14	0.05	0.12	0.02
Go to galleries/museums	-0.02	**0.45**	0.20	0.06	0.19	0.17	0.01	-0.17
Attend public talk	0.01	**0.56**	0.20	0.19	0.21	0.06	0.04	-0.03
Attend sports events	0.23	0.10	0.15	0.01	0.12	0.01	-0.02	**0.53**
Talk on phone to friends/relatives	-0.14	0.03	0.13	0.15	0.03	**0.37**	0.08	0.03
Visit relatives/friends	-0.08	0.07	0.13	0.04	0.01	**1.00**	0.09	-0.04
Go out with friends	-0.17	0.07	0.05	0.03	-0.05	**0.36**	0.11	-0.07
Attend religious services	-0.03	0.13	0.05	**0.91**	-0.03	0.02	0.02	0.01
Engage in prayer/meditation	0.02	0.21	0.13	**0.56**	0.14	0.04	-0.12	-0.15
Attend organised social events	-0.04	0.22	0.11	**0.49**	0.09	0.17	-0.01	-0.05
Engage in political activities	0.18	**0.47**	0.10	0.06	0.17	0.02	-0.06	0.02
Give public talk	0.14	**0.52**	0.01	0.13	0.14	-0.05	0.10	0.21
Travel outside region	0.07	0.04	0.12	0.02	0.09	0.08	**0.72**	-0.01
Travel outside town	0.11	0.04	0.08	-0.02	0.14	0.07	**0.61**	0.04

Note. **Bold** = loading > .3. Abbreviated versions of the VLS-ALQ items are included with permission to support the analyses; access to the VLS-ALQ and permission to use the scale in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Appendix C

Table C1

Complete Case Analysis: Six-Factor Model Pattern Matrix

Item	Factor						h^2
	1. Man	2. Int	3. Gam	4. Rel	5. Exe	6. Soc	
Do household repairs (for example, painting or leaky faucets)	**0.91**	-0.04	0.02	0.01	0.03	0.02	0.82
Repair a mechanical device (for example, a car or lawn mower)	**0.74**	0.07	-0.06	-0.02	-0.03	0.03	0.57
Purchase a new item requiring some set-up or assembly	**0.68**	0.03	0.10	0.01	0.05	-0.07	0.50
Engage in creative writing, writing poems, writing newspaper articles, etc.	0.16	**0.55**	-0.08	0.05	-0.10	0.04	0.34
Read books or magazines as part of my job, career, or formal education	0.07	**0.51**	0.04	-0.09	-0.02	0.04	0.28
Go to galleries or museums	-0.11	**0.52**	0.10	-0.01	0.10	0.04	0.33
Attend a public lecture or talk	-0.09	**0.63**	0.08	0.06	0.09	-0.03	0.46
Engage in political activities (for example, neighbourhood organisation)	0.07	**0.51**	-0.05	-0.08	-0.03	-0.01	0.26
Give a public talk or lecture (for example, to a club, service organisation, etc.)	0.08	**0.47**	-0.12	0.09	-0.08	-0.03	0.24
Do aerobics (for example, cardiovascular, fitness training, or workout)	0.07	-0.02	0.01	0.05	**0.63**	-0.01	0.41
Do flexibility training (for example, stretching, yoga, or tai chi)	-0.09	0.09	0.07	0.02	**0.53**	0.03	0.32
Do weight lifting, strength training, or calisthenics	0.04	-0.02	-0.07	-0.05	**0.76**	0.00	0.59
Play card games (for example, Bridge)	-0.03	-0.03	**0.47**	0.06	0.10	0.02	0.24
Play board games (for example, chess or checkers)	0.08	0.08	**0.63**	-0.05	-0.01	-0.09	0.41
Play knowledge games (for example, Trivial Pursuit)	0.03	0.04	**0.66**	0.00	-0.05	0.00	0.45
Play word games (for example, Scrabble)	-0.01	-0.07	**0.71**	0.01	-0.03	0.07	0.51
Talk on the phone to friends, or relatives	-0.09	-0.01	0.10	0.14	0.04	**0.40**	0.23
Visit relatives, friends, or neighbours	0.02	0.00	0.00	-0.01	0.00	**1.00**	1.00
Go out with friends	-0.17	0.15	0.05	0.00	0.03	**0.37**	0.23
Attend church or other religious services	0.02	-0.03	-0.01	**0.97**	-0.03	-0.01	0.93
Engage in prayer, meditation, or philosophical contemplation	-0.04	0.10	0.05	**0.55**	0.11	0.00	0.36
Attend organised social events (for example, activities at the community centre or church social groups)	-0.06	0.17	0.00	**0.47**	0.04	0.10	0.30

Note. Man = Manual, Int = Intellectual, Gam = Games, Rel = Religious, Exe = Exercise, Soc = Social; **Bold** = loading > .3; h^2 = communality. VLS-ALQ items are included with permission to support the analyses; permission to use the VLS-ALQ in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Table C2

Complete Case Analysis: Six-Factor Model Structure Matrix

Item	Factor					
	1. Man	2. Int	3. Gam	4. Rel	5. Exe	6. Soc
Do household repairs (for example, painting or leaky faucets)	**0.90**	0.09	0.03	-0.05	0.12	-0.09
Repair a mechanical device (for example, a car or lawn mower)	**0.75**	0.15	-0.04	-0.05	0.05	-0.06
Purchase a new item requiring some set-up or assembly	**0.70**	0.14	0.10	-0.03	0.13	-0.12
Engage in creative writing, writing poems, writing newspaper articles, etc.	0.21	**0.55**	0.02	0.13	0.01	0.08
Read books or magazines as part of my job, career, or formal education	0.13	**0.51**	0.12	-0.01	0.09	0.11
Go to galleries or museums	-0.03	**0.55**	0.19	0.08	0.19	0.14
Attend a public lecture or talk	0.00	**0.66**	0.19	0.17	0.19	0.09
Engage in political activities (for example, neighbourhood organisation)	0.14	**0.49**	0.02	0.00	0.06	0.04
Give a public talk or lecture (for example, to a club, service organisation, etc.)	0.13	**0.46**	-0.05	0.15	0.00	0.01
Do aerobics (for example, cardiovascular, fitness training, or workout)	0.13	0.11	0.04	0.03	**0.64**	0.02
Do flexibility training (for example, stretching, yoga, or tai chi)	-0.03	0.19	0.12	0.03	**0.54**	0.09
Do weight lifting, strength training, or calisthenics	0.12	0.10	-0.03	-0.08	**0.76**	0.02
Play card games (for example, Bridge)	-0.02	0.07	**0.48**	0.08	0.11	0.10
Play board games (for example, chess or checkers)	0.10	0.17	**0.62**	-0.01	0.04	0.01
Play knowledge games (for example, Trivial Pursuit)	0.04	0.14	**0.67**	0.04	0.00	0.10
Play word games (for example, Scrabble)	-0.03	0.05	**0.71**	0.04	0.00	0.17
Talk on the phone to friends, or relatives	-0.14	0.08	0.17	0.17	0.05	**0.44**
Visit relatives, friends, or neighbours	-0.10	0.13	0.15	0.05	0.05	**1.00**
Go out with friends	-0.19	0.19	0.13	0.06	0.06	**0.42**
Attend church or other religious services	-0.05	0.12	0.03	**0.96**	-0.06	0.04
Engage in prayer, meditation, or philosophical contemplation	-0.05	0.22	0.10	**0.57**	0.11	0.06
Attend organised social events (for example, activities at the community centre or church social groups)	-0.07	0.26	0.07	**0.51**	0.06	0.16

Note. Man = Manual, Int = Intellectual, Gam = Games, Rel = Religious, Exe = Exercise, Soc = Social. **Bold** = loading > .3. VLS-ALQ items are included with permission to support the analyses; permission to use the VLS-ALQ in full or in part must be obtained from Professor Roger Dixon (rdixon@ualberta.ca).

Appendix D

Complete Case Analysis: Regression Models and Path Models

Table D1

Multiple Regression Models

Predictor	Estimate	SE	*t*	*p*
		Verbal Comprehension		
(Intercept)	99.97	13.23	7.56	<0.001
Age	0.05	0.12	0.42	0.677
Gender (Female)	-0.85	1.39	-0.61	0.542
Education	**1.35**	**0.18**	**7.44**	**<0.001**
Deprivation	0.20	0.13	1.53	0.128
Neuroticism	**-0.09**	**0.03**	**-2.76**	**0.006**
Extraversion	**-0.10**	**0.04**	**-2.56**	**0.011**
Openness	**0.16**	**0.04**	**4.10**	**<0.001**
Agreeableness	**-0.10**	**0.04**	**-2.42**	**0.016**
Conscientiousness	-0.07	0.04	-1.86	0.065
		Perceptual Reasoning		
(Intercept)	128.99	17.58	7.34	<0.001
Age	**-0.42**	**0.16**	**-2.66**	**0.008**
Gender (Female)	**-4.62**	**1.85**	**-2.50**	**0.013**
Education	**1.18**	**0.24**	**4.87**	**<0.001**
Deprivation	0.33	0.17	1.93	0.055
Neuroticism	**-0.13**	**0.04**	**-3.13**	**0.002**
Extraversion	-0.10	0.05	-1.90	0.059
Openness	**0.11**	**0.05**	**2.16**	**0.032**
Agreeableness	0.01	0.06	0.12	0.909
Conscientiousness	-0.08	0.05	-1.59	0.113
		Working Memory		
(Intercept)	144.23	17.97	8.03	<0.001
Age	-0.18	0.16	-1.15	0.252
Gender (Female)	**-4.55**	**1.89**	**-2.41**	**0.017**
Education	**0.92**	**0.25**	**3.73**	**<0.001**
Deprivation	0.34	0.18	1.92	0.057
Neuroticism	-0.04	0.04	-0.87	0.383
Extraversion	-0.04	0.05	-0.75	0.452
Openness	-0.04	0.05	-0.74	0.459
Agreeableness	-0.11	0.06	-1.87	0.062
Conscientiousness	-0.10	0.05	-1.87	0.062

Predictor	Estimate	SE	*t*	*p*
	Processing Speed			
(Intercept)	155.45	16.76	9.28	<0.001
Age	**-0.81**	**0.15**	**-5.45**	**<0.001**
Gender (Female)	**4.29**	**1.76**	**2.43**	**0.016**
Education	-0.03	0.23	-0.14	0.887
Deprivation	0.21	0.16	1.28	0.202
Neuroticism	-0.01	0.04	-0.22	0.830
Extraversion	0.01	0.05	0.26	0.795
Openness	0.07	0.05	1.41	0.161
Agreeableness	-0.04	0.05	-0.68	0.499
Conscientiousness	-0.02	0.05	-0.33	0.742
	Auditory Memory			
(Intercept)	98.13	19.26	5.09	<0.001
Age	-0.10	0.17	-0.60	0.546
Gender (Female)	**6.00**	**2.03**	**2.96**	**0.003**
Education	**1.14**	**0.26**	**4.32**	**<0.001**
Deprivation	0.17	0.19	0.91	0.364
Neuroticism	-0.02	0.05	-0.43	0.670
Extraversion	-0.04	0.06	-0.65	0.515
Openness	0.05	0.06	0.87	0.388
Agreeableness	0.04	0.06	0.74	0.462
Conscientiousness	-0.03	0.05	-0.64	0.522
	Visual Memory			
(Intercept)	111.60	17.10	6.53	<0.001
Age	-0.28	0.15	-1.87	0.063
Gender (Female)	0.54	1.80	0.30	0.763
Education	**0.83**	**0.23**	**3.52**	**<0.001**
Deprivation	0.12	0.17	0.74	0.460
Neuroticism	**-0.09**	**0.04**	**-2.08**	**0.038**
Extraversion	**-0.17**	**0.05**	**-3.55**	**<0.001**
Openness	**0.11**	**0.05**	**2.14**	**0.033**
Agreeableness	-0.02	0.05	-0.42	0.672
Conscientiousness	0.06	0.05	1.33	0.186

Note. Deprivation = Scottish Index of Multiple Deprivation (vigintile ranking [i.e. 1-20] based on postcode - lower values indicate higher deprivation). **Bold** = significant at $p < .05$.

Table D2

Parameter Estimates of Path Model

Parameter			Estimate (95% CI)	*SE*	Standardised Estimate	*p*
			Direct Effects			
VCI	←	Neuroticism	-0.04 (-0.10, 0.02)	0.03	-0.09	0.156
VCI	←	Extraversion	-0.09 (-0.17, -0.02)	0.04	-0.16	0.018
VCI	←	Openness	0.13 (0.05, 0.21)	0.04	0.21	0.001
VCI	←	Intellectual	0.10 (-0.05, 0.24)	0.07	0.06	0.185
VCI	←	Gender	-1.71 (-4.24, 0.82)	1.29	-0.07	0.185
VCI	←	Education	1.32 (0.96, 1.68)	0.18	0.42	<0.001
PRI	←	Neuroticism	-0.10 (-0.17, -0.02)	0.04	-0.17	0.013
PRI	←	Extraversion	-0.09 (-0.19, 0.02)	0.05	-0.12	0.099
PRI	←	Openness	0.08 (-0.02, 0.17)	0.05	0.10	0.134
PRI	←	Pack Years	-0.03 (-0.10, 0.05)	0.04	-0.03	0.494
PRI	←	Gender	-4.39 (-7.47, -1.31)	1.57	-0.15	0.005
PRI	←	Education	1.20 (0.71, 1.68)	0.25	0.30	<0.001
PRI	←	Age	-0.42 (-0.72, -0.12)	0.15	-0.16	0.006
PRI	←	Deprivation	0.19 (-0.11, 0.48)	0.15	0.06	0.217
VMI	←	Neuroticism	-0.10 (-0.17, -0.02)	0.04	-0.18	0.011
VMI	←	Extraversion	-0.12 (-0.19, -0.04)	0.04	-0.17	0.002
VMI	←	Pack Years	-0.02 (-0.11, 0.06)	0.05	-0.03	0.584
VMI	←	Education	0.93 (0.55, 1.32)	0.19	0.25	<0.001
VMI	←	Age	-0.31 (-0.59, -0.03)	0.14	-0.13	0.029
Intellectual	←	Openness	0.12 (0.07, 0.16)	0.02	0.29	<0.001
Pack Years	←	Neuroticism	0.08 (0.01, 0.14)	0.03	0.11	0.026

Parameter					Estimate (95% CI)	*SE*	Standardised Estimate	*p*
					Indirect Effects			
VCI	←	Intellectual	←	Openness	0.01 (-0.01, 0.03)[a]	0.01	0.02	0.206
PRI	←	Pack Years	←	Neuroticism	0.00 (-0.01, 0.00)[a]	0.00	0.00	0.518
VMI	←	Pack Years	←	Neuroticism	0.00 (-0.01, 0.00)[a]	0.00	0.00	0.611
					Total Effects			
VCI	←	Openness			0.14 (0.07, 0.22)	0.04	0.23	<0.001
PRI	←	Neuroticism			-0.10 (-0.18, -0.02)	0.04	-0.17	0.011
VMI	←	Neuroticism			-0.10 (-0.17, -0.02)	0.04	-0.18	0.009

Note. Model fit indices: $\chi^2(21) = 63.29$, $p < .001$; CFI = 0.86; RMSEA = 0.092 (90% CI = 0.067, 0.119). VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index; AMI = Auditory Memory Index; VMI = Visual Memory Index

[a] Monte Carlo confidence intervals

Appendix E

Search String Used for Database Searches

("cognitive aging" OR "cognitive ageing" OR "cognitive decline" OR "memory decline" OR “processing decline” OR “executive decline” OR “reasoning decline” OR “cognitive change” OR “memory change” OR “older people” OR "older adults" OR elder*) **AND** ("cognitive intervention" OR "cognitive training" OR "cognitive rehabilitation" OR "memory training" OR "brain training" OR “skills training” OR "mnemonic training" OR "cognitive engagement" OR "cognitive stimulation" OR “mental stimulation” OR "cognitive enrichment" OR "intellectual enrichment" OR "physical intervention" OR "exercise intervention" OR "resistance training" OR "social engagement" OR "social club" OR “social group” OR “social activit*” OR danc* OR walk* OR yoga OR meditat*) **AND** (personality OR neurotic* OR extraver* OR openness OR agreeable* OR conscientious* OR “emotional stability” OR intellect OR imagination OR “big five” OR “five factor”)

Appendix F

Assessment of Study Quality Using the Cochrane Collaboration's 'Risk of Bias' Tool

Study	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting
Belleville et al. (2018)	+	+	?	+	-	?
Carretti et al. (2011)	-	-	-	-	+	-
Cerino et al. (2020)	+	+	?	?	+	+
Finkel & Yesavage (1989)	-	-	-	-	+	?
Gajewski & Falkenstein (2012)	?	?	-	?	+	?
Gratzinger et al. (1990)	?	?	-	?	?	+
Guye et al. (2017)[a]	+	+	+	+	+	+
Hering et al. (2017)	?	?	-	?	?	?
McDougall et al. (2010)	?	?	-	?	-	+
Stine-Morrow et al. (2014)	?	?	-	?	+	?

Note. + = low risk of bias; - = high risk of bias; ? = unclear risk of bias

[a] Information regarding randomisation/blinding procedures comes from Guye & von Bastian (2017)

Appendix G

Analysis of Data from Gajewski and Falkenstein (2012)

This study examined task-switching performance after two kinds of training: cognitive and physical. Controls were either active (relaxation training) or no-contact. The dependent variable was mixing costs in accuracy, i.e., number of errors in mixed task trials compared to single-task trials. Lower mixing costs are indicative of better performance.

The original paper found that reduction in mixing costs in accuracy after intervention was significantly greater in the cognitive training group compared to the control group. Analyses were conducted to see whether this effect was moderated by personality.

A moderating effect of personality was characterised as a group x personality interaction predicting change in mixing costs from pre to post-intervention. This is adapted from Wang et al.'s (2007) recommended method for subgroup analysis of treatment effects in clinical trials (see Sharpe et al., 2014 for an example of the same method used to examine the moderating of self-efficacy on intervention outcome).

Using regression, first the main effect of group was added, followed by main effects of, and interactions with, each of the 5 personality traits. Separate models were constructed for each personality trait. As shown in Table G1, the main effect of group alone was significant (i.e., those in the cognitive training group improved significantly more than controls; $p < .01$).

However, when the personality traits were added separately, no significant main effects of personality or personality-group interactions were found (see Tables G2-G6). These results suggest that personality had no influence on the beneficial effects of cognitive training.

Table G1

Main Group Effect

	Estimate	*SE*	*t*-value	*p*
Intercept	-0.717	1.858	-0.386	0.70073
Group	8.964	2.787	3.216	0.00197

Table G2

Group x Neuroticism Interaction

	Estimate	*SE*	*t*-value	*p*
Intercept	1.085	6.398	0.170	0.866
Group	-4.483	9.114	-0.492	0.624
Neuroticism	-1.179	4.008	-0.294	0.770
Group x Neuroticism	9.745	6.048	1.611	0.112

Table G3

Group x Extraversion Interaction

	Estimate	*SE*	*t*-value	*p*
Intercept	-8.392	7.188	-1.168	0.247
Group	4.903	11.189	0.438	0.663
Extraversion	3.827	3.465	1.105	0.273
Group x Extraversion	1.445	5.098	0.283	0.778

Table G4

Group x Openness Interaction

	Estimate	*SE*	*t*-value	*p*
Intercept	-2.6356	7.8400	-0.336	0.738
Group	18.9105	13.3806	1.413	0.162
Openness	0.9163	3.6357	0.252	0.802
Group x Openness	-4.2020	5.6726	-0.741	0.461

Table G5

Group x Agreeableness Interaction

	Estimate	*SE*	*t*-value	*p*
Intercept	7.640	6.708	1.139	0.259
Group	-3.572	10.289	-0.347	0.730
Agreeableness	-3.861	2.978	-1.297	0.199
Group x Agreeableness	5.590	4.306	1.298	0.199

Table G6

Group x Conscientiousness Interaction

	Estimate	*SE*	*t*-value	*p*
Intercept	4.096	9.160	0.447	0.656
Group	-13.191	15.197	-0.868	0.388
Conscientiousness	-1.956	3.646	-0.537	0.593
Group x Conscientiousness	8.333	5.709	1.460	0.149

Appendix H

Summary of Intervention Activity Selection

A longlist of potential intervention activities was drawn together based on an audit of existing activities offered in Edinburgh and the surrounding areas. The audit consulted a published list of activities offered by the City of Edinburgh council, evening classes offered by the University of Edinburgh, groups/classes organised by the University of the Third Age, and additional class-based activities listed on websites of community centres, adult learning facilities, etc. The longlist was then reduced by removing duplicates or similar activities (i.e., multiple fitness classes could appear as one named activity rather than by individual classes), and the types of activities considered were limited to those that were available in multiple locations and at various times throughout the year. The resulting shortlist comprised the following 23 activities:

- Adult education classes (for example on subjects like Architecture, History or Philosophy)
- Art classes (for example drawing, painting, etc.)
- Creative writing course
- Digital photography course
- Film studies/appreciation course
- Computer classes
- Creative crafts (for example crochet & knitting, patchwork, quilting, applique, embroidery, dressmaking, tapestry weaving)
- Handicrafts (ceramics, lapidary, pottery, stained glass)
- Jewellery making
- Woodcraft
- Bingo
- Bridge

- Social clubs
- Language classes
- Learning to play a musical instrument
- Singing groups
- Gardening
- Dance classes
- Drama course
- Exercise classes (including Pilates, tai chi, yoga, Zumba, etc.)
- Mindfulness and relaxation activities
- Sports (such as badminton, golf, etc.)
- Walking groups

The shortlist was distributed to community groups comprising older adults and a group of experts (comprising members of the Intervention Factory Forum and Advisory Panel and other experts in the field of cognitive ageing). These individuals provided ratings of the mental, physical and social demands of each activity on the shortlist. Table H1 presents average ratings of demand among the community group (N = 106), the expert group (N = 63) and over both groups combined.

These ratings were then used to narrow down the shortlist to six activities, with the goal of selecting three activities that were predominantly mentally, physically and socially demanding respectively, as well as two activities with mixed demands, and a further activity with low overall demands to serve as an active control group. The final selections were made after discussing the ratings with the Intervention Factory Forum and Advisory Panel. The discussion considered the ratings as well as the distinctiveness of one group of activity versus another, to ensure a broad range of activities were selected. The aim of having predominantly mental, physical and social activities as well as mixed-demands activities was in the context of the ratings often showing that each activity consisted of mixed demands in most cases. The final selection of activities therefore represented a compromise between study aims and the constraints of user-rated demands, and reflected the consensus of the panel discussion.

Table H1

Average Ratings of Mental, Physical and Social Demands of Each Activity on the Shortlist

Type of demand	Overall		Experts		Community	
	Median Rating	Mean Rating	Median Rating	Mean Rating	Median Rating	Mean Rating
Adult Education Classes						
Mental Demands	2.00	2.27	3.00	2.44	2.00	2.16
Physical Demands	1.00	0.79	1.00	0.54	1.00	0.93
Social Demands	2.00	1.57	2.00	1.60	2.00	1.55
Art Classes						
Mental Demands	2.00	1.91	2.00	2.06	2.00	1.82
Physical Demands	1.00	1.16	1.00	1.03	1.00	1.24
Social Demands	2.00	1.49	2.00	1.71	1.00	1.35
Creative Writing						
Mental Demands	3.00	2.51	3.00	2.75	3.00	2.37
Physical Demands	1.00	0.96	1.00	0.60	1.00	1.17
Social Demands	2.00	1.56	2.00	1.67	2.00	1.50
Digital Photography						
Mental Demands	2.00	2.20	2.00	2.24	2.00	2.17
Physical Demands	1.00	1.37	1.00	1.23	2.00	1.45
Social Demands	2.00	1.47	1.00	1.49	2.00	1.44
Film Studies						
Mental Demands	2.00	1.95	2.00	1.92	2.00	1.97
Physical Demands	1.00	0.96	1.00	0.60	1.00	1.16
Social Demands	2.00	1.61	2.00	1.60	2.00	1.62
Computer Classes						
Mental Demands	3.00	2.46	3.00	2.63	3.00	2.37
Physical Demands	1.00	1.05	1.00	0.69	1.00	1.25
Social Demands	1.00	1.37	1.00	1.25	1.00	1.43
Creative Crafts						
Mental Demands	2.00	1.89	2.00	1.95	2.00	1.86
Physical Demands	1.00	1.35	1.00	1.33	1.00	1.37
Social Demands	2.00	1.45	2.00	1.50	2.00	1.42
Handicrafts						
Mental Demands	2.00	2.04	2.00	1.81	2.00	2.16
Physical Demands	2.00	1.73	2.00	1.64	2.00	1.77
Social Demands	2.00	1.48	1.00	1.38	2.00	1.53
Jewellery Making[a]						
Mental Demands	2.00	1.97	2.00	1.88	2.00	2.02
Physical Demands	1.00	1.43	1.00	1.41	1.00	1.44
Social Demands	1.00	1.29	1.00	1.26	1.00	1.30
Woodcraft						
Mental Demands	2.00	2.12	2.00	2.00	2.00	2.18
Physical Demands	2.00	2.10	2.00	1.98	2.00	2.17
Social Demands	1.00	1.46	1.00	1.29	2.00	1.55
Bingo						
Mental Demands	1.00	1.23	1.00	1.26	1.00	1.21
Physical Demands	0.00	0.60	0.00	0.49	0.00	0.65
Social Demands	1.00	1.37	1.00	1.53	1.00	1.29

Type of demand	Overall		Experts		Community	
	Median Rating	Mean Rating	Median Rating	Mean Rating	Median Rating	Mean Rating
Bridge						
Mental Demands	3.00	2.48	3.00	2.54	3.00	2.45
Physical Demands	1.00	0.96	1.00	0.58	1.00	1.16
Social Demands	2.00	1.90	2.00	2.05	2.00	1.82
Social Clubs						
Mental Demands	1.00	1.33	1.00	1.49	1.00	1.24
Physical Demands	1.00	1.09	1.00	1.00	1.00	1.14
Social Demands	2.00	1.99	3.00	2.67	2.00	1.63
Language Classes						
Mental Demands	3.00	2.63	3.00	2.86	3.00	2.50
Physical Demands	1.00	0.89	1.00	0.61	1.00	1.04
Social Demands	2.00	1.83	2.00	2.02	2.00	1.72
Musical Instrument						
Mental Demands	3.00	2.60	3.00	2.77	3.00	2.51
Physical Demands	2.00	1.69	2.00	1.63	2.00	1.73
Social Demands	1.00	1.45	1.00	1.47	1.00	1.44
Singing						
Mental Demands	2.00	1.79	2.00	1.65	2.00	1.86
Physical Demands	1.00	1.37	1.00	1.28	1.00	1.42
Social Demands	2.00	1.85	2.00	2.12	2.00	1.71
Gardening						
Mental Demands	2.00	1.56	1.00	1.26	2.00	1.73
Physical Demands	3.00	2.42	2.00	2.39	3.00	2.43
Social Demands	1.00	1.02	1.00	0.81	1.00	1.14
Dance Classes						
Mental Demands	2.00	1.99	2.00	1.93	2.00	2.02
Physical Demands	3.00	2.51	3.00	2.70	3.00	2.41
Social Demands	2.00	2.09	2.00	2.35	2.00	1.94
Drama						
Mental Demands	2.00	2.29	2.00	2.26	3.00	2.31
Physical Demands	2.00	1.83	2.00	1.72	2.00	1.90
Social Demands	2.00	2.10	2.00	2.35	2.00	1.96
Exercise Classes						
Mental Demands	2.00	1.91	2.00	1.56	2.00	2.09
Physical Demands	3.00	2.63	3.00	2.86	3.00	2.51
Social Demands	2.00	1.66	2.00	1.58	2.00	1.70
Mindfulness						
Mental Demands	2.00	1.51	1.00	1.49	2.00	1.52
Physical Demands	1.00	1.05	1.00	0.95	1.00	1.10
Social Demands	1.00	1.12	1.00	0.89	1.00	1.24
Sports						
Mental Demands	2.00	2.04	2.00	1.72	2.00	2.22
Physical Demands	3.00	2.59	3.00	2.75	3.00	2.50
Social Demands	2.00	1.91	2.00	1.96	2.00	1.89
Walking Groups						
Mental Demands	1.00	1.35	1.00	1.09	1.50	1.49
Physical Demands	2.00	2.16	2.00	2.26	2.00	2.10
Social Demands	2.00	1.74	2.00	1.95	2.00	1.63

Note. **Bold** indicates the activities selected to be interventions. Participants rated how mentally/physically/socially demanding they thought each activity might be on a scale of 0-3 (0 = not demanding, 1 = low demands, 2 = moderately demanding, 3 = highly demanding).

[a] Jewellery Making was not initially selected as an intervention activity, but was later included as an option for participants alongside other Handicraft/Woodcraft classes in order to provide more choices of class when options were particularly limited (i.e., when other classes were fully booked). Jewellery Making and other Handicraft/Woodcraft classes comprised the Creative group used in all analyses.

Appendix I

Missing Data Rates for Chapter 5 Study Variables Measured at Baseline and Follow-up

Variable	Full Sample N Missing	Full Sample % Missing	Excluding Non-Completers N Missing	Excluding Non-Completers % Missing
Variables Measured at Baseline				
Age	0	0.0	0	0.0
Gender	0	0.0	0	0.0
Years of Education	0	0.0	0	0.0
Deprivation Level	0	0.0	0	0.0
Self-Rated Health	0	0.0	0	0.0
SPPPB Total Score	0	0.0	0	0.0
HADS Anxiety Score	0	0.0	0	0.0
HADS Depression Score	0	0.0	0	0.0
Neuroticism	14	4.2	9	3.0
Extraversion	19	5.7	12	4.0
Openness to Experience	13	3.9	7	2.3
Agreeableness	14	4.2	9	3.0
Conscientiousness	17	5.1	10	3.3
MMSE Score	0	0.0	0	0.0
CDT Score	16	4.8	15	5.0
Full Scale IQ	1	0.3	1	0.3
Verbal Comprehension	0	0.0	0	0.0
Perceptual Reasoning	0	0.0	0	0.0
Working Memory	7	2.1	6	2.0
Processing Speed	1	0.3	1	0.3
Auditory Memory	15	4.5	11	3.6
Visual Memory	4	1.2	4	1.3
Immediate Memory	15	4.5	11	3.6
Delayed Memory	19	5.7	15	5.0
Activity Group	16	4.8	0	0.0
Cognitive Variables Measured at Follow-up				
Full Scale IQ	38	11.3	4	1.3
Verbal Comprehension	37	11.0	3	1.0
Perceptual Reasoning	37	11.0	3	1.0
Processing Speed	39	11.6	5	1.7
Working Memory	40	11.9	6	2.0
Auditory Memory	46	13.7	12	4.0
Visual Memory	37	11.0	3	1.0
Immediate Memory	46	13.7	12	4.0
Delayed Memory	45	13.4	11	3.6

Note. Full sample N = 336. Sample excluding non-completers N = 302. SPPPB = Short Portable Physical Performance Battery, HADS = Hospital Anxiety and Depression Scale, MMSE = Mini Mental State Examination, CDT = Clock Drawing Test.

Appendix J

Supplementary Analyses: Participants with Assessment Intervals > 90 Days Pre/Post-Activity Excluded

Table J1

Summary of Linear Mixed Models Analysing Intervention Effects for Each Cognitive Outcome

Model	No. of parameters	AIC	BIC	Log-Likelihood	χ^2	*df*	*p*
Full Scale IQ							
Intercept Only	3	3333.65	3346.17	-1663.83	-	-	-
Time	4	3273.05	3289.74	-1632.53	62.60	1	<0.001
Time + Group	9	3274.23	3311.78	-1628.12	8.82	5	0.116
Time + Group + Time x Group	14	3280.89	3339.30	-1626.45	3.34	5	0.648
Verbal Comprehension							
Intercept Only	3	3398.49	3411.02	-1696.24	-	-	-
Time	4	3374.39	3391.09	-1683.19	26.10	1	<0.001
Time + Group	9	3382.14	3419.73	-1682.07	2.24	5	0.814
Time + Group + Time x Group	14	3387.66	3446.13	-1679.83	4.48	5	0.482
Perceptual Reasoning							
Intercept Only	3	3609.06	3621.58	-1801.53	-	-	-
Time	4	3601.79	3618.50	-1796.90	9.26	1	0.002
Time + Group	9	3605.46	3643.04	-1793.73	6.34	5	0.275
Time + Group + Time x Group	14	3612.74	3671.20	-1792.37	2.72	5	0.743
Working Memory							
Intercept Only	3	3503.80	3516.28	-1748.90	-	-	-
Time	4	3494.88	3511.53	-1743.44	10.92	1	<0.001
Time + Group	9	3499.97	3537.42	-1740.98	4.91	5	0.426
Time + Group + Time x Group	14	3501.09	3559.35	-1736.54	8.88	5	0.114

Model	No. of parameters	AIC	BIC	Log-Likelihood	χ^2	*df*	*p*
Processing Speed							
Intercept Only	3	3442.10	3454.61	-1718.05	-	-	-
Time	4	3392.87	3409.56	-1692.43	51.23	1	<0.001
Time + Group	9	3379.69	3417.23	-1680.84	23.18	5	<0.001
Time + Group + Time x Group	14	3382.40	3440.81	-1677.20	7.29	5	0.200
Auditory Memory							
Intercept Only	3	3558.66	3571.08	-1776.33	-	-	-
Time	4	3471.23	3487.78	-1731.62	89.43	1	<0.001
Time + Group	9	3474.31	3511.55	-1728.15	6.92	5	0.227
Time + Group + Time x Group	14	3482.34	3540.27	-1727.17	1.97	5	0.853
Visual Memory							
Intercept Only	3	3794.90	3807.42	-1894.45	-	-	-
Time	4	3665.80	3682.50	-1828.90	131.10	1	<0.001
Time + Group	9	3669.38	3706.94	-1825.69	6.42	5	0.267
Time + Group + Time x Group	14	3673.87	3732.30	-1822.93	5.51	5	0.357
Immediate Memory							
Intercept Only	3	3585.45	3597.87	-1789.73	-	-	-
Time	4	3474.79	3491.34	-1733.40	112.66	1	<0.001
Time + Group	9	3476.67	3513.91	-1729.34	8.12	5	0.150
Time + Group + Time x Group	14	3481.65	3539.58	-1726.83	5.02	5	0.414
Delayed Memory							
Intercept Only	3	3649.45	3661.87	-1821.73	-	-	-
Time	4	3509.18	3525.73	-1750.59	142.27	1	<0.001
Time + Group	9	3514.35	3551.59	-1748.17	4.83	5	0.437
Time + Group + Time x Group	14	3521.31	3579.24	-1746.66	3.04	5	0.694

Table J2

Parameter Estimates of Full Time x Group Interaction Model for Each Cognitive Outcome

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
Full Scale IQ						
(Intercept)	**111.05**	**1.87**	**259.63**	**59.46**	**<0.001**	**<0.001**
Time	**2.92**	**0.73**	**238.48**	**3.98**	**<0.001**	**<0.001**
Group (Computer)	-6.87	3.98	259.63	-1.73	0.086	0.257
Group (Creative)	-2.00	2.31	259.63	-0.87	0.388	0.664
Group (Language)	-0.80	2.48	259.63	-0.32	0.748	0.807
Group (Physical)	-0.90	2.45	259.63	-0.37	0.713	0.807
Group (Social)	-9.05	3.85	259.63	-2.35	0.019	0.078
Time x Group (Computer)	-2.20	1.55	238.14	-1.42	0.158	0.379
Time x Group (Creative)	-0.22	0.90	238.33	-0.24	0.807	0.807
Time x Group (Language)	-0.95	0.97	238.44	-0.98	0.329	0.658
Time x Group (Physical)	-0.34	0.96	238.43	-0.36	0.721	0.807
Time x Group (Social)	0.49	1.50	238.14	0.33	0.742	0.807
Verbal Comprehension						
(Intercept)	**109.67**	**1.74**	**281.86**	**62.97**	**<0.001**	**<0.001**
Time	**3.24**	**0.98**	**240.28**	**3.32**	**0.001**	**0.006**
Group (Computer)	-1.30	3.71	281.86	-0.35	0.726	0.827
Group (Creative)	-0.56	2.15	281.86	-0.26	0.794	0.827
Group (Language)	0.76	2.31	281.86	0.33	0.741	0.827
Group (Physical)	-0.50	2.29	281.86	-0.22	0.827	0.827
Group (Social)	-3.17	3.59	281.86	-0.88	0.379	0.757
Time x Group (Computer)	-1.33	2.06	239.60	-0.65	0.518	0.827
Time x Group (Creative)	-0.66	1.20	239.98	-0.55	0.584	0.827
Time x Group (Language)	-2.08	1.30	240.19	-1.60	0.111	0.344
Time x Group (Physical)	-1.43	1.28	240.18	-1.12	0.266	0.638
Time x Group (Social)	-3.16	2.00	239.61	-1.58	0.115	0.344
Perceptual Reasoning						
(Intercept)	**106.64**	**2.12**	**289.53**	**50.41**	**<0.001**	**<0.001**
Time	1.24	1.29	239.92	0.96	0.337	0.812
Group (Computer)	-6.64	4.51	289.53	-1.47	0.142	0.568
Group (Creative)	-2.23	2.61	289.53	-0.85	0.394	0.812
Group (Language)	-0.41	2.81	289.53	-0.14	0.885	0.966
Group (Physical)	-1.16	2.78	289.53	-0.42	0.676	0.812
Group (Social)	-9.14	4.36	289.53	-2.10	0.037	0.222
Time x Group (Computer)	-0.06	2.74	239.13	-0.02	0.982	0.982
Time x Group (Creative)	1.10	1.59	239.58	0.69	0.489	0.812
Time x Group (Language)	-1.10	1.72	239.82	-0.64	0.523	0.812
Time x Group (Physical)	0.81	1.70	239.80	0.48	0.634	0.812
Time x Group (Social)	1.26	2.65	239.14	0.47	0.636	0.812
Working Memory						
(Intercept)	**114.59**	**2.16**	**271.28**	**53.14**	**<0.001**	**<0.001**
Time	1.94	1.11	233.63	1.75	0.082	0.289
Group (Computer)	-4.04	4.60	271.28	-0.88	0.380	0.452
Group (Creative)	-4.04	2.67	272.90	-1.52	0.131	0.289
Group (Language)	-3.25	2.87	272.24	-1.13	0.258	0.443
Group (Physical)	-4.16	2.83	271.28	-1.47	0.142	0.289
Group (Social)	-6.76	4.45	271.28	-1.52	0.130	0.289
Time x Group (Computer)	-3.39	2.32	232.54	-1.46	0.145	0.289
Time x Group (Creative)	-1.28	1.37	233.53	-0.94	0.350	0.452
Time x Group (Language)	1.50	1.47	233.50	1.02	0.307	0.452
Time x Group (Physical)	-1.18	1.44	233.26	-0.82	0.414	0.452

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
Time x Group (Social)	1.48	2.24	232.56	0.66	0.510	0.510
Processing Speed						
(Intercept)	**105.49**	**1.92**	**268.68**	**55.08**	**<0.001**	**<0.001**
Time	**2.56**	**0.89**	**238.08**	**2.88**	**0.004**	**0.026**
Group (Computer)	**-11.12**	**4.08**	**268.68**	**-2.72**	**0.007**	**0.027**
Group (Creative)	-0.01	2.36	268.68	0.00	0.998	0.998
Group (Language)	-0.41	2.54	268.68	-0.16	0.872	0.998
Group (Physical)	3.14	2.51	268.68	1.25	0.212	0.364
Group (Social)	**-9.82**	**3.95**	**268.68**	**-2.49**	**0.013**	**0.040**
Time x Group (Computer)	-2.93	1.88	237.61	-1.56	0.121	0.280
Time x Group (Creative)	0.05	1.09	237.98	0.05	0.963	0.998
Time x Group (Language)	-0.24	1.18	238.22	-0.20	0.838	0.998
Time x Group (Physical)	0.93	1.17	238.01	0.80	0.426	0.639
Time x Group (Social)	2.69	1.82	237.62	1.48	0.140	0.280
Auditory Memory						
(Intercept)	**121.24**	**2.16**	**277.79**	**56.01**	**<0.001**	**<0.001**
Time	**4.96**	**1.29**	**224.99**	**3.83**	**<0.001**	**<0.001**
Group (Computer)	-8.33	4.60	274.91	-1.81	0.071	0.285
Group (Creative)	-1.92	2.69	277.19	-0.71	0.476	0.665
Group (Language)	-4.80	2.87	277.40	-1.67	0.096	0.288
Group (Physical)	-4.04	2.84	277.35	-1.42	0.155	0.311
Group (Social)	-7.15	4.66	285.75	-1.54	0.126	0.302
Time x Group (Computer)	-2.23	2.68	222.78	-0.83	0.406	0.665
Time x Group (Creative)	0.48	1.59	224.17	0.30	0.764	0.764
Time x Group (Language)	1.16	1.71	224.68	0.68	0.499	0.665
Time x Group (Physical)	0.74	1.69	224.64	0.44	0.664	0.724
Time x Group (Social)	1.22	2.77	225.25	0.44	0.661	0.724
Visual Memory						
(Intercept)	**103.62**	**2.15**	**303.91**	**48.15**	**<0.001**	**<0.001**
Time	**5.95**	**1.49**	**239.32**	**4.00**	**<0.001**	**<0.001**
Group (Computer)	-5.65	4.66	318.14	-1.21	0.227	0.302
Group (Creative)	-5.38	2.65	303.91	-2.03	0.044	0.089
Group (Language)	-5.77	2.86	303.91	-2.02	0.044	0.089
Group (Physical)	-4.26	2.82	303.91	-1.51	0.132	0.227
Group (Social)	-9.12	4.44	303.91	-2.05	0.041	0.089
Time x Group (Computer)	-0.74	3.25	241.92	-0.23	0.821	0.821
Time x Group (Creative)	1.76	1.83	238.89	0.96	0.338	0.405
Time x Group (Language)	2.49	1.97	239.19	1.26	0.209	0.302
Time x Group (Physical)	4.06	1.95	239.17	2.08	0.038	0.089
Time x Group (Social)	1.80	3.04	238.36	0.59	0.555	0.605
Immediate Memory						
(Intercept)	**118.64**	**2.10**	**286.23**	**56.44**	**<0.001**	**<0.001**
Time	**5.31**	**1.34**	**227.20**	**3.96**	**<0.001**	**<0.001**
Group (Computer)	-8.64	4.47	283.04	-1.93	0.054	0.162
Group (Creative)	-3.08	2.61	285.57	-1.18	0.241	0.321
Group (Language)	-6.01	2.79	285.80	-2.15	0.032	0.128
Group (Physical)	-4.67	2.76	285.74	-1.69	0.092	0.183
Group (Social)	-8.05	4.53	295.04	-1.78	0.076	0.183
Time x Group (Computer)	-2.86	2.78	224.71	-1.03	0.305	0.366
Time x Group (Creative)	1.25	1.65	226.28	0.76	0.451	0.492
Time x Group (Language)	2.24	1.77	226.86	1.26	0.208	0.321
Time x Group (Physical)	2.12	1.75	226.81	1.21	0.227	0.321
Time x Group (Social)	1.74	2.87	227.50	0.60	0.546	0.546

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
Delayed Memory						
(Intercept)	**113.96**	**2.22**	**280.67**	**51.24**	**<0.001**	**<0.001**
Time	**7.08**	**1.37**	**223.08**	**5.16**	**<0.001**	**<0.001**
Group (Computer)	-6.71	4.79	289.09	-1.40	0.162	0.324
Group (Creative)	-3.40	2.76	280.78	-1.23	0.219	0.345
Group (Language)	-4.98	2.95	280.26	-1.69	0.093	0.312
Group (Physical)	-4.54	2.92	280.20	-1.56	0.121	0.312
Group (Social)	-7.26	4.79	289.09	-1.52	0.130	0.312
Time x Group (Computer)	-1.96	2.94	223.35	-0.67	0.505	0.674
Time x Group (Creative)	0.39	1.69	222.39	0.23	0.817	0.817
Time x Group (Language)	1.01	1.81	222.75	0.56	0.577	0.692
Time x Group (Physical)	2.16	1.79	222.71	1.20	0.230	0.345
Time x Group (Social)	0.86	2.94	223.35	0.29	0.770	0.817

Note. The within-subjects predictor Time is coded as 0 = *baseline* and 1 = *follow-up*. The between-subjects predictor Group is dummy coded with the Control group serving as the reference group. The parameter estimate for (Intercept) represents the average score in the Control group at baseline. The parameter estimate for Time represents the change from baseline to follow-up in the Control group. The parameter estimates for the five Group contrasts represent the difference between the respective activity group and the Control group at baseline. The parameter estimates for the interaction terms between Time and each of the five Group contrasts represent the difference in change over time between the respective activity group and the Control group. p_{adj} = *p*-value adjusted using the Benjamini-Hochberg procedure to control the false discovery rate. **Bold** = $p_{adj} < .05$.

Appendix K

Supplementary Analyses: Control Group Excluded and Social Group Treated as the Reference Group

Table K1

Summary of Linear Mixed Models Analysing Intervention Effects for Each Cognitive Outcome

Model	No. of parameters	AIC	BIC	Log-Likelihood	χ^2	*df*	*p*
Full Scale IQ							
Intercept Only	3	3609.45	3622.20	-1801.72	-	-	-
Time	4	3548.65	3565.65	-1770.32	62.80	1	<0.001
Time + Group	8	3549.64	3583.64	-1766.82	7.00	4	0.136
Time + Group + Time x Group	12	3550.71	3601.71	-1763.35	6.94	4	0.139
Verbal Comprehension							
Intercept Only	3	3694.30	3707.06	-1844.15	-	-	-
Time	4	3677.01	3694.03	-1834.51	19.29	1	<0.001
Time + Group	8	3683.49	3717.52	-1833.75	1.52	4	0.823
Time + Group + Time x Group	12	3688.13	3739.18	-1832.07	3.36	4	0.499
Perceptual Reasoning							
Intercept Only	3	3907.34	3920.10	-1950.67	-	-	-
Time	4	3895.77	3912.79	-1943.89	13.57	1	<0.001
Time + Group	8	3898.98	3933.01	-1941.49	4.79	4	0.309
Time + Group + Time x Group	12	3902.65	3953.70	-1939.33	4.32	4	0.364
Working Memory							
Intercept Only	3	3757.55	3770.26	-1875.77	-	-	-
Time	4	3749.70	3766.65	-1870.85	9.85	1	0.002
Time + Group	8	3756.83	3790.74	-1870.42	0.87	4	0.929
Time + Group + Time x Group	12	3755.90	3806.76	-1865.95	8.93	4	0.063

Model	No. of parameters	AIC	BIC	Log-Likelihood	χ^2	*df*	*p*
Processing Speed							
Intercept Only	3	3765.74	3778.49	-1879.87	-	-	-
Time	4	3722.13	3739.12	-1857.06	45.62	1	<0.001
Time + Group	8	3710.00	3743.98	-1847.00	20.13	4	<0.001
Time + Group + Time x Group	12	3711.88	3762.86	-1843.94	6.12	4	0.190
Auditory Memory							
Intercept Only	3	3857.42	3870.08	-1925.71	-	-	-
Time	4	3761.14	3778.01	-1876.57	98.29	1	<0.001
Time + Group	8	3765.21	3798.96	-1874.61	3.93	4	0.416
Time + Group + Time x Group	12	3769.82	3820.44	-1872.91	3.40	4	0.494
Visual Memory							
Intercept Only	3	4072.73	4085.47	-2033.36	-	-	-
Time	4	3946.74	3963.72	-1969.37	127.99	1	<0.001
Time + Group	8	3951.53	3985.50	-1967.77	3.20	4	0.524
Time + Group + Time x Group	12	3953.79	4004.74	-1964.89	5.74	4	0.219
Immediate Memory							
Intercept Only	3	3872.85	3885.51	-1933.43	-	-	-
Time	4	3758.78	3775.66	-1875.39	116.07	1	<0.001
Time + Group	8	3762.22	3795.97	-1873.11	4.56	4	0.335
Time + Group + Time x Group	12	3766.47	3817.10	-1871.24	3.75	4	0.441
Delayed Memory							
Intercept Only	3	3942.50	3955.14	-1968.25	-	-	-
Time	4	3801.72	3818.58	-1896.86	142.78	1	<0.001
Time + Group	8	3808.84	3842.54	-1896.42	0.89	4	0.926
Time + Group + Time x Group	12	3813.94	3864.49	-1894.97	2.90	4	0.575

Table K2

Parameter Estimates of Full Time x Group Interaction Model for Each Cognitive Outcome

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
Full Scale IQ						
(Intercept)	**103.21**	**3.10**	**281.51**	**33.29**	**<0.001**	**<0.001**
Time	**3.50**	**1.24**	**257.98**	**2.82**	**0.005**	**0.026**
Group (Computer)	1.85	4.25	281.51	0.44	0.664	0.737
Group (Creative)	6.22	3.31	281.51	1.88	0.061	0.154
Group (Language)	5.93	3.43	281.51	1.73	0.085	0.170
Group (Physical)	7.50	3.41	281.51	2.20	0.029	0.095
Time x Group (Computer)	-2.00	1.70	257.98	-1.18	0.241	0.322
Time x Group (Creative)	-0.20	1.33	257.98	-0.15	0.880	0.880
Time x Group (Language)	-1.78	1.37	258.04	-1.30	0.196	0.322
Time x Group (Physical)	-1.55	1.37	258.03	-1.13	0.258	0.322
Verbal Comprehension						
(Intercept)	**107.29**	**2.97**	**305.79**	**36.07**	**<0.001**	**<0.001**
Time	0.79	1.68	259.28	0.47	0.640	0.915
Group (Computer)	-0.22	4.07	305.79	-0.05	0.956	0.956
Group (Creative)	1.76	3.17	305.79	0.56	0.579	0.915
Group (Language)	2.92	3.29	305.79	0.89	0.375	0.915
Group (Physical)	2.31	3.27	305.79	0.71	0.480	0.915
Time x Group (Computer)	1.34	2.30	259.28	0.58	0.561	0.915
Time x Group (Creative)	1.79	1.79	259.28	1.00	0.319	0.915
Time x Group (Language)	0.14	1.86	259.39	0.07	0.940	0.956
Time x Group (Physical)	0.63	1.85	259.38	0.34	0.734	0.918
Perceptual Reasoning						
(Intercept)	**99.64**	**3.52**	**314.42**	**28.34**	**<0.001**	**<0.001**
Time	1.71	2.17	258.74	0.79	0.429	0.839
Group (Computer)	1.11	4.81	314.42	0.23	0.818	0.967
Group (Creative)	5.54	3.75	314.42	1.48	0.141	0.353
Group (Language)	5.98	3.89	314.42	1.54	0.125	0.353
Group (Physical)	5.88	3.87	314.42	1.52	0.129	0.353
Time x Group (Computer)	0.29	2.97	258.74	0.10	0.923	0.967
Time x Group (Creative)	1.26	2.31	258.74	0.54	0.587	0.839
Time x Group (Language)	-1.47	2.40	258.87	-0.61	0.541	0.839
Time x Group (Physical)	0.10	2.38	258.86	0.04	0.967	0.967
Working Memory						
(Intercept)	**107.93**	**3.44**	**297.13**	**31.36**	**<0.001**	**<0.001**
Time	3.64	1.83	251.25	2.00	0.047	0.157
Group (Computer)	2.01	4.71	297.13	0.43	0.670	0.745
Group (Creative)	3.03	3.68	297.81	0.82	0.410	0.586
Group (Language)	2.42	3.81	297.52	0.64	0.526	0.657
Group (Physical)	3.53	3.78	297.13	0.93	0.351	0.585
Time x Group (Computer)	-5.02	2.50	251.25	-2.01	0.046	0.157
Time x Group (Creative)	-2.58	1.95	251.42	-1.32	0.187	0.374
Time x Group (Language)	-0.57	2.03	251.56	-0.28	0.778	0.778
Time x Group (Physical)	-3.12	2.01	251.34	-1.55	0.122	0.305

Predictor	*b*	*SE*	*df*	*t*	*p*	p_{adj}
Processing Speed						
(Intercept)	**95.86**	**3.28**	**294.93**	**29.19**	**<0.001**	**<0.001**
Time	**5.71**	**1.64**	**256.23**	**3.49**	**<0.001**	**0.002**
Group (Computer)	3.56	4.51	298.63	0.79	0.430	0.430
Group (Creative)	**9.96**	**3.50**	**294.93**	**2.84**	**0.005**	**0.012**
Group (Language)	7.05	3.63	294.93	1.94	0.053	0.072
Group (Physical)	**13.22**	**3.61**	**294.93**	**3.66**	**<0.001**	**0.001**
Time x Group (Computer)	-4.88	2.27	257.14	-2.15	0.033	0.065
Time x Group (Creative)	-2.49	1.75	256.27	-1.43	0.155	0.172
Time x Group (Language)	-3.48	1.81	256.41	-1.92	0.056	0.072
Time x Group (Physical)	-3.44	1.80	256.31	-1.91	0.057	0.072
Auditory Memory						
(Intercept)	**113.11**	**3.83**	**307.05**	**29.51**	**<0.001**	**<0.001**
Time	**7.89**	**2.21**	**245.91**	**3.57**	**<0.001**	**0.002**
Group (Computer)	1.77	5.13	301.72	0.34	0.731	0.731
Group (Creative)	6.13	4.08	305.83	1.50	0.134	0.388
Group (Language)	2.80	4.20	305.83	0.67	0.506	0.567
Group (Physical)	4.50	4.18	305.48	1.08	0.283	0.425
Time x Group (Computer)	-3.71	2.93	244.70	-1.27	0.207	0.413
Time x Group (Creative)	-2.45	2.35	245.64	-1.04	0.298	0.425
Time x Group (Language)	-1.60	2.43	245.96	-0.66	0.510	0.567
Time x Group (Physical)	-3.44	2.41	245.73	-1.43	0.155	0.388
Visual Memory						
(Intercept)	**95.01**	**3.66**	**344.23**	**25.93**	**<0.001**	**<0.001**
Time	**7.84**	**2.58**	**258.56**	**3.04**	**0.003**	**0.013**
Group (Computer)	8.07	5.05	350.22	1.60	0.111	0.370
Group (Creative)	4.24	3.90	342.63	1.09	0.278	0.555
Group (Language)	3.11	4.04	341.48	0.77	0.441	0.638
Group (Physical)	4.40	4.02	341.61	1.10	0.274	0.555
Time x Group (Computer)	-2.67	3.58	260.00	-0.75	0.456	0.638
Time x Group (Creative)	-1.38	2.74	258.16	-0.50	0.616	0.685
Time x Group (Language)	-0.08	2.84	258.02	-0.03	0.977	0.977
Time x Group (Physical)	1.86	2.83	258.04	0.66	0.510	0.638
Immediate Memory						
(Intercept)	**109.94**	**3.63**	**323.50**	**30.31**	**<0.001**	**<0.001**
Time	**8.52**	**2.36**	**247.73**	**3.61**	**<0.001**	**0.002**
Group (Computer)	3.56	4.85	317.05	0.73	0.463	0.579
Group (Creative)	6.05	3.86	322.02	1.57	0.118	0.295
Group (Language)	2.25	3.98	322.02	0.56	0.573	0.611
Group (Physical)	4.84	3.96	321.60	1.22	0.222	0.444
Time x Group (Computer)	-5.27	3.13	246.21	-1.69	0.093	0.295
Time x Group (Creative)	-2.17	2.50	247.39	-0.87	0.387	0.553
Time x Group (Language)	-1.32	2.59	247.79	-0.51	0.611	0.611
Time x Group (Physical)	-2.33	2.57	247.51	-0.91	0.366	0.553
Delayed Memory						
(Intercept)	**106.64**	**4.10**	**323.65**	**26.00**	**<0.001**	**<0.001**
Time	**8.36**	**2.49**	**244.08**	**3.36**	**<0.001**	**0.004**
Group (Computer)	5.11	5.51	321.13	0.93	0.354	0.778
Group (Creative)	4.20	4.35	321.11	0.96	0.335	0.778
Group (Language)	2.16	4.49	319.97	0.48	0.631	0.789
Group (Physical)	2.71	4.46	319.74	0.61	0.545	0.778
Time x Group (Computer)	-2.80	3.32	243.58	-0.84	0.400	0.778
Time x Group (Creative)	-1.71	2.63	243.58	-0.65	0.516	0.778
Time x Group (Language)	-0.24	2.71	243.65	-0.09	0.929	0.997
Time x Group (Physical)	0.01	2.69	243.47	0.00	0.997	0.997

Note. The within-subjects predictor Time is coded as 0 = *baseline* and 1 = *follow-up*.

The between-subjects predictor Group is dummy coded with the Social group serving as the reference group. The parameter estimate for (Intercept) represents the average score in the Social group at baseline. The parameter estimate for Time represents the change from baseline to follow-up in the Social group. The parameter estimates for the four Group contrasts represent the difference between the respective activity group and the Social group at baseline. The parameter estimates for the interaction terms between Time and each of the five Group contrasts represent the difference in change over time between the respective activity group and the Social group. p_{adj} = *p*-value adjusted using the Benjamini-Hochberg procedure to control the false discovery rate. **Bold** = $p_{adj} < .05$.

Appendix L

Participant Time Log Used to Record Class/Group Attendance

NAME: ____________________________________

TIME LOG

Please log the approximate time you spend on your activity as part of your course. You should also record any time you spend on your new activity that isn't part of the formal time in your class or group.

For example:

Day	Date	Time
Monday		0hrs
Tuesday	19/09/2017	1hr
Wednesday	20/09/2017	2hrs
Thursday		0hrs
Friday	22/09/2017	30min
Saturday		0hrs
Sunday		0hrs

Week 1

Day	Date	Time
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 2

Day	Date	Time
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 3

Day	**Date**	**Time**
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 4

Day	**Date**	**Time**
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 5

Day	**Date**	**Time**
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 6

Day	Date	Time
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 7

Day	Date	Time
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 8

Day	Date	Time
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 9

Day	Date	Time
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 10

Day	Date	Time
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

The Ageing Lab
0131 451 8009
HealthyAgeing@hw.ac.uk

HERIOT WATT UNIVERSITY

Appendix M

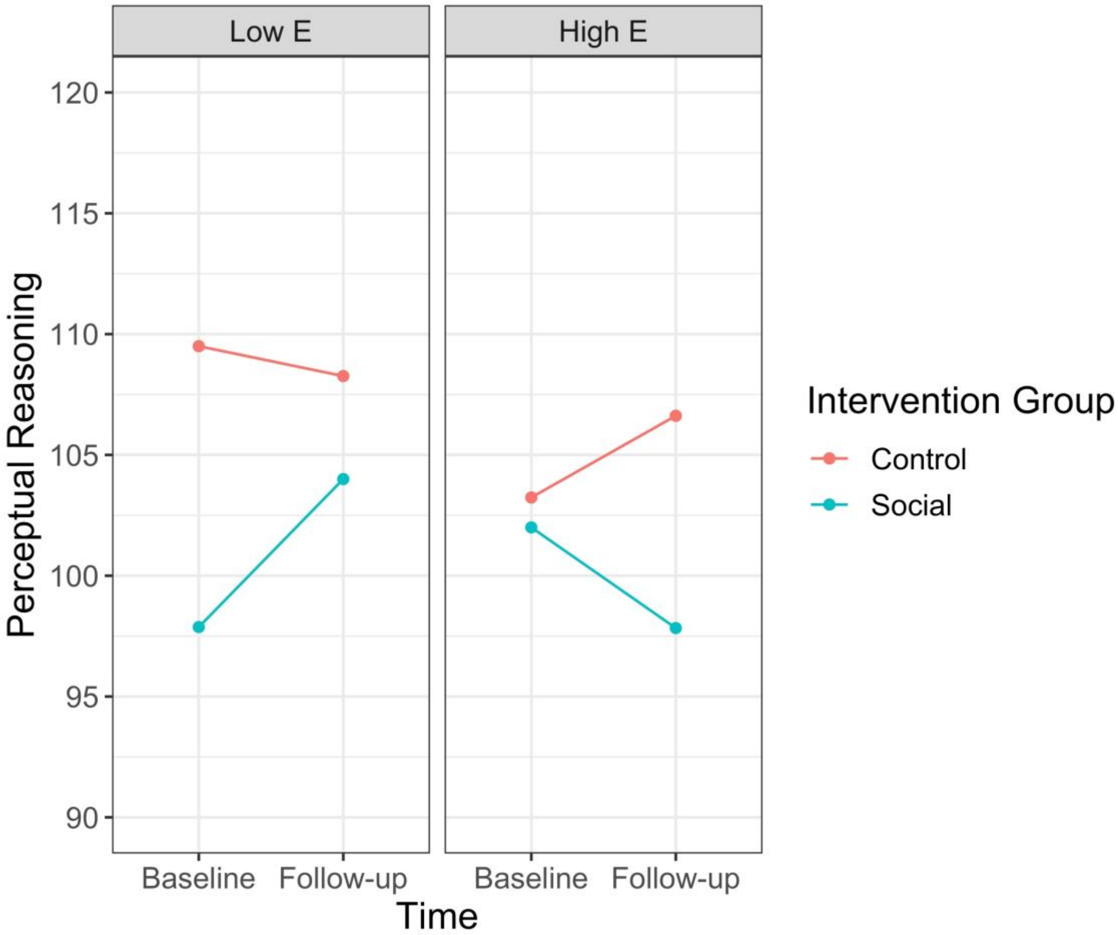
Missing Data Rates for Chapter 6 Study Variables

Variable	Full Sample		Excluding Non-Completers	
	N Missing	% Missing	N Missing	% Missing
Predictors				
Total MET-minutes per week	28	8.3	19	6.3
History of High Blood Pressure	0	0.0	0	0.0
History of Diabetes	0	0.0	0	0.0
Current Smoker	0	0.0	0	0.0
BMI	2	0.6	2	0.7
Activity Adherence Measures				
Activity Duration (Weeks)	52	15.5	36	11.9
No of Weeks Attended	81	24.1	47	15.6
Percentage Adherence	81	24.1	47	15.6
Time Spent	85	25.3	51	16.9

Note. Full sample N = 336. Sample excluding non-completers N = 302. Missing data for adherence variables includes those who completed the study but did not return their time log and participants in the no-contact control group who did not do a new activity. MET-minutes per week = metabolic equivalent of task minutes per week, BMI = Body Mass Index.

Appendix N

Perceptual Reasoning Change in the Social Group and the Control Group for High and Low Extraversion Participants



Note. E = Extraversion. High and Low E groups were categorised on the basis of a median split on the complete sample. It should be emphasised that this was an arbitrary cut-off chosen to visually illustrate the association between and Extraversion and the difference in cognitive change between the Social and Control groups.

Appendix O

Descriptive Statistics for Subjective Ratings of Mental, Physical and Social Demand

Variable	N	Mean (SD)	SE	Min	Max	Skew	Kurtosis
Mental Demand	255	6.1 (2.7)	0.17	0	10	-0.67	-0.31
Physical Demand	255	3.8 (3.2)	0.20	0	10	0.30	-1.18
Social Demand	255	3.9 (2.6)	0.16	0	10	-0.02	-1.00

Appendix P

Means and Standard Deviations of Subjective Ratings of Demand for Each Activity Group and Between-Group ANOVA

	Computer (*N* = 16)	Creative (*N* = 97)	Language (*N* = 61)	Physical (*N* = 67)	Social (*N* = 14)		
Variable	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)	*F*	*df*
Mental Demand[a]	4.7 (2.7)	6.2 (2.0)	8.0 (2.1)	5.3 (2.9)	2.7 (3.0)	17.04***	4, 51.48
Physical Demand[a]	1.3 (1.5)	4.6 (2.6)	1.0 (1.7)	6.4 (2.7)	1.2 (2.1)	63.37***	4, 56.42
Social Demand	2.8 (2.5)	4.3 (2.5)	4.6 (2.5)	3.2 (2.6)	3.5 (2.9)	3.71**	4, 250

Note. Ratings range from 0-10.

[a] Welch's F is reported due to significance of Levene's test for violation of homogeneity of variance assumption.

**p* < .05. ***p* < .01. ****p* < .001

Appendix Q

Post-hoc Pairwise Comparisons Comparing Subjective Ratings of Demands Between Activity Groups

Table Q1

Mental Demands

Group 1	Group 2	Mean Difference	*t*	*df*	p^{adj}
Computer	Creative	1.54	2.18	17.78	.230
Computer	**Language**	**3.26**	**4.49**	**20.05**	**.002**
Computer	Physical	0.60	0.78	24.03	.934
Computer	Social	-1.97	1.87	26.36	.355
Creative	**Language**	**1.72**	**5.11**	**121.94**	**<.001**
Creative	Physical	-0.94	2.31	107.76	.150
Creative	**Social**	**-3.51**	**4.22**	**14.66**	**.006**
Language	**Physical**	**-2.67**	**5.98**	**120.19**	**<.001**
Language	**Social**	**-5.24**	**6.15**	**16.02**	**<.001**
Physical	Social	-2.57	2.91	18.37	.062

Note. Games-Howell post-hoc tests were used to control for Type-I error due to violation of assumption of homogeneity of variance. **Bold** = adjusted $p < .05$.

Table Q2

Physical Demands

Group 1	Group 2	Mean Difference	*t*	*df*	p^{adj}
Computer	**Creative**	**3.32**	**7.13**	**31.83**	**<.001**
Computer	Language	-0.27	0.61	25.63	.973
Computer	**Physical**	**5.20**	**10.34**	**40.14**	**<.001**
Computer	Social	-0.04	0.05	23.33	1.000
Creative	**Language**	**-3.58**	**10.45**	**155.81**	**<.001**
Creative	**Physical**	**1.88**	**4.47**	**139.89**	**<.001**
Creative	**Social**	**-3.35**	**5.36**	**19.21**	**<.001**
Language	**Physical**	**5.46**	**13.92**	**112.98**	**<.001**
Language	Social	0.23	0.38	17.03	.995
Physical	**Social**	**-5.23**	**8.00**	**22.61**	**<.001**

Note. Games-Howell post-hoc tests were used to control for Type-I error due to violation of assumption of homogeneity of variance. **Bold** = adjusted $p < .05$.

Table Q3

Social Demands

Group 1	Group 2	Mean Difference	*t*	*df*	p^{adj}
Computer	Creative	-1.47	-2.19	20.25	.405
Computer	Language	-1.79	-2.56	23.81	.171
Computer	Physical	-0.41	-0.59	23.31	1.000
Computer	Social	-0.69	-0.69	25.81	1.000
Creative	Language	-0.33	-0.80	125.84	1.000
Creative	Physical	1.05	2.62	138.70	.097
Creative	Social	0.78	0.95	15.86	1.000
Language	**Physical**	**1.38**	**3.07**	**125.25**	**.026**
Language	Social	1.11	1.32	17.79	1.000
Physical	Social	-0.28	-0.33	17.51	1.000

Note. Welch's t-tests with Bonferroni correction were used to control for Type-I error.

Bold = adjusted $p < .05$.

Appendix R

Hierarchical Regression Predicting Performance Change in Each Cognitive Domain

Table R1

Full Scale IQ

Predictor	Step 1				Step 2				Step 3			
	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
(Intercept)	**2.69**	**0.33**	**8.25**	**<.001**	**2.69**	**0.33**	**8.22**	**<.001**	**2.70**	**0.33**	**8.24**	**<.001**
Age	**-0.15**	**0.06**	**-2.39**	**.018**	**-0.16**	**0.07**	**-2.36**	**.019**	**-0.16**	**0.07**	**-2.44**	**.015**
MMSE	0.10	0.33	0.32	.747	0.12	0.33	0.37	.711	0.12	0.33	0.35	.723
Adherence	0.02	0.02	0.97	.331	0.01	0.02	0.85	.396	0.02	0.02	1.08	.282
Assessment Interval	0.01	0.01	1.31	.192	0.01	0.01	1.29	.199	0.01	0.01	1.18	.238
Neuroticism	0.02	0.02	1.30	.195	0.02	0.02	1.28	.201	0.02	0.02	1.17	.243
Extraversion	0.01	0.02	0.60	.549	0.01	0.02	0.60	.547	0.01	0.02	0.57	.567
Openness to Experience	-0.02	0.02	-0.98	.327	-0.02	0.02	-0.92	.360	-0.02	0.02	-0.85	.396
Agreeableness	0.03	0.02	1.43	.154	0.03	0.02	1.42	.156	0.03	0.02	1.51	.133
Conscientiousness	0.00	0.02	-0.05	.957	0.00	0.02	-0.01	.992	0.00	0.02	-0.14	.886
Mental Demand					-0.04	0.13	-0.33	.739	-0.02	0.14	-0.15	.880
Physical Demand					0.08	0.10	0.78	.438	0.07	0.10	0.69	.494
Social Demand					0.04	0.14	0.27	.784	0.03	0.14	0.19	.847
Openness x Mental Demand									0.00	0.01	0.21	.837
Extraversion x Social Demand									0.01	0.01	1.35	.177
Agreeableness x Social Demand									0.01	0.01	1.35	.179
Conscientiousness x Social Demand									-0.01	0.01	-1.59	.114
R^2	0.06				0.06				0.08			
Adjusted R^2	0.02				0.01				0.01			
ΔF	1.46				0.26				1.14			
p	.166				.852				.337			

Note. Valid N = 217 (38 participants excluded due to missing data). All predictor variables were mean centred. ΔF = F-ratio for change in model fit with the addition of new predictors at each step of the hierarchical regression. **Bold** = $p < .05$.

Table R2

Verbal Comprehension

Predictor	Step 1				Step 2				Step 3			
	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
(Intercept)	**1.98**	**0.44**	**4.46**	**<.001**	**1.97**	**0.44**	**4.44**	**<.001**	**1.98**	**0.44**	**4.46**	**<.001**
Age	-0.02	0.09	-0.26	.793	-0.01	0.09	-0.12	.905	-0.01	0.09	-0.10	.923
MMSE	-0.05	0.44	-0.11	.916	-0.04	0.45	-0.08	.937	-0.02	0.45	-0.05	.957
Adherence	0.02	0.02	0.94	.350	0.01	0.02	0.66	.508	0.02	0.02	0.96	.341
Assessment Interval	0.01	0.01	1.34	.182	0.01	0.01	1.15	.250	0.01	0.01	1.24	.218
Neuroticism	0.04	0.03	1.65	.101	0.04	0.03	1.49	.137	0.04	0.03	1.36	.175
Extraversion	0.04	0.03	1.32	.188	0.03	0.03	1.17	.245	0.03	0.03	1.17	.245
Openness to Experience	-0.06	0.03	-1.97	.051	-0.06	0.03	-1.89	.060	-0.06	0.03	-1.91	.057
Agreeableness	**0.07**	**0.03**	**2.38**	**.018**	**0.07**	**0.03**	**2.22**	**.027**	**0.07**	**0.03**	**2.34**	**.020**
Conscientiousness	-0.02	0.03	-0.51	.611	-0.02	0.03	-0.49	.626	-0.02	0.03	-0.65	.514
Mental Demand					0.11	0.18	0.58	.564	0.12	0.18	0.65	.517
Physical Demand					0.23	0.14	1.61	.109	0.23	0.14	1.58	.115
Social Demand					-0.05	0.19	-0.28	.776	-0.08	0.19	-0.44	.664
Openness x Mental Demand									0.01	0.01	0.58	.563
Extraversion x Social Demand									0.01	0.01	1.13	.261
Agreeableness x Social Demand									0.02	0.01	1.78	.077
Conscientiousness x Social Demand									-0.01	0.01	-1.14	.257
R^2	0.06				0.07				0.09			
Adjusted R^2	0.01				0.01				0.02			
ΔF	1.36				0.97				1.23			
p	.207				.407				.301			

Note. Valid N = 218 (37 participants excluded due to missing data). All predictor variables were mean centred. ΔF = F-ratio for change in model fit with the addition of new predictors at each step of the hierarchical regression. **Bold** = $p < .05$.

Table R3

Perceptual Reasoning

Predictor	Step 1				Step 2				Step 3			
	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
(Intercept)	**2.13**	**0.55**	**3.89**	**<.001**	**2.13**	**0.55**	**3.89**	**<.001**	**2.12**	**0.55**	**3.85**	**<.001**
Age	**-0.22**	**0.11**	**-2.00**	**.047**	-0.22	0.11	-1.96	.051	**-0.23**	**0.11**	**-2.02**	**.044**
MMSE	0.05	0.55	0.10	.924	0.12	0.55	0.21	.831	0.14	0.56	0.26	.795
Adherence	0.01	0.03	0.23	.822	0.00	0.03	-0.02	.984	0.00	0.03	-0.11	.914
Assessment Interval	0.00	0.01	0.19	.850	0.00	0.01	0.18	.854	0.00	0.01	0.10	.921
Neuroticism	0.04	0.03	1.17	.243	0.04	0.03	1.15	.251	0.04	0.03	1.13	.262
Extraversion	0.00	0.04	-0.11	.912	0.00	0.04	-0.14	.892	0.00	0.04	0.07	.946
Openness to Experience	-0.02	0.04	-0.64	.522	-0.02	0.04	-0.51	.609	-0.03	0.04	-0.66	.508
Agreeableness	0.02	0.04	0.47	.640	0.02	0.04	0.47	.640	0.02	0.04	0.41	.681
Conscientiousness	-0.01	0.04	-0.20	.843	-0.01	0.04	-0.13	.893	0.00	0.04	-0.10	.922
Mental Demand					-0.08	0.22	-0.33	.738	-0.04	0.23	-0.16	.873
Physical Demand					0.21	0.17	1.23	.221	0.22	0.18	1.23	.220
Social Demand					0.19	0.24	0.79	.428	0.18	0.24	0.75	.453
Openness x Mental Demand									0.00	0.01	0.20	.841
Extraversion x Social Demand									0.02	0.01	1.48	.139
Agreeableness x Social Demand									0.00	0.01	0.03	.974
Conscientiousness x Social Demand									0.00	0.01	-0.26	.798
R^2	0.04				0.05				0.06			
Adjusted R^2	0.00				-0.01				-0.01			
ΔF	0.91				0.79				0.61			
p	.516				.500				.659			

Note. Valid N = 218 (37 participants excluded due to missing data). All predictor variables were mean centred. ΔF = F-ratio for change in model fit with the addition of new predictors at each step of the hierarchical regression. **Bold** = $p < .05$.

Table R4

Working Memory

Predictor	Step 1				Step 2				Step 3			
	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
(Intercept)	**1.56**	**0.49**	**3.19**	**.002**	**1.58**	**0.49**	**3.22**	**.001**	**1.59**	**0.49**	**3.25**	**.001**
Age	-0.10	0.10	-0.98	.330	-0.10	0.10	-1.06	.292	-0.13	0.10	-1.35	.180
MMSE	0.18	0.50	0.37	.714	0.23	0.50	0.45	.652	0.17	0.50	0.34	.737
Adherence	0.02	0.02	0.97	.332	0.03	0.02	1.06	.290	0.03	0.02	1.27	.207
Assessment Interval	-0.01	0.01	-1.07	.288	-0.01	0.01	-0.86	.391	-0.01	0.01	-1.25	.213
Neuroticism	0.01	0.03	0.33	.745	0.01	0.03	0.50	.619	0.01	0.03	0.43	.668
Extraversion	0.01	0.03	0.33	.741	0.01	0.03	0.43	.669	0.00	0.03	-0.02	.987
Openness to Experience	0.03	0.03	1.03	.306	0.03	0.03	1.05	.295	0.05	0.03	1.58	.115
Agreeableness	0.03	0.03	0.94	.350	0.04	0.03	1.08	.283	0.04	0.03	1.14	.257
Conscientiousness	0.03	0.03	0.91	.362	0.03	0.03	0.89	.372	0.03	0.03	0.78	.434
Mental Demand					-0.11	0.20	-0.53	.595	-0.07	0.20	-0.37	.711
Physical Demand					-0.24	0.15	-1.56	.121	-0.28	0.15	-1.84	.068
Social Demand					0.26	0.21	1.23	.222	0.28	0.21	1.32	.188
Openness x Mental Demand									-0.01	0.01	-0.95	.341
Extraversion x Social Demand									-0.01	0.01	-0.44	.661
Agreeableness x Social Demand									0.00	0.01	0.01	.989
Conscientiousness x Social Demand									**-0.03**	**0.01**	**-2.20**	**.029**
R^2	0.03				0.05				0.09			
Adjusted R^2	-0.01				-0.01				0.01			
ΔF	0.80				1.21				1.78			
p	.612				.308				.134			

Note. Valid $N = 212$ (43 participants excluded due to missing data). All predictor variables were mean centred. ΔF = F-ratio for change in model fit with the addition of new predictors at each step of the hierarchical regression. **Bold** = $p < .05$.

Table R5

Processing Speed

Predictor	Step 1				Step 2				Step 3			
	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
(Intercept)	**2.74**	**0.41**	**6.61**	**<.001**	**2.74**	**0.41**	**6.63**	**<.001**	**2.76**	**0.42**	**6.62**	**<.001**
Age	-0.15	0.08	-1.82	.070	-0.16	0.08	-1.97	.050	-0.16	0.08	-1.94	.054
MMSE	0.05	0.41	0.13	.897	0.00	0.41	0.01	.993	-0.01	0.42	-0.03	.976
Adherence	0.00	0.02	0.23	.818	0.01	0.02	0.57	.571	0.02	0.02	0.81	.417
Assessment Interval	0.01	0.01	1.89	.060	0.02	0.01	1.95	.052	0.02	0.01	1.93	.055
Neuroticism	-0.03	0.02	-1.46	.146	-0.03	0.02	-1.35	.180	-0.03	0.02	-1.33	.186
Extraversion	0.00	0.03	-0.07	.941	0.00	0.03	0.11	.914	0.00	0.03	0.10	.919
Openness to Experience	0.01	0.03	0.19	.852	0.00	0.03	0.07	.944	0.00	0.03	0.13	.898
Agreeableness	-0.04	0.03	-1.26	.211	-0.03	0.03	-1.15	.250	-0.03	0.03	-1.04	.300
Conscientiousness	-0.01	0.03	-0.34	.732	-0.01	0.03	-0.32	.747	-0.01	0.03	-0.37	.715
Mental Demand					-0.12	0.17	-0.72	.470	-0.12	0.17	-0.67	.503
Physical Demand					-0.10	0.13	-0.72	.470	-0.11	0.13	-0.79	.429
Social Demand					-0.17	0.18	-0.96	.336	-0.19	0.18	-1.05	.293
Openness x Mental Demand									0.00	0.01	-0.05	.959
Extraversion x Social Demand									0.01	0.01	0.71	.480
Agreeableness x Social Demand									0.01	0.01	1.26	.209
Conscientiousness x Social Demand									-0.01	0.01	-0.85	.396
R^2	0.05				0.06				0.07			
Adjusted R^2	0.01				0.01				0.00			
ΔF	1.14				1.03				0.54			
p	.340				.379				.709			

Note. Valid $N = 216$ (39 participants excluded due to missing data). All predictor variables were mean centred. ΔF = F-ratio for change in model fit with the addition of new predictors at each step of the hierarchical regression. **Bold** = $p < .05$.

Table R6

Auditory Memory

Predictor	Step 1				Step 2				Step 3			
	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
(Intercept)	**5.20**	**0.54**	**9.55**	**<.001**	**5.20**	**0.55**	**9.52**	**<.001**	**5.19**	**0.55**	**9.38**	**<.001**
Age	0.03	0.11	0.32	.750	0.03	0.11	0.29	.769	0.04	0.11	0.39	.700
MMSE	-0.39	0.55	-0.71	.478	-0.37	0.55	-0.68	.499	-0.34	0.56	-0.61	.541
Adherence	0.01	0.03	0.23	.821	0.01	0.03	0.27	.787	0.01	0.03	0.26	.792
Assessment Interval	0.00	0.01	0.20	.845	0.00	0.01	0.28	.777	0.00	0.01	0.44	.659
Neuroticism	-0.04	0.03	-1.22	.224	-0.04	0.03	-1.17	.242	-0.04	0.03	-1.20	.232
Extraversion	**-0.07**	**0.04**	**-2.04**	**.042**	**-0.07**	**0.04**	**-2.05**	**.042**	-0.07	0.04	-1.88	.062
Openness to Experience	**0.07**	**0.04**	**2.02**	**.044**	**0.08**	**0.04**	**2.04**	**.042**	0.07	0.04	1.82	.071
Agreeableness	-0.02	0.04	-0.41	.679	-0.01	0.04	-0.35	.726	-0.01	0.04	-0.33	.739
Conscientiousness	0.01	0.04	0.28	.776	0.01	0.04	0.22	.828	0.01	0.04	0.16	.873
Mental Demand					0.01	0.22	0.03	.973	0.00	0.23	-0.02	.987
Physical Demand					-0.17	0.17	-0.96	.338	-0.15	0.18	-0.84	.403
Social Demand					0.19	0.24	0.81	.420	0.18	0.24	0.75	.454
Openness x Mental Demand									0.01	0.01	0.62	.538
Extraversion x Social Demand									0.00	0.01	0.29	.773
Agreeableness x Social Demand									0.00	0.01	0.33	.743
Conscientiousness x Social Demand									0.01	0.01	0.43	.671
R^2	0.03				0.04				0.05			
Adjusted R^2	-0.01				-0.02				-0.03			
ΔF	0.79				0.51				0.23			
p	.627				.676				.922			

Note. Valid $N = 209$ (46 participants excluded due to missing data). All predictor variables were mean centred. ΔF = F-ratio for change in model fit with the addition of new predictors at each step of the hierarchical regression. **Bold** = $p < .05$.

Table R7

Visual Memory

Predictor	Step 1				Step 2				Step 3			
	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
(Intercept)	**7.67**	**0.63**	**12.21**	**<.001**	**7.68**	**0.63**	**12.15**	**<.001**	**7.67**	**0.64**	**12.01**	**<.001**
Age	-0.20	0.12	-1.62	.106	-0.20	0.13	-1.62	.106	-0.19	0.13	-1.45	.147
MMSE	0.31	0.63	0.49	.624	0.35	0.63	0.55	.583	0.40	0.64	0.63	.532
Adherence	0.02	0.03	0.70	.485	0.02	0.03	0.58	.562	0.02	0.03	0.53	.597
Assessment Interval	**-0.03**	**0.01**	**-2.15**	**.033**	**-0.02**	**0.01**	**-2.04**	**.042**	-0.02	0.01	-1.84	.067
Neuroticism	0.00	0.04	-0.14	.892	0.00	0.04	-0.09	.925	0.00	0.04	-0.06	.956
Extraversion	0.00	0.04	0.00	.999	0.00	0.04	0.03	.973	0.01	0.04	0.26	.798
Openness to Experience	0.04	0.04	1.03	.303	0.05	0.04	1.09	.277	0.04	0.04	0.80	.426
Agreeableness	-0.04	0.04	-0.96	.338	-0.04	0.04	-0.89	.373	-0.04	0.04	-0.93	.353
Conscientiousness	0.02	0.04	0.35	.727	0.02	0.04	0.39	.695	0.02	0.05	0.45	.650
Mental Demand					-0.11	0.26	-0.41	.682	-0.12	0.27	-0.44	.662
Physical Demand					0.11	0.20	0.54	.588	0.13	0.20	0.63	.532
Social Demand					0.17	0.28	0.62	.539	0.14	0.28	0.51	.611
Openness x Mental Demand									0.00	0.02	0.27	.785
Extraversion x Social Demand									0.01	0.02	0.48	.635
Agreeableness x Social Demand									0.00	0.02	0.23	.818
Conscientiousness x Social Demand									0.02	0.02	0.96	.339
R^2	0.05				0.05				0.06			
Adjusted R^2	0.01				0.00				-0.02			
ΔF	1.14				0.25				0.44			
p	.334				.859				.778			

Note. Valid N = 215 (40 participants excluded due to missing data). All predictor variables were mean centred. ΔF = F-ratio for change in model fit with the addition of new predictors at each step of the hierarchical regression. **Bold** = $p < .05$.

Table R8

Immediate Memory

Predictor	Step 1				Step 2				Step 3			
	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
(Intercept)	**6.50**	**0.56**	**11.63**	**<.001**	**6.51**	**0.56**	**11.58**	**<.001**	**6.55**	**0.57**	**11.58**	**<.001**
Age	-0.10	0.11	-0.89	.374	-0.10	0.11	-0.91	.361	-0.10	0.11	-0.84	.403
MMSE	-0.21	0.56	-0.37	.709	-0.17	0.57	-0.31	.759	-0.20	0.57	-0.36	.721
Adherence	0.00	0.03	0.15	.884	0.00	0.03	0.12	.904	0.01	0.03	0.21	.830
Assessment Interval	-0.01	0.01	-1.46	.147	-0.01	0.01	-1.34	.181	-0.01	0.01	-1.15	.250
Neuroticism	**-0.07**	**0.03**	**-2.08**	**.039**	**-0.06**	**0.03**	**-2.01**	**.046**	-0.06	0.03	-1.82	.070
Extraversion	0.02	0.04	0.57	.567	0.02	0.04	0.56	.578	0.03	0.04	0.85	.396
Openness to Experience	**0.08**	**0.04**	**2.02**	**.044**	**0.08**	**0.04**	**2.10**	**.037**	0.07	0.04	1.86	.065
Agreeableness	-0.04	0.04	-0.94	.346	-0.03	0.04	-0.84	.402	-0.03	0.04	-0.80	.423
Conscientiousness	-0.06	0.04	-1.44	.153	-0.06	0.04	-1.44	.151	-0.05	0.04	-1.23	.219
Mental Demand					-0.06	0.23	-0.28	.781	-0.07	0.23	-0.31	.756
Physical Demand					-0.05	0.18	-0.28	.782	-0.04	0.18	-0.25	.804
Social Demand					0.26	0.25	1.06	.292	0.24	0.25	0.96	.340
Openness x Mental Demand									-0.01	0.01	-0.43	.671
Extraversion x Social Demand									0.01	0.01	1.06	.290
Agreeableness x Social Demand									0.01	0.01	0.68	.497
Conscientiousness x Social Demand									0.01	0.01	0.75	.453
R^2	0.07				0.07				0.09			
Adjusted R^2	0.03				0.02				0.01			
ΔF	1.62				0.39				0.79			
p	.111				.761				.531			

Note. Valid N = 209 (46 participants excluded due to missing data). All predictor variables were mean centred. ΔF = F-ratio for change in model fit with the addition of new predictors at each step of the hierarchical regression. **Bold** = $p < .05$.

Table R9

Delayed Memory

Predictor	Step 1				Step 2				Step 3			
	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
(Intercept)	**7.32**	**0.56**	**13.07**	**<.001**	**7.33**	**0.56**	**13.01**	**<.001**	**7.24**	**0.57**	**12.76**	**<.001**
Age	-0.06	0.11	-0.55	.584	-0.06	0.11	-0.58	.561	-0.04	0.11	-0.36	.716
MMSE	-0.22	0.56	-0.39	.699	-0.20	0.57	-0.35	.725	-0.09	0.57	-0.16	.873
Adherence	0.02	0.03	0.88	.378	0.02	0.03	0.87	.386	0.02	0.03	0.69	.493
Assessment Interval	0.00	0.01	-0.39	.700	0.00	0.01	-0.27	.786	0.00	0.01	-0.01	.992
Neuroticism	0.02	0.03	0.53	.596	0.02	0.03	0.58	.564	0.01	0.03	0.37	.715
Extraversion	**-0.11**	**0.04**	**-3.01**	**.003**	**-0.11**	**0.04**	**-2.94**	**.004**	**-0.11**	**0.04**	**-2.82**	**.005**
Openness to Experience	**0.08**	**0.04**	**2.12**	**.036**	**0.08**	**0.04**	**2.16**	**.032**	0.07	0.04	1.84	.067
Agreeableness	-0.01	0.04	-0.26	.794	-0.01	0.04	-0.16	.873	-0.01	0.04	-0.20	.838
Conscientiousness	**0.09**	**0.04**	**2.32**	**.021**	**0.09**	**0.04**	**2.29**	**.023**	**0.08**	**0.04**	**2.06**	**.041**
Mental Demand					-0.07	0.23	-0.32	.748	-0.11	0.23	-0.45	.650
Physical Demand					-0.04	0.18	-0.23	.816	0.00	0.18	0.02	.981
Social Demand					0.20	0.25	0.83	.409	0.20	0.25	0.81	.419
Openness x Mental Demand									0.02	0.01	1.72	.087
Extraversion x Social Demand									0.00	0.01	-0.36	.722
Agreeableness x Social Demand									0.00	0.01	-0.19	.849
Conscientiousness x Social Demand									0.01	0.01	0.88	.382
R^2	0.07				0.07				0.09			
Adjusted R^2	0.03				0.02				0.01			
ΔF	1.63				0.23				0.87			
p	.110				.872				.485			

Note. Valid N = 206 (49 participants excluded due to missing data). All predictor variables were mean centred. ΔF = F-ratio for change in model fit with the addition of new predictors at each step of the hierarchical regression. **Bold** = $p < .05$.