Intersectional Social Inequalities and Cognitive Functioning among Community-Dwelling Older Adults in England: A Decomposition Analysis of the Mediating Role of Loneliness

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Abstract

Normative cognitive decline is an emerging public health issue for older adult populations. It is necessary that we take an intersectional approach to examining heterogeneity in cognitive health outcomes. Using complex longitudinal survey data from the English Longitudinal Study of Ageing (ELSA), multiple linear regression models were used to examine the relationship between intersectional group membership based on age, education, and sex, and change in cognitive functioning domains (memory function, and executive function) over an 8-year period. Three-way decomposition analysis was also used to examine the mediating effect of loneliness on the association between intersectional group membership and the change in cognition domains. Intersectional group membership was found to be significantly associated with change in memory function and executive function over time. However, loneliness was not observed to have a significant mediating effect on the relationship between intersectional group membership and the change in cognition outcomes.

Keywords

Aging; Intersectionality; Loneliness; Cognitive decline; Memory function; Executive function; England; Three-way decomposition; Survey data; Casual mediation
Summary for Lay Audience

Cognitive decline is an emerging public health issue for cognitive-disease free older adult populations. Memory function and executive function are two key areas of cognitive health in old age. Declines in memory and executive function weaken an individual’s ability to function independently in day-to-day life in activities such as taking daily medications or being able to perform self-care practices. Loneliness refers to poor feelings caused by differences in the expected quality and the received quality of an individual’s social relationships. Frequent feelings of loneliness are also a key public health concern in aging populations they have been linked to negative physical and emotional health outcomes.

Intersectionality is a framework that refers to the interlocking relationship between an individual’s multiple social identities. Intersectionality is commonly used to examine disparities in health in the population. To better understand cognitive health, we must examine how people with different interlocking social identities, commonly referred to as belonging to an intersectional group, experience changes in cognitive health over time. As well, it is important to examine how modifiable factors like loneliness potentially influence the disparities we observe amongst different intersectional groups.

This thesis used data from Wave 4 (2008 to 2009) and Wave 8 (2016 to 2017) of the English Longitudinal Study of Ageing (ELSA), a sample of older adults age 50 years and over living in England. In this study, we found that intersectional groups based on age group, biological sex, and education level, experienced differences in the decline in memory function and executive function over an 8-year time-period. Specifically, individuals who belonged to the group Females age 65 years and older with high levels of education attainment declined at a quicker pace when compared to those who were Male 50 to 64 years old with low educational attainment. Additionally, while these groups experienced disparities in memory functioning and executive functioning over time, differences in their levels of loneliness did not play a large role in the disparities that we observed. Disparities in cognitive decline would persist even if each intersectional group experienced loneliness at the same level.
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Chapter 1

1 Introduction

This chapter will discuss the rationale and objectives for the current thesis.

1.1 Thesis Rationale

With reductions in population fertility rates and increased life expectancy, there has been a major global shift in the population age distribution. Reports from the United Nations suggest that the population age 60 years and older has increased from 382 million to 962 million over the period of 1986 to 2017 (United Nations, 2017). By the year 2050 it is projected that worldwide, 2.1 billion individuals, approximately 1 in 6 of the world’s population, will be age 60 or older (United Nations, 2017).

Growth in old age populations have been associated with a reduction in the available labour force, and increase in the burden on social pension programs, healthcare and social care (Ahmed et al., 2016). Many high-income countries have observed large increases in their health expenditure per capita. This change has been hypothesized to be driven by increased health spending due to marked changes in health status between the ages of 50 to 60 years of age (Ahmed et al., 2016). With the growth of the aging population and the increasing costs for homecare and healthcare services for older adults, age-specific health issues, such as changes to cognitive functioning, have become significant public health concerns (Institute of Medicine, 2015).

Cognitive functioning, a key determinant of the successful aging process, is a multidimensional concept referring to the mental operations used in the process of acquiring and manipulating learnt information for the purpose of problem solving and reasoning (C. A. Depp & Jeste, 2009). In cognitive disease-free populations, scholars note that declines in cognitive functioning have been associated with lower levels of functional independence, an impaired ability to perform self-care practices, and increased medication non-adherence (“Handbook of Executive Functioning,” 2014; Institute of Medicine, 2015; Osman & Walsemann, 2016). Because cognitive health is directly related to the ability to uptake and understand new information, to recall memories, and to make judgements and decisions,
accelerated cognitive decline has a serious negative impact on an individual’s ability to interact and function in day-to-day life (Institute of Medicine, 2015).

In the absence of disease, the decline in cognition over time has been theorized to be caused by natural age-related changes to the brain (Bishop et al., 2010). While biological processes play a role in the decline of cognitive functioning, they do not completely explain age and gender disparities in cognitive aging (Nichols et al., 2019).

Current research has shown that changes in cognitive functioning are not distributed equally within the aging population. There has been heterogeneity observed in cognitive health outcomes by various social identities and positions (Abrams & Swift, 2012; Levine et al., 2018; Nichols et al., 2019; Wang & Tian, 2018). For example, current research suggests that age-related discrimination negatively impacts cognitive health over time in older adult populations (Abrams & Swift, 2012). Moreover, scholars note that cognitive health exists on a social gradient, as individuals with low socioeconomic resources perform worse cognitively at baseline and see greater declines in cognition over the life course. While these social positions and discriminatory processes that impact cognition have been observed on a single axis, there is a lack of literature examining the way that they intersect and interact together to influence cognitive health outcomes.

Loneliness refers to adverse feelings caused by discordance in the expected quality and the received quality of an individual’s social companionships (Weiss, 1973). High frequency loneliness is a key public health concern in aging populations as it has been attributed to poor health outcomes, both physical and emotional (Heinrich & Gullone, 2006). Previous research has suggested that loneliness has a strong negative impact on cognitive function over time. Specifically, older individuals who experience frequent loneliness have been observed to decline at accelerated rates when compared to populations who do not (Boss et al., 2015).

While there is a growing body of research examining modifiable social provisions like loneliness on cognitive health, as well as the predictors and interventions available for these social provisions, research findings have been generalized to entire sample populations. Few attempts have been made to account for the potential heterogeneous effects across populations, especially in regard to populations with multiple pathways of oppression and discrimination.
This study seeks to use the intersectional framework to address gaps in the research regarding the influence of multiple marginalization on cognitive health outcomes. Intersectionality has historically been used to study the complex interactions and interlocking nature of social positions and their impact on outcome disparities in the population (Crenshaw, 1991; Hankivsky et al., 2014). There is a need to examine cognitive functioning associations with an intersectional lens and examining the role that social power and discrimination play in the development of cognitive health inequalities in aging populations. It is also important to consider the interconnecting role of the social determinants on cognitive health over the life-course, while identifying the differential impact of modifiable factors on cognitive function within intersections (Lopez & Gadsden, 2016).

1.2 Thesis objectives

The current thesis uses research data from the English Longitudinal Study of Ageing (ELSA). ELSA is a biennial, nationally comprehensive longitudinal study administered in a population of community dwelling adults age 50 years and older, residing in England (Steptoe et al., 2013). The ELSA study was designed for the purpose of improving public policy in England associated with older adults and the aging process (Steptoe et al., 2013). Through the use of repeated measurements, the study collects high quality data on relevant issues, including but not limited to, retirement and participation in the labour force, social and economic provisions, physical health and functional status, and psychosocial and cognitive health (Steptoe et al., 2013). Since it first began operation in 2002, there have been eight iterations (research waves) of ELSA, collectively involving approximately 10,000 research participants (Natcen Social Research, 2018a). In order to examine change in cognitive health over time, this thesis uses data from two ELSA research waves: Wave 4, collected in 2007 and 2008, and Wave 8 which was collected over the period of 2015 and 2016.

Following the intersectional framework, the intent of this thesis is to examine the relationship between intersectional group membership based on sex, educational attainment, and age (the exposure groups), loneliness (the mediator) and 8-year changes in cognitive functioning in the domains of memory function and executive function (the outcomes). The target population of this study includes cognitive disease-free community dwelling adults age 50
years and older residing in England. Using longitudinal data from ELSA, this thesis seeks to complete the following research objectives:

1.2.1 Objective 1

- To determine the baseline characteristics for cognitive functioning and loneliness for the overall sample population and for the population based on intersectional group membership.

1.2.2 Objective 2

A. To investigate the association between intersectional group membership and 8-year change in memory function, while controlling for confounding factors including childhood experiences of abuse, childhood social status, immigration status and ethnicity.

B. To investigate the association between intersectional group membership, and 8-year change in executive function, while controlling for confounding factors including childhood experiences of abuse, childhood social status, immigration status and ethnicity.

1.2.3 Objective 3

A. To examine loneliness as a potential mediator in the relationship between the exposure, intersectional group membership, and the outcome, 8-year change in memory function, while controlling for confounders.

B. To examine loneliness as a potential mediator in the relationship between the exposure, intersectional group membership, and the outcome, 8-year change in executive function, controlling for confounders.
Chapter 2

2 Literature Review

This chapter provides an overview of cognitive functioning and cognitive aging in older adults. This chapter also discusses the role of feelings of loneliness on the cognitive health. Using a singular approach, the associations between the social positions of sex/gender, educational attainment, and age group, and the confounders on cognitive health and loneliness in aging populations will be discussed. Finally, the intersectional approach to exploring questions of equity will be outlined.

2.1 Cognitive functioning

Cognition is defined as the mental processes required for the purpose of acquiring, storing, retrieving and processing information (Bayne et al., 2019; Institute of Medicine, 2015). These mental processes are key to an individual’s ability to effectively retain, learn, and understand new information, as well as to use information for functions such as problem solving and decision-making activities (Institute of Medicine, 2015). Cognitive functioning is comprised of six neurocognitive dimensions, including executive functioning, memory function and learning, social cognition, language, perceptual-motor, and complex attention (Peters & Rabins, 2017).

2.1.1 Executive function

Executive function is the neurocognitive dimension referring to the mental processes responsible for functions such as self-regulation during goal-directed behaviours and activities (“Handbook of Executive Functioning,” 2014). Executive functioning skills are important when completing new and ambiguous tasks where there are not pre-established sequences or routines for action (Kerstin & Karbach, 2016). Executive functioning skills are used in situations where there are tasks that require planning, inhibition and attention to detail, as well as in situations that demand self-monitoring and self-regulation (“Handbook of Executive Functioning,” 2014).

There are three main executive function processes including: 1) response inhibition, 2) working memory and 3) cognitive flexibility/switching (Miyake et al., 2000). Response
inhibition refers to the functional ability to maintain control over emotions, thoughts and behaviour, while simultaneously blocking competing stimuli (Diamond, 2013; Institute of Medicine, 2015). Working memory refers to the ability to maintain, process and update learnt information, as well as manipulating and using previously learnt information (“Handbook of Executive Functioning,” 2014; Institute of Medicine, 2015; Rhodes & Parra, 2016). Working memory and response inhibition are highly related, and resultingly, the ability to inhibit competing stimuli strengthens the ability to retain and utilize previously learnt concepts. Likewise, previously learnt information helps individuals to distinguish between which stimuli is worth attention, and which stimuli can be ignored (Diamond, 2013). Lastly, cognitive flexibility refers to the ability to shift between competing stimuli, as well as the ability to adapt thinking, emotions and behaviours based on changes to one’s environment (Dajani & Uddin, 2015; Diamond, 2013; Institute of Medicine, 2015). This process is heavily reliant on working memory and inhibition (Diamond, 2013). Executive function systems are complex. Located in the brain, the system involves the neural networks, the parietal area, subcortical structures, the dorsolateral prefrontal cortex (DLPFC) and the anterior cingulate cortex (ACC) regions (“Handbook of Executive Functioning,” 2014; Rhodes & Parra, 2016).

2.1.2 Long-term memory

Long-term memory function and learning is the neurocognitive dimension responsible for the long-term and permanent storage of knowledge and information (Institute of Medicine, 2015). The long-term memory dimension is comprised of two overlapping domains, explicit memory, which refers to conscious and intentional recollection of information, and implicit memory, the memory that is acquired and utilized without conscious awareness (Brem et al., 2013). Explicit memory is comprised of episodic memory, and semantic memory. Semantic memory is a memory system that allows individuals to store, obtain and retrieve general facts and words, and to create concept and symbol associations for future use (Institute of Medicine, 2015; Nilsson, 2003). Episodic memory refers to memory system collected over the lifetime, which stores and acquires an individual’s own autobiographical information, such as past events that have occurred at a specific place, or period of time, as well as emotional and contextual associations (Institute of Medicine, 2015; Shing, 2016). Episodic memory is reliant of environmental and contextual cues for recall (Nilsson, 2003). Memory events can be recalled explicitly as a recollection where individuals recall specific detailed
information about the memory event, or as a familiarity, where individuals remember the feelings associated with the memory without the ability to recall the specific information tied to the event (Shing, 2016).

2.1.3 Cognitive changes in older adults

Cognitive aging refers to the changes that occur in cognitive functioning processing over the lifespan (Institute of Medicine, 2015). Cognitive aging is a dynamic process that occurs in all individuals, irrespective of their initial cognitive functioning performance (Institute of Medicine, 2015). There are inter-individual differences related to the degree of change over time for each neurocognitive dimension, due to individual differences in the modifiable and non-modifiable factors related to behavioural, socio-demographic, physical or genetic determinants that impact an individual’s ability to resist and adjust to changes in brain functioning (Depp et al., 2010; Depp & Jeste, 2009). The decline in cognitive functioning processes over time is also heterogenous on the intra-individual level, as neurocognitive dimensions change at varying rates within each individual (Institute of Medicine, 2015). Research findings from the Baltimore Longitudinal Study of Aging suggest that the inhibition and switching components of executive functioning, and episodic memory are sensitive to the aging process, and significantly decrease over time (Goh et al., 2012).

Specifically, the episodic memory system declines throughout the cognitive aging process, with the decline process beginning in young adults in their 20s, especially with demands for more complex memory retrieval tasks (Institute of Medicine, 2015; Shing, 2016). Yet, semantic memory is not as sensitive to the aging process. Old and young adult populations have been observed to score similarly when tested for semantic memory recall (Nilsson, 2003).

In cognitive disease-free populations, sharp declines in cognitive health negatively impact older people’s ability to independently complete tasks which involve one to process complex information such as completing self-care practices, decision-making activities and driving activities (Harada et al., 2013; Parikh et al., 2016). Declines in executive functioning, or more specifically, in working memory, are associated with poor medication adherence in older adults (Stilley et al., 2010). Research by Insel et al. (2006) found a negative correlation between working memory score and the percentage of days an elderly failed to
correctly take their medication dosage. As working memory score decreased, medication non-adherence increased (Insel et al., 2006).

Cognitive changes over the lifespan also have an impact on long-term health and wellness. Maintaining cognitive health over the lifespan decreases the risk of mortality and disability. A longitudinal study by Yaffe et al. (2010) examining the impact of 4-year cognitive trajectories on long term health risks in elderly populations found that individuals with major declines in cognitive functioning had a 58 percent greater hazard of mortality when compared to individuals who had minor declines. In contrast, individuals who were able to maintain their cognitive functioning had a 54 percent lower hazard of mortality when compared to minor decliners (Yaffe et al., 2010). Furthermore, steep declines in cognitive functioning are indicative of future diagnoses of cognitive diseases in older adults. Research from Levine and colleagues (2018) found that after adjusting for covariates, as the rate of change for cognitive decline increased by 1-unit, the likelihood of developing dementia significantly increased by 33 percent, suggesting that above average rates of change for cognitive trajectories predict future diagnosis of dementia in cognitive disease-free adults (Levine et al., 2018; Nyberg et al., 2012).

2.1.4 Age, ageism, and cognitive functioning

Age is directly associated with changes in cognitive functioning over the lifespan. In older adult populations, the research suggests that as age increases cognitive functioning decreases (Salthouse, 2004). Middle age individuals have been observed to experience declines in cognitive functioning at a slower rate than individuals in old age (Karlamangla et al., 2009; Nyberg et al., 2012; Olaya et al., 2017; Salthouse, 2009). A study conducted by Reas et al. (2017) examining the effect of sociodemographic factors, specifically sex and education, on 27-year cognitive change in adults highlights the heterogeneity of cognitive functioning by age. The study, comprised of participants age 31 to 99 years of age at baseline used repeated measures to assess global cognitive performance, executive functioning, verbal fluency, and memory function, specifically verbal episodic recall (Reas et al., 2017). The findings of the study showed evidence of accelerated decline in cognitive functioning after the age of 65 in all 4 measured cognitive categories (Reas et al., 2017). Similar findings from scholar Salthouse (2004) suggest that adults under 60 years old see an overall cognitive functioning
decline at a rate of 0.02 to 0.03 units per year, while adults over 61 to 96 years old see declines of 0.04 to 0.05 units per year on average (Salthouse, 2009).

Experiences of ageism in older adult populations have also been observed to adversely impact cognitive functioning over time. Ageism is defined as the unjust treatment or stereotyping of individuals based on one’s chronological age or perceived age group membership (Abrams & Swift, 2012). Older adult individuals commonly face experiences of ageism, presented as negative cultural or societal stereotypes, or structurally, as policies, services and practices that unfairly discriminate against the aging and elderly population (Horhota et al., 2018). Middle aged individuals are likely to experience age-based discrimination through employment and the labour force, while aged individuals are more likely to experience discrimination through health service interactions (Horhota et al., 2018). The literature overwhelmingly shows that ageism, which commonly presents as internalized negative self-perceptions of aging, adversely impacts health, with the ill effects of age-based discrimination appearing to vary based on the population social gradient. Older adults with low educational attainment are more likely to experience negative health outcomes due to ageist discrimination when compared to individuals with high levels of educational attainment (Chang et al., 2020).

Experiences of age-based discrimination have been associated with an increased risk of poor functioning, disability and mortality (Abrams & Swift, 2012; Robertson et al., 2016). Specifically, experiences of negative age stereotypes in elderly adults have predicted adverse changes to cognitive functioning over time, particularly in the memory functioning domain (Chang et al., 2020). A longitudinal study examining the impact of negative perceptions of aging at baseline with decline in self-rated memory and verbal fluency over a 2-year period was conducted in a population of 7,622 adults age 50 years and older. After adjustment, the results of the study indicated that individuals with negative perceptions based on age saw a larger decline in cognitive functioning scores over time when compared to individuals without negative perceptions (Lara et al., 2019).

2.1.5 Education as a risk factor for cognitive decline in older populations

Existing literature highlights a positive association between educational attainment and cognitive function. Specifically, the research suggests that adults with higher levels of
educational qualifications start with a higher baseline level of cognitive functioning, and
decline at a slower rate than those with low levels of education (Karlamangla et al., 2009; 
Reas et al., 2017; Weuve et al., 2018). A nationally representative study sample of 19,594 
adults 51 years and older residing in the United States highlights these associations. The 
study examined the sociodemographic and genetic predictors of cognitive aging (Levine et 
al., 2018). Survey participants were measured for educational attainment, reporting their 
highest academic qualification, and cognitive age, a measure derived using the results of four 
cognitive functioning assessments. The findings of the study suggested that low educational 
attainment influenced the progression of cognitive aging. After adjustment, individuals with 
lower educational qualifications were cognitively older than those with higher educational 
qualifications. Moreover, as educational qualifications increased, the rate of change for 
cognitive functioning over time decreased (Levine et al., 2018).

Educational attainment is an important social determinant of health for aging populations 
(Kubzansky et al., 1998). Health exists on a social gradient. Low socioeconomic status, 
denoted as having reduced access to resources such as education, income and high-skilled 
occupations, is correlated with negative health outcomes in old age (Sachdev et al., 2015). 
Educational attainment is a strong predictor of health over the lifespan. Individuals with low 
levels of education are less likely to experience high incomes, and satisfactory workplace 
experiences (Arcaya et al., 2015). Differences in educational attainment also impacts an 
individual’s ability to seek out and access social resources and materials, and health 
resources and services (Delaruelle et al., 2020; McMunn et al., 2005). Differential access to 
resources and care adversely impacts health, and as a result individuals with low educational 
qualifications are more likely to experience long-term disability and chronic disease (Arcaya 
et al., 2015). The cognitive reserve theory in cognitive health has attempted to explain the 
impact of socioeconomic resources on cognitive aging. The cognitive reserve theory states 
that socioeconomic factors such as educational qualifications, and occupational qualifications 
atained over the lifespan result in an increased level of cognitive functioning capacity 
through increased neural capacity and efficiency (Stern, 2010). Due to the high baseline 
cognitive functioning capacity, the brain is more tolerant to changes over time which helps to 
offset age-related and clinical regressions. Stern (2010) suggests that the brain is better able
to adapt and compensate for changes to cognitive functioning as it is better able to recruit secondary neural networks.

2.1.6 Gender differences in cognitive functioning in older adults

There are gendered differences in lived experiences that influence health and well-being outcomes over the life course (McMunn et al., 2005). Men and women experience differential access to education, occupational experiences and financial resources, which differentially impact their ability to both access and utilize health and social services necessary for the maintenance of health (Birn et al., 2017). In aging populations, the literature shows a significant gender difference in cognitive functioning, with men having worse cognitive outcomes in comparison to women. While there are observed biological differences in the way men and women experience brain aging, researchers have suggested that biological differences are necessary but not sufficient in explaining gender differences in cognitive function over time (Nichols et al., 2019; Wang & Tian, 2018). Overall, the literature suggests that there is a significant gendered difference in regard to baseline cognitive functioning in older adult populations. Older adult men have been reported to have lower baseline cognitive functioning scores when compared to women. A study examining the predictors of cognitive aging in a sample of 2,353 older adults residing in the United States, found that after accounting for confounders, baselines cognition, a measure derived from the assessments of delayed recall, working memory, attention, and language, was significantly higher in females than in males (Karlamangla et al., 2009). Furthermore, there are also reported differences in the rate of cognitive aging (Goveas et al., 2016; Levine et al., 2018; Zaninotto et al., 2018). An English study comprised of 10,626 community dwelling older adults with a mean age of approximately 65 which examined cognitive trajectories in aging adult populations found a significant association between gender and cognitive decline. Men were observed to decline at a faster rate than women for memory function, executive function and overall cognitive function (Zaninotto et al., 2018).

Researchers in the field suggest that there may be social and environmental differences in the experiences of men and women over the life-course that may contribute to the observed differences which favour women. In particular, men are more likely to participate in negative lifestyle behaviours such as smoking and drinking that adversely impact cognitive aging
Researchers also hypothesize that gender differences in cognitive functioning in older adult populations may reflect societal improvements that have benefited the health of women (Weber et al., 2014). Progress in gender equity have prompted socioeconomic growth through improvements in access and participation in the educational system and the workforce. These changes have led to overall improvements in women’s cognitive health and well-being. However, the effects of these societal changes may have had differing effects on the health of men and women (Nichols et al., 2019; Weber et al., 2014).

2.2 Perceived loneliness

Peplau & Perlman (1982) define loneliness as a subjective feeling of lacking social relationships, caused by a difference in an individual’s perceived experience and their desired experience of social companionships and relationships. Loneliness is a distinct concept from social isolation. Social isolation indicates that an individual lacks social and institutional ties or relationships, and reflects an individual’s inability to make societal connections (Shiovitz-Ezra et al., 2018; Tesch-Romer & Huxhold, 2019). While the quantity of social connections plays a role in perceived level of loneliness, the quality of these connections bares more importance (Age UK, 2014; Heinrich & Gullone, 2006).

There are emotional and social components to loneliness. Social loneliness refers to a perceived deficiency in the quality and quantity of social networks offering a sense of community connectedness or sense of belonging, typically characterized by a disruption or lack of integration into one’s social network (Drennan et al., 2008; Dykstra, 2009). Emotional loneliness is described as a lack of emotional attachment that results in the feeling of desolation and insecurity (Dykstra, 2009). Weiss (1973) describes emotional loneliness as an aversive state, where individuals facing emotional loneliness have a persistent feeling of apprehensiveness, an inability to concentrate or to place energy toward remedying their existing state of loneliness.

Feelings of loneliness are most prevalent in adolescence, and in old age. Loneliness in adolescence has been described as a normative experience due to the increasing importance of peer group affiliation and sense of belonging that commonly develops during the transition from childhood to adolescence (Heinrich & Gullone, 2006). In terms of loneliness in aging populations, research examining wellness across the life course estimates that approximately
6 to 13 percent of adults aged 52 years and older always or often experience feelings of loneliness (Great Britain Department of Health, 2014). Home setting has an impact on self-perceived feelings of loneliness. Institutionalized elderly people report significantly higher loneliness scores when compared to non-institutionalized elderly populations (Prieto-Flores et al., 2011).

Feelings of loneliness can be transient or chronic. Research suggests that loneliness may be a continued experience for many adults in later life (Heinrich & Gullone, 2006). A longitudinal study by Dahlberg, et al. (2015) examining feelings of loneliness amongst Swedish elderly adults found that 79.6 percent of elderly adults who had reported feeling frequently lonely at baseline also reported feeling frequently lonely at 7-year follow up. Frequent loneliness has been observed to have a negative impact on the health of aging populations. Persistent feelings of loneliness are problematic and lead to reduced wellbeing and life satisfaction (Age UK, 2019). Frequent feelings of loneliness also have long-term damaging effects to physical and mental health and appear to increase the risk for mortality in older adult populations. A longitudinal study on loneliness and health outcomes in the United States found that elderly individuals who reported frequent feelings of loneliness had a significant increase in the risk for mortality at 6-year follow-up when compared to non-lonely individuals (Luo, 2012).

2.2.1 Loneliness as a mediator in the association between exposure groups and cognitive functioning

The literature strongly suggests a direct association between the frequency of loneliness and changes in cognitive function within populations of older adults (Boss et al., 2015; Maharani et al., 2019; Montoliu et al., 2019; Shankar et al., 2016; Zhong et al., 2017). The mechanisms driving the relationship between loneliness and cognitive changes are unclear. Researchers hypothesize that negative coping methods used to compensate for the adverse psychological effects of loneliness may contribute to changes to cognitive functioning (Maharani et al., 2019). Alternately, researchers theorize that biological and physical changes to the body induced by loneliness may adversely impact cognitive health. High frequency loneliness increases sympathetic nervous system and hypothalamic-pituitary-adrenal axis activity, increases inflammation, and reduces sleep quality. These changes adversely impact neural
responses to stimuli, and could potentially result in accelerated cerebral aging (Maharani et al., 2019).

Frequent feelings of loneliness have been reported to predict baseline cognitive functioning (Maharani et al., 2019; Montoliu et al., 2019). Frequent feelings of loneliness are also associated with the rate of change in cognitive functioning over time. Researchers have suggested that older adults with high reported frequencies of loneliness experience accelerated decline in cognitive functioning (Lara et al., 2019). Results from a longitudinal study in the United States examining the relationship between loneliness and cognitive functioning trajectories highlight this association (Donovan et al., 2017). Researchers Donovan et al. (2017) examined the relationship between self-reported loneliness with the rate of change in memory functioning over a 12-year period. At baseline, a sample of 8,382 older American adults age 65 and older were evaluated for their loneliness status using a single item binary measure from the CESD-8, examining past-week feelings of loneliness. Over the period of 12-years, memory functioning was measured using an immediate and delayed episodic memory evaluation. The results of the study indicated that after adjusting for covariates, older adults who had reported past week feelings of loneliness at study baseline had an accelerated rate of change in memory functioning when compared to those who did not report feelings of loneliness. Furthermore, Boss and colleagues (2015) conducted a systematic review examining the relationship between loneliness and cognitive functioning, and assessed 10 cross-sectional and longitudinal studies which were conducted in populations residing in Europe and North America with a reported mean age greater than 60 years of age. The review concluded that there was a significant negatively correlated association between loneliness and multiple cognitive function domains, including global cognition, and memory functioning, specifically in the form of semantic memory and visual memory. However, they also concluded that there was inconclusive evidence on the association between loneliness and the cognitive functioning domain executive functioning (Boss et al., 2015).

2.2.2 Age differences in the frequency of perceived loneliness

There is a direct association between age and the severity of loneliness for older adult populations. Elderly people commonly face experiences of age-related discrimination through social exclusion and social rejection, in forms such as mandatory retirement or
structures and services that inadequately meet the mobility needs of seniors. These negative social experiences can result in social withdrawal. Social withdrawal can generate adverse feelings towards pre-established social connections, and as a result, lead to feelings of loneliness (Shiovitz-Ezra et al., 2018; Sutin et al., 2015). Research suggests that there is a positive correlation between age and loneliness; as age increases the reported severity and frequency of loneliness increases (Drennan et al., 2008; Losada et al., 2012; Shiovitz-Ezra et al., 2018). A cross-sectional study conducted by Drennan et al. (2008), which examined social and emotional loneliness in 683 adults age 65 years and older in Ireland, supports findings suggesting that the severity of loneliness increased with age. The study found that age significantly predicted the frequency of loneliness, as a one-year increase in age resulted in a 0.154 increase in loneliness severity score (Drennan et al., 2008).

While there is a well-established association between age and loneliness for individuals aged 65 years and older, there is limited research on the association between age and the frequency or severity of loneliness for individuals who are in middle age, specifically in the 45 to 64 years old age group. There is also limited research involving age group comparisons for the frequency or severity of self-reported loneliness within populations, specifically comparisons examining differences between individuals in middle age and those in old age. Still, the available literature does show age group difference in loneliness. Research conducted by the Great Britain Public Health found that individuals 80 years and older were more likely to report being lonely when compared to those who were in the 52 to 79 age group, however it is unclear if the reported difference was meaningful (Great Britain Department of Health, 2014).

2.2.3 Educational attainment as a predictor of perceived loneliness in older adulthood

There is a negative association between level of education and frequency of feelings of loneliness, suggesting that as education level increases, the severity and frequency of loneliness experienced decreases (Alma et al., 2011; Greenfield & Russell, 2011; Pereira et al., 2015; Savikko et al., 2005). Research has shown that socioeconomic resources like education act as protective factors against stressors that can negatively impact the quality and quantity of social connections. The diminished quality of social relationships play a role in increasing individual vulnerability to feelings of loneliness (A. J. Bishop & Martin, 2007;
Hawkley et al., 2008). Specifically, a study conducted in a sample of 225 American men and women age 50 to 68 years old examining the social structural factors influencing perceptions of the quality of social relationships and loneliness found that low socioeconomic resources in the form of education and income were negatively associated with perceived loneliness. Individuals in the population with low educational attainment, defined as less than a high school level education, on average had higher frequencies of loneliness when compared to those with higher levels of education (Hawkley et al., 2008).

2.2.4 Sex and gender differences in perceived loneliness

Based on the literature, the presence of a gender difference for frequency of loneliness is unclear. Research supporting an association between loneliness and gender have suggested that women are at a higher risk for loneliness in old age due to changes in social relationships (Beaumont & Office for National Statistics, 2013; Drennan et al., 2008; Savikko et al., 2005). Women generally outlive men, and as a result may differentially experience losses to social relationship through the death of friends and family members, and the loss of romantic relationships through widowhood (Savikko et al., 2005). The United Kingdom’s Office of National statistics (2013) features gender as a determinant of loneliness in elderly populations. They have reported that the prevalence of feeling lonely is higher in females than males. In a sample of community dwelling adults age 52 years and older surveyed in 2009 to 2010, 39 percent of women reported often feeling lonely compared to 27 percent of men (Beaumont & Office for National Statistics, 2013). Also in a sample of 6,786 elderly individuals age 75 years and older, Savikko and colleagues (2005) found that women were 55 percent more likely to report having feelings of loneliness when compared to men after adjustment for confounders. Nonetheless, there is opposing evidence regarding the presence of an association. Several research studies have concluded that after adjustment there was no significant association between gender and loneliness amongst older adults (Barrett-Connor & Kritz-Silverstein, 1999; Gul et al., 2018; Victor et al., 2006).

2.3 Other associated variables

The following section describes variables including childhood social status, childhood experiences of abuse, ethnicity and immigration status and their confounding associations with the exposure, mediator, and outcome variables.
2.3.1 Ethnicity

Previous research has strong evidence of ethnic and racial disparities in educational participation and success, underpinned by a history of racism within traditionally white educational systems (Noltemeyer et al., 2012). Within the secondary educational system in the United Kingdom, racial and ethnic inequalities in the allocation of educational resources, biases in academic streaming, harmful racial stereotypes and a lack of diversity in representation in academic curriculum negatively impact educational performance for ethnic minority students, and further impact their ability to qualify for higher education programs (Stevens, 2007). The literature states that experiences of covert and overt racism, including, but not limited to, discrimination against applicants with non-European names, poor racial and/or ethnic diversity in staffing, racial biases in grading, as well as feelings of exclusion in educational institutions negatively impact student representation and success in higher educational programs (Phillips et al., 2006). Black and ethnic minority students have been shown to be 16 percent more likely to not complete their first or second years of higher education when compared to white students (60 percent vs 76 percent) (Higher Education Funding Council for England (HEFCE), 2015). Moreover, the Dearing Report on higher education in the United Kingdom found that in 1994 while as a whole, ethnic minorities were proportionately represented in the United Kingdom’s higher education system, there was an underrepresentation of all ethnic minorities in professional higher education programs (National Committee of Inquiry into Higher Education, 1997).

The literature also suggests that there may be racial and ethnic disparities in the cognitive aging process. Current research suggests that non-white elderly individuals experience accelerated rates of cognitive decline when compared to their white counterparts (Karlamangla et al., 2009; Levine et al., 2018). In the United States, Hispanic white and Non-Hispanic Black individuals have been observed to be more likely to have accelerated rates of decrease in cognition over time, defined as having a cognitive functioning score that did not match the expected score for their age, when compared to Non-Hispanic whites (Levine et al., 2018). However, research suggests that differences in cognitive functioning by ethnicity may be a function of socioeconomic disadvantages. Poor access to education may strongly contribute to observed racial disparities in cognitive functioning (Weuve et al., 2018).
2.3.2 Childhood experiences of abuse

Experiences of violence or neglect during childhood has been strongly suggested to predict educational outcomes in adulthood. The trauma associated with neglect and abuse during childhood increases levels of stress and negatively impacts a child’s ability to learn. Childhood experiences of abuse are associated with poor school attendance, and may strongly impact a student’s ability to remain enrolled in their educational programs (Maclean et al., 2016). Various studies examining the association between childhood experiences of abuse and educational outcomes have concluded that individuals with reported cases of abuse or neglect during childhood are at a higher risk of experiencing poor educational outcomes (Fry et al., 2018). Specifically, the results from a birth cohort study found that individuals who had a reported case of child maltreatment in the form of physical abuse, sexual abuse or neglect were less likely to complete high school by age 21 when compared to individuals who had not experienced child maltreatment (Mills et al., 2019). Furthermore, the study also found that individuals with reported childhood abuse were less likely to continue on with further education, as they were less likely to be enrolled in post-secondary educational program (Mills et al., 2019).

2.3.3 Childhood social status

Familial socioeconomic status during childhood is strongly associated with educational outcomes attained in adulthood (Jonsson & Mills, 2009; National Committee of Inquiry into Higher Education, 1997; Raffe et al., 2006; Rainey & Murova, 2004). Families in low socioeconomic classes have differential access to educational opportunities, and income due to low paying occupations. Poor socioeconomic status and in many cases, poverty, negatively impact parents and children’s ability to access key resources influencing childhood development and school readiness, such as sufficient food and nutrition that aid in mental and physical development, or access to paid services such as early child educational programs that support in the development of fundamental skills (American Psychological Association, 2020). Disparities in the quality of schools and living conditions in low income areas, as well as limited financial and school resources diminish the quality of in-class educational experiences, which can have an adverse effect on a student’s ability to succeed educationally (American Psychological Association, 2020; van der Berg, 2008).
Familial socioeconomic status has been observed to be associated with educational attainment in the United Kingdom in the 20th century. Historically, even with the introduction of compulsory education laws, social status has played a large role in the ability of students’ to remain enrolled in secondary education, or to continue on into higher education programs (Heath & Clifford, 1990). In the mid to late 20th century individuals with low familial socioeconomic status saw higher rates of school attrition and were less likely to enroll in post-secondary programs. In regard to the British educational system for students enrolled in school in 1965 to 1991, students with parents in high social occupational classes were more likely to enroll in higher education programs when compared to those in lower occupational classes (Boliver, 2011). This trend appears to have continued on into the 1990s. A study conducted by British researchers examining the social class inequalities in educational participation in the United Kingdom’s educational system estimated that between the years 1991 to 1999, 55 to 72 percent of adolescents with parents holding professional career positions participated in post-secondary education. Participation was much lower for students from low socioeconomic positions. It is estimated that only 6 to 13 percent of students from families who worked unskilled jobs attended post-secondary programs (Glennerster, 2002).

2.3.4 Immigration status

Immigration status is directly associated with educational attainment and school outcomes (Banerjee, 2016). While factors such as host country language acquisition, and age of immigration have been reported as common barriers to student success in immigrant populations, current literature suggests that immigrant adolescents have better educational outcomes such as higher high school graduation rates and lower school attrition when compared to their non-immigrant counterparts (Camilleri et al., 2012).

Research examining the relationship between education and immigration mainly focuses on migrant populations from the 21st century, hence it is unclear if all associations presented in current literature are applicable to older immigrant populations who entered the educational system in the mid to late 20th century. Nonetheless, research examining ethnic first-generation immigrants to the United Kingdom in the late 1970s to mid-1980s have found that on average ethnic first-generation immigrants were reported to spend more years in full time education than their white peers (Bonikowska & Hou, 2011). Age of immigration also influences educational success. Migrants who immigrated early into their educational careers
were also observed to be more likely to obtain a university degree by age 34 in comparison to non-immigrants (Bonikowska & Hou, 2011). Nonetheless, researchers Warnes et al. (2004) note that migrants to Europe in the mid 20th century commonly arrived with lower educational qualifications, and were funneled to low skilled manual occupations, rather than having the opportunity to further pursue their education (Warnes et al., 2004). Hence, it is possible that working aged individuals who migrated to their host country would have had less access to educational programs when compared to younger immigrants.

Immigration status has a direct impact on loneliness. Migrant status has been associated with increased frequency of feelings of loneliness at various stages over the life course. Immigrants often experience difficulty maintaining the quality of social connections from their country of origin, leading to feelings of loneliness (Rich Madsen et al., 2016). Moreover, stress and anxiety related to the process of assimilating or acculturating into the general population can induce feelings of loneliness (Rich Madsen et al., 2016; Wu & Penning, 2015). Research has shown that feelings of loneliness in immigrant populations may vary by age of immigration. A study comprised of 10,553 older adults age 60 years and older residing in Canada examining loneliness in immigrant populations found that only Canadians who immigrated to Canada after the age of 12 reported significantly higher levels of loneliness, when compared to those who had been born in Canada (Wu & Penning, 2015).

2.4 Intersectionality framework

Intersectionality is a framework that provides insight on the interlocking nature of social positions and their impact on social inequality and in turn, outcome disparities (Collins, 2015; Crenshaw, 1991; Hancock, 2007). The intersectional framework is grounded in Black feminist and critical race theories (McCall, 2005). It was introduced by legal scholar Kimberlé Crenshaw in 1989, when she argued that an individual’s social position, their membership to social groups based on factors such as gender and class, are not independent of each other and as a result cannot be examined on a single axis (Crenshaw, 1991). Social positions and historical systems of oppression, like sexism and racism, overlap and interconnect, and consequently are experienced by the individual simultaneously (Bowleg, 2012; Hankivsky et al., 2014; May, 2015). Social positions are contextual nature, and vary based on the social and environmental context they are examined in. As a result, it is
important to contextualize intersectional social positions based on the historical and societal circumstances specific to the population group being observed (Collins, 2016; Hankivsky et al., 2014; May, 2015).

Single-axis examinations fail to truly explore complexity as they limit analyses to the experiences of privileged members of the social group and erase the experiences of diverse populations and individuals who faced multiple streams of disadvantage or oppression (Crenshaw, 1991). Due to the non-mutually exclusive nature of these social positions, examinations regarding individuals who experience multiple jeopardy, multiple positions of marginalization, cannot simply rely on additive approaches where the effect of disparities are summed together (Bowleg, 2008). Hence, in order to better understand the impact of identity and processes of oppression it is important to investigate the effect of social positions in relation to other social positions as well as the way in which these social positions interact with one another, rather than just examining them in isolation of one another (Collins, 2016).

McCall (2005) has further expanded intersectionality and provided key information on the methods of examination of intersectional groups, groups encompassing the multiple axes of social positions. Through her research, McCall has highlighted three distinct approach for intersectional analyses (McCall, 2005). The anticategorical approach is a methodology which rejects the examination of outcomes through the use of intersectional groups due to the complexity of social life and fluidity of social positions. The intracategorical approach allows for the examination of outcomes while focusing on a single intersectional group, for example Black women (McCall, 2005). Lastly, the intercategorical approach examines outcomes within and across intersectional groups, like the comparison of an outcome between Black women of high socioeconomic status versus white men of low socioeconomic status.

Intersectionality is primarily used in qualitative research; Quantitative research has previously been criticized for its reliance on single axis analyses (McCall, 2005). As of recent, leading scholars have developed and adapted methods to better allow for the intersectional framework to be utilized in fields such as the social sciences, population health and epidemiology (Bauer & Scheim, 2019; Bowleg, 2008; Evans, 2019; McCall, 2005). Scholars have noted that the use of intersectional-informed analyses in quantitative research allows for a more nuanced understanding of health and wellbeing (Bauer & Scheim, 2019;
Intersectionality can assist in addressing research questions surrounding the issue of equity as it highlights the hidden disparities in health outcomes within the general population. As quantitative intersectional analyses improve our ability to examine heterogeneity, researchers are better able to apply tailored knowledge towards the development of policies and evidence-informed programs targeted towards multiple marginalized or at-risk population groups (Hunting, 2014; Jackson, 2017). In this study we intend to use the intersectional intercategorical approach to examine the association between the exposure, intersectional groups of age, sex/gender, and educational attainment and the outcome, 8-year change in cognitive functioning in older adults in England. We also seek to identify if a modifiable social provision, loneliness, mediates this causal association.

The Government of the United Kingdom has placed special emphasis on improving wellness in the aging population, safeguarding the maintenance of the physical, psychological, and cognitive health of the population. The middle age to older age adult population in the United Kingdom, age 50 years and older, comprised approximately 38 percent of the total population in 2018 (Koenig & Mumme, 2020). The aging proportion of the population will continue to increase, with recent projections estimating that by the year 2030, 20% of the population of the United Kingdom will be 65 years and older (Age UK, 2019). With the increase in life expectancy, increase in the percentage of the population in middle and older age, and the prospect of the increased need of resources for healthcare and homecare for individuals approaching old age, the maintenance of cognitive health has become an important public health concern (Age UK, 2019; Great Britain Department of Health, 2014).

Cognitive functioning is a major component in the successful aging process for older adults (Cosco et al., 2014; C. Depp et al., 2010; Luszcz & Lane, 2008; Rowe & Kahn, 1987). Resultingly, key scholars in cognitive aging have recommended the collection and dissemination of population health research that examines cognitive functioning over the life course for normal cognitive aging for adults outside of the scope of cognitive diseases such as dementia or Alzheimer’s disease. They have also called for research that assists to better describe cognitive health over diverse population, as it can help us to better understand heterogeneity in health among the elderly (Institute of Medicine, 2015).
In this study we acknowledge the need to examine cognitive functioning associations with an intersectional lens, to examine the intersecting role that the social positions of age, biological sex and educational attainment have in the development of cognitive health inequalities in aging populations, and to fully consider the interlocking role of the social determinants on cognitive health over the life-course (Lopez, 2016). While scholars have examined associations between age, educational attainment, biological sex, and cognitive health separately, there are gaps in the literature, as there is a lack of research examining the way in which these social positions intersect and interact to influence cognitive functioning. As scholars seek to understand the social factors that contribute to the disparities in cognitive health in cognitive disease-free individuals it is important that we also identify heterogeneous effects within our aging adults. Through the examination of cognitive aging through an intercategorical lens, we will be better able to understand the characteristics of various subsets of the population. As well, we will be able to provide novel evidence on groups that are at greater risk for accelerated decline over the life-course. Research in this area is especially important as scholars cannot assume that belonging to intersectional groups with multiple marginalized social identities (i.e., old age women with low educational attainment) will equate to having the poorest health outcomes (Purdie-Vaughns & Eibach, 2008).

Yet, similar to the associations with cognitive functioning, there are gaps in the literature regarding the lack of research examining loneliness on multiple axes (Greenfield & Russell, 2011). Through the examination of loneliness as a mediator in the relationship between the intersectional groups of age, sex and educational attainment and cognitive outcomes, we seek to identify the way that social provisions impact health in elderly populations. Current research in the field of quantitative intersectionality has highlighted the need for solution-focused research (Bauer & Scheim, 2019; Jackson, 2017). Pinpointing and intervening on modifiable factors that drive causal associations could potentially assist in minimizing or eliminating the observed health disparities in cognitive health within and across intersectional groups and could assist health organizations in targeting vulnerable groups for public health interventions.
Chapter 3

3 Methodology

This chapter will discuss the data source, the target population, and the main variables used in the present study. This chapter will also discuss the methods used for the statistical analysis, and data considerations when working with complex survey data.

3.1 Study design

3.1.1 Data source

The English Longitudinal Study of Ageing (ELSA) is a long-term longitudinal panel study. Using repeated measures, ELSA seeks to study the dynamics and patterns within the aging process, with research topics including but not limited to social participation, physical and psychological health, cognition, work, retirement and pension (Natcen Social Research, 2018a). ELSA is comprised of a representative sample of individuals ages 50 years and older who reside in private residences in England. Table 1 shows the timeline of the ELSA data collection period. ELSA has had eight data collection periods: Wave 1 (2002 to 2003), Wave 2 (2004 to 2005), Wave 3 (2006 to 2007), Wave 4 (2008 to 2009), Wave 5 (2010 to 2011), Wave 6 (2012 to 2013), Wave 7 (2014 to 2015), and Wave 8 (2016 to 2017), with additional study waves planned for the future (Rogers et al., 2016). ELSA is conducted in collaboration with University College London (UCL), the Institute for Fiscal Studies (IFS), the University of Manchester and the National Centre for Social Research (Natcen Social Research, 2018a; Rogers et al., 2016).
Table 1

*Data collection and study measurement timeline for ELSA study*

<table>
<thead>
<tr>
<th>ELSA study wave</th>
<th>Data collection timeline for the ELSA study</th>
<th>Measurement timepoints for outcomes in thesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave 1</td>
<td>2002-2003</td>
<td></td>
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<tr>
<td>Wave 2</td>
<td>2004-2005</td>
<td></td>
</tr>
<tr>
<td>Wave 3</td>
<td>2006-2007</td>
<td></td>
</tr>
<tr>
<td>Wave 4</td>
<td>2008-2009</td>
<td>Time 1</td>
</tr>
<tr>
<td>Wave 5</td>
<td>2010-2011</td>
<td></td>
</tr>
<tr>
<td>Wave 6</td>
<td>2012-2013</td>
<td></td>
</tr>
<tr>
<td>Wave 7</td>
<td>2014-2015</td>
<td></td>
</tr>
<tr>
<td>Wave 8</td>
<td>2016-2017</td>
<td>Time 2</td>
</tr>
</tbody>
</table>

3.1.2 Recruitment and sampling

The ELSA study population was selected from the sampling frame of households that had responded to the cross-sectional Health Surveys for England Study (HSE) during the 1999, 2000, and/or 2001 cycles, where there was at least one participant aged 50 and older residing in the home and who had agreed to be re-contacted for follow-up (Banks et al., 2006; Natcen Social Research, 2018a). The HSE is an annual national survey conducted by the Office for National Statistics (ONS) on the behalf of England’s Department of Health for the purpose of examining the health and lifestyle of a representative sample of private households in England (NatCen Social Research, 2018). In total the sampling frame included 11,578 households and 18,813 individuals within those households (Natcen Social Research, 2018a).

Refreshment samples were added at Wave 3, 4, 6 and 7 of the study in order to retain the age representation in the sample (Steptoe et al., 2013). The ELSA study aimed to examine a target population age 50 years and older (Natcen Social Research, 2018a). As the study progressed and the members of the sample aged, the youngest eligible age range would no longer be represented in the sample. As a result, new participants were added to the sample in order to ensure that the minimum age of the study participants remained at 50 years. Participants were eligible to be selected for the refreshment sample if they 1) met the specific age criteria needing refreshment for that year, 2) had previously participated in the HSE survey during the 2001, 2002, 2003 or 2004 survey cycles, and 3) had provided permission to be re-contacted for follow-up during their participation in the HSE survey (Natcen Social Research, 2018a; Rogers et al., 2016).
The ELSA core sample members and refreshment sample members were selected into the study using a clustered stratified multi-stage design (English Longitudinal Study of Ageing, 2007). Households were clustered based on English postal districts and then stratified by household address (English Longitudinal Study of Ageing, 2007; Hamer et al., n.d.). The longitudinal sample size, which includes core and refreshment cohorts, was 11,391 at wave 1 of the study, and 7,223 at wave 8 of the study (Natcen Social Research, 2018a).

### 3.1.3 Survey administration

The main ELSA survey is administered by trained surveyors via face-to-face interviews using a computer assisted personal interview (CAPI) tool (Natcen Social Research, 2018b). Surveys are conducted every two years in the household of the survey participant, with proxy interviews available for study participants with physical and/or cognitive disabilities (Natcen Social Research, 2012; Rogers et al., 2016). Survey participants also complete private paper-based survey modules. Private modules include, but are not limited to, topics related to personal life history, health and lifestyle, and sexual relationships and activities. Private modules are conducted outside the presence of other household members in order to reduce bias (Natcen Social Research, 2018a). The ELSA survey also consists of a nurse visit involving biomedical testing which has been conducted on a volunteer basis at Wave 2, 4, 6, and 8 of the study (Rogers et al., 2016). Questions administered through the CAPI tool and private survey modules were tested in a sample of households prior to the widespread administration of the survey (Hardcastle et al., 2015).

### 3.2 Present study

#### 3.2.1 Target population

The target population for the current study were cognitive-disease free adults age 50 years and older, residing in private residences.

#### 3.2.1.1 Inclusion and exclusion criteria

As shown in Figure 1, individuals were included in the study if they 1) were recruited into the sample as a core member at wave 1 (2002 to 2003) or at wave 3 as a refreshment sample member (recruited during 2006 to 2007 at age 50 to 53), and 2) had fully completed the memory function and executive function test modules at Wave 4 (Time 1 for the current
study) and Wave 8. Individuals were excluded from the sample if they 1) answered survey questions with the help of a proxy during the Wave 4 or Wave 8 interview, 2) did not complete a life history interview at Wave 3, 3) did not receive a self-completion survey package at Wave 4, 4) had missing values for the confounder variables, 5) had been diagnosed with Alzheimer’s disease or dementia before the start of the Wave 1 study period, or 6) had been diagnosed with Alzheimer’s disease or dementia during the duration of Wave 1 to Wave 8. After exclusion, and the removal of missing data, the final analytic sample contained 2,871 study subjects.

Figure 1

Flow chart of sample selection into present study

<table>
<thead>
<tr>
<th>Wave 1 Core Member or Wave 3 Core Refreshment Sample Member, at the beginning of the Wave 3 study period (n=8,810)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluded due to (n=5,634):</td>
</tr>
<tr>
<td>• No longitudinal weight due to not participating in at least one wave, over the wave 4 through 8 study period (n=4,660)</td>
</tr>
<tr>
<td>• Proxy responses (n=81)</td>
</tr>
<tr>
<td>• No life-history questionnaire at Wave 3 or self-completed questionnaire at Wave 4 (n=831)</td>
</tr>
<tr>
<td>• Alzheimer’s disease, or dementia, senility or another serious memory diagnosis (n=62)</td>
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<table>
<thead>
<tr>
<th>Wave 4 (Time 1)</th>
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<tbody>
<tr>
<td>Excluded due to missing data (n=285)</td>
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<table>
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<tr>
<th>Wave 8 (Time 2)</th>
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</thead>
<tbody>
<tr>
<td>Excluded due to missing data (n=20)</td>
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</table>

| Complete case sample size (n=2,871) |

3.2.1.2 Measurement timeframe

Table 1 outlines the measurement timepoints for the present study. Participants included in this study were recruited at Wave 1 and Wave 3 of the ELSA study. Time 1 measurements
for the exposure, mediator, and outcome variables were recorded at ELSA Wave 4. Additionally, the outcome variable was again measured at Time 2, ELSA Wave 8.

### 3.3 Study measures

#### 3.3.1 Outcome measures

The outcome of interest, cognitive functioning, was measured using two separate cognitive functioning domains, retrospective episodic memory functioning (also referred to as memory functioning) and executive functioning. Domains measured in the ELSA study were selected based on their 1) relevance to the daily capabilities of older adults, 2) sensitivity to age-related changes, 3) similarity to domains used in other studies in order to allow for comparison between studies, and 4) the avoidance of floor or ceiling effects where test scores cluster around the low and high ends of the cognitive measurement tests (Banks et al., 2006). Cognitive functioning tests were completed individually in private rooms, without the presence of any other household members (Natcen Social Research, 2018a).

**Change in memory functioning.** The outcome 8-year change in memory function represented the change in retrospective episodic memory functioning from Wave 4 to Wave 8. Retrospective episodic memory functioning was measured as a continuous variable and recorded the participant’s ability to retain and recall information that had been attained verbally (Banks et al., 2006). Retrospective episodic memory function was measured consecutively at each study wave using a delayed and immediate word list learning test. The word lists used in the study were originally developed for the Health and Retirement Survey (HRS), used specifically to examine study participant’s working memory and episodic memory functioning (Banks et al., 2006; Luszcz & Lane, 2008). While the use of the word list in the ELSA study does not appear to have been assessed for internal validity or reliability, memory tests using word lists are commonly used by professionals in populations of older adults to assess memory functioning due to their sensitivity to detect declines in memory due to age and to detect early signs of Alzheimer’s disease (Luszcz & Lane, 2008).

Study subjects were presented 10 common words aurally through an audio assistive computer or a tape recorder to ensure that the participant could hear the list clearly (Banks et al., 2006). Survey participants were given a word list selected at random, and each study subject received a different word list at each study wave interview. During the test, study subjects
were asked to immediately verbally recall the words. Study subjects were then asked to recall the words after a short delay. The overall memory function score is comprised of the sum of the total amount of words recalled immediately (memory test 1), and the total amount of words recalled after a short delay (memory test 2). The potential range for the score is a minimum of 0 and a maximum of 20 (Banks et al., 2006). The value for 8-year change in memory functioning was calculated as the difference in the retrospective episodic memory function domain score from Wave 4 (Time 1) to Wave 8 (Time 2). Positive values indicated that the subject had an increase in function over the 8-year time period, while negative values indicated that the subject had a decrease in functioning over the same time period.

**Change in executive functioning.** Change in executive function was measured as a continuous variable and represented an 8-year change in executive function from Wave 4 to Wave 8. Executive functioning at Wave 4 and Wave 8 were measured using a non-validated semantic word verbal fluency test, modelled based on researchers Borkowski et al. (1967)’s widely adapted oral verbal fluency task (Banks et al., 2006; Borkowski et al., 1967). The verbal fluency test was used to record the study participant’s ability to self-initiate activity, organize and abstract thought, as well as their level of cognitive flexibility (Banks et al., 2006). In order to conduct the word fluency test, test administrators presented the survey participant with a specific subject category (i.e., types of animals). Survey participants were then instructed to name as many items as possible within that subject category within a 1-minute time period. Test administrators recorded the number of items that were correctly named within that time period. Executive functioning score was calculated as the number of correct items named within the 1-minute time period. Higher scores indicated higher levels of executive functioning. The value for 8-year change in executive functioning variable was calculated as the difference in the executive function domain score from Wave 4 (Time 1) to Wave 8 (Time 2). Positive values indicated that the subject had an increase in executive function over the 8-year time period, while negative values indicated that the subject had a decrease in functioning over the same period.

### 3.3.2 Exposure variables

**Educational attainment.** Prior to changes to the educational qualification system in 1987, secondary school education qualifications in the United Kingdom were divided into three distinct categories, 1) General Certificate of Education (GCE) Advanced-level, comparable
to having completed 13 years of pre-university education 2) General Certificate of Education (GCE) Ordinary-level, comparable to having completed 11 years of pre-university education, and, 3) Certificate of Secondary Education (CSE), a secondary level certificate equivalent to the CSE Ordinary-level certificate (Tse & Sahasrabudhe, 2016). The educational system also included a National Vocational Qualifications (NVQ) program, a multi-tiered occupational based qualification system which denoted competency for a specific job based on the United Kingdom’s National Operating Standards (NOS). High NVQ level qualifications denoted highly specialized occupational training.

Educational attainment was measured as a categorical variable reflecting the study respondent’s highest educational attainment and was measured at Wave 4. Respondents were instructed to examine a card that listed 30 possible education qualifications, and were asked “do you have any of the qualifications listed on this card?” Potential answers were “Yes” or “No”. Respondents were then asked the question “Which of the qualifications on this card?” and were instructed to list the number associated with the education qualification they had achieved. The 30 potential responses were categorized into 6 categories, “Level 4 or Level 5 NVQ/ higher education degree or equivalent” for individuals who had completed the highest levels of vocation training or a post-secondary degree program, “Higher education below degree” for individuals who had completed a post-secondary program below the level of a degree such as a diploma or certificate program, “Level 3 NVQ/ GCE Advanced-level equivalent”, “Level 2 NVQ/GCE O-level equivalent”, “Level 1 NVQ /CSE other grade equivalent”, “Foreign education or other education”, and “ No qualifications”. ELSA researchers then arbitrarily recoded the variable into a two-category level variable, for individuals who had received 1) Low educational attainment (Below O-level qualifications), representing individuals who had below an ordinary-level secondary school education and 2) High educational attainment (O-level qualifications and above), indicating an individual who had at least completed an ordinary-level secondary school education.

**Biological sex.** A binary variable was used to record the sex variable. Response categories included male or female. The sex variable was derived from two variables, the survey participants answer to the sex question in the individual survey, and the household demographics module. Specifically, if data for the sex variable was missing in the individual
survey module, data from the household demographic module was used as a replacement (English Longitudinal Study of Ageing, 2007).

**Age.** The age variable measured the participant’s age, in years, at the time of interview at Wave 4. The variable was derived using the date of birth, and the date of the interview. Age was grouped into a binary variable, with response categories including 1) 50 to 64 years old, and 2) 65 year and older (Natcen Social Research, 2012). The cut point was selected based on existing evidence suggesting differential rates of decline in cognitive functioning for individuals below 65 years of age, and those 65 years and older (Reas et al., 2017).

**Intersectional groups.** The three binary exposure variables of chronological age, biological sex, and education were cross classified in order to create eight intersectional groups. The intersectional groups included: 1) Males 50 to 64 years old with low educational attainment, 2) Males 65 years and older with low educational attainment, 3) Females 50 to 64 years old with low educational attainment, 4) Females 65 years and older with low educational attainment, 5) Males 50 to 64 years old with high educational attainment, 6) Males 65 years and older with high educational attainment, 7) Females 50 to 64 years old with high educational attainment, and 8) Females 65 years and older with high educational attainment.

### 3.3.3 Mediator variable

**Loneliness.** Loneliness was measured as a continuous variable at Wave 4. The loneliness variable was measured using the 3-item UCLA Loneliness Scale, a shortened version of the 20-item R-UCLA Loneliness Scale (Pikhartova et al., 2016; D. Russell et al., 1980). The 3-item scale is used to assess the survey participants self-perception of their experiences of social isolation, as well as their experiences of relational and social connectedness (Banks et al., 2006). In elderly populations the 3-item UCLA loneliness scale is valid, and highly reliable for internal consistency and 1-year test retest reliability (D. W. Russell, 1996). In order to measure loneliness, participants were asked a series of three questions, “How often do you feel you lack companionship?”, “How often do you feel left out?”, and “How often do you feel isolated from others?” Responses were measured on a 3-point Likert scale, with response options including: 1) Hardly ever or never, 2) Some of the time, or 3) Often. High overall loneliness scores indicate high levels of isolation, and low levels of relational and social connectedness.
3.3.4 Covariates

**Childhood experiences of abuse.** A binary variable was used to record if the participants ever had experienced abuse in the form of physical abuse by a parent before the age of 16, or a physical or sexual assault before the age of 18. During Wave 3 of the ELSA survey in a face-to-face interview, survey participants were asked a series of questions related to difficult life events that occurred over the life course. Participants were categorized as having childhood experiences of abuse if they responded yes to the question “When you were aged under 16, were you physically abused by your parents?” Participants were also categorized as having had childhood experiences of abuse if they responded yes to “Have you ever been a victim of serious physical attack or assault?” or “Have you ever been a victim of sexual assault (including rape or harassment?)” and stated that the event occurred before the age of 18 (Ward et al., 2009).

**Ethnicity.** Ethnicity was measured as a binary variable during Wave 4 of the survey. In reference to their ethnic background, participants were shown a card displaying various ethnic groups and were asked “Which of the groups on this card do you consider that you belong [to]?” Participants were asked to select the one ethnicity group that best described their ethnic background. Response categories included “white”, “mixed ethnic group”, “Black”, “Black British”, “Asian”, “Asian British”, and “any other group”. ELSA researchers then derived a binary variable for broad ethnic origin that categorized participants as being white, or an ethnic minority. The ethnicity variable was used to record whether the participant was 1) white, or 2) ethnic minority.

**Immigration status.** Immigration status was measured at wave 1 through 8 of the ELSA study and was used to record the participant’s place of birth. In the survey, participants were asked the question “In which country were you/ was [name] born?” with response categories including England, Scotland, Wales, Northern Ireland, Republic of Ireland, and Elsewhere outside of UK. A consolidated binary variable which merged responses from wave 1 through 8 was derived to indicate whether the participant was either 1) Born in the UK or 2) Born elsewhere outside of the UK.

**Childhood social status.** Social status during childhood was measured as a categorical variable and was derived using information from wave 1 to 8 of the study. The variable
captured the occupation of the respondent’s main male or female carer at the age of 14 and was used to assess the participant’s socioeconomic position experienced during childhood. Potential response options included the following categories: 1) armed forces, 2) manager or senior official in someone else’s business, 3) running his own business, 4) professional or technical, 5) administrative, clerical or secretarial, 6) skilled trade, 7) caring, leisure, travel or personal services, 8) sales or customer service, 9) plant, process or machine drivers or operators, 10) other jobs, 11) something else, 12) casual jobs, 13) retired, 14) unemployed, 15) sick / disabled, and 16) lived in children’s home. Due to low numbers of responses in certain categories, the occupational categories were collapsed into three categories based on the three-class version of the National Statistics Socio-economic Classification (NS-SEC), a socioeconomic status classification system used officially in the United Kingdom (Connelly et al., 2016). An additional “other” category was added to account for carer’s occupations that did not distinctly fit the NS-SEC three-class categorization. The four categories are as follows: 1) High managerial, administrative, and professional occupations (response categories 1 through 4), 2) Intermediate occupations (response categories 5, 7 and 8), 3) Routine and manual occupations (response categories 6, 9, and 12 through 16), and 4) Other (response categories 10 and 11). Childhood social status was also used as a dummy coded variable, for 1) Intermediate social occupational class vs. otherwise, 2) routine and manual social occupational class vs. otherwise, and 3) Other social occupational class vs. otherwise, with High managerial, administrative, and professional occupations used as the reference group.

3.4 Summary of statistical methods

3.4.1 Temporality

It was assumed that the social position categories biological sex and educational attainment are fixed and occurred before the measurement of the outcome, though for a very small (assumed negligible) number of participants this may not be the case. Also, the binary age category relates to the study subject’s age at the Wave 4 time period. The measure of loneliness records the subjects perceived level of loneliness at Wave 4. Loneliness can be a transient feeling; however, it is possible that the severity of loneliness may have developed at an earlier time point. Current research suggests that self-perceived feelings of loneliness at baseline predict long-term feels of loneliness (Dahlberg et al., 2015). In this study we assume
that the level of loneliness assessed occurred after intersectional group membership was assigned, and as a result we assume temporality for the exposure-mediator association. Similarly, since the outcomes of interest (calculated based on measurements from Wave 4 to Wave 8), occurred after the intersectional groups and overall loneliness score had been determined at Wave 4, it can be assumed that there is a temporality for the exposure-outcome, and mediator-outcome associations.

### 3.4.2 Causal mediation analysis: Three-way decomposition

Three-way decomposition is a causal mediation analysis method that allows the total effect (TE) of the exposure on an outcome to be decomposed into three parts, the natural direct effect (NDE), pure indirect effect (PIE) and the mediated interaction ($\text{INT}_{\text{MED}}$) (VanderWeele, 2013). Bauer and Scheim (2019) state that while other causal mediation analysis methods are available, the three-way decomposition method is best suited for mediation analysis in intersectional research as 1) it allows researchers to clearly examine the way in which disparities among intersectional groups influence the mediator-outcome association, and 2) it allows for researchers to calculate effect measures with the mediator set to an intervenable level, rather than at a level that may not exist or may not be attainable in real-life settings (Bauer & Scheim, 2019). Resultingly, in this study three-way decomposition was used to estimate what proportion of the observed total effect of the relationship between intersectional groups and 8-year change in memory function or executive function, was contributed by loneliness score (Yung et al., 2018). The model also allowed us to examine if there were any differences in the effects of loneliness score on the outcomes of interest, based on intersectional group membership (Bauer & Scheim, 2019).

For a causal model with a continuous outcome, categorical exposure and continuous mediator, for each comparison between an intersection and a reference intersection, three-way decomposition uses two multiple linear regression models to model the association between 1) the exposure and the outcome with mediator and confounders present, and 2) the exposure and the mediator, with confounders present.
Table 2

Notation for the multiple linear regression models used in the three-way decomposition analysis*

<table>
<thead>
<tr>
<th>Notation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>𝑌</td>
<td>Represents a continuous outcome variable</td>
</tr>
<tr>
<td>𝑎</td>
<td>Represents the binary exposure variable created to compare a selected intersectional group to the reference intersectional group</td>
</tr>
<tr>
<td>𝑚</td>
<td>Represents a continuous mediator variable</td>
</tr>
<tr>
<td>𝜃ₙ</td>
<td>Standardized coefficients computed from the model representing the exposure-outcome association, given the presence of the mediator and the confounders</td>
</tr>
<tr>
<td>𝛽ₙ</td>
<td>Standardized coefficients computed from the model representing the exposure-mediator association, given the presence of the confounders</td>
</tr>
<tr>
<td>𝛿 or 𝜖</td>
<td>Observed confounding variables and their coefficients</td>
</tr>
<tr>
<td>𝜃₀</td>
<td>Represents the model intercept, the expected mean value of 𝑌 when the value for the mediator, exposure and confounders are all set to 0</td>
</tr>
</tbody>
</table>

Notation refers to Equation (1) through (4).

Equation (1) shows the multiple linear regression model for the association between the exposure and the outcome, given the presence of the mediator and the confounders (VanderWeele, 2013). Equation (2) shows the multiple linear regression model for the exposure and the mediator, given the presence of the confounders (VanderWeele, 2013).

\[
Y = \theta_0 + \theta_1 a + \theta_2 m + \theta_3 a m + \delta
\]

\[
M = \beta_0 + \beta_1 a + \epsilon
\]

The computed standardized coefficients (β’s and θ’s in Equation (1) and (2)), and the mean levels of the confounding variables are used to calculate the effect measures: PIE, the value of the total effect of the exposure-outcome relationship that is due to mediation only, \(\text{INT}_{\text{MED}}\), the value of the total effect of the exposure-outcome relationship that is due to both mediation and interaction, and NDE, the value of the total effect of the exposure-outcome relationship that is due to the direct relationship between the exposure and outcome (Yung et al., 2018).

3.4.2.1 Counterfactual theory

Three-way decomposition analysis is reliant on the counterfactual approach to causal effect estimation (VanderWeele, 2013). Counterfactual theory is a philosophical theory that states that the true causal effect between two distinct exposure states (for example, the exposed
group $a = 1$ and the unexposed group, $a = 0$) can only be truly observed when disease frequencies can be measured simultaneously in an observed exposure state ($a = 1$) and a counterfactual alternative exposure state ($a = 0$) within the same target population, $P$, over the same etiologic time period, $t$ (Maldonado & Greenland, 2002). Since it is not possible for an individual to concurrently be in two different exposure states over the same time period, a true causal contrast cannot be measured. As an alternative, a similar and substitute population can be used to estimate the disease frequency for unobservable counterfactual target populations (Maldonado & Greenland, 2002). Counterfactual theory states that the association between variables can potentially be biased when there are differences between the unobservable counterfactual population and the selected substitute population (Maldonado & Greenland, 2002). In order to ensure that these differences are properly accounted for, when estimating effect measures, confounding variables need to be properly controlled for (Maldonado & Greenland, 2002; VanderWeele, 2013).

3.4.2.2 Model assumptions

As a result of the use of substitute populations, in order to meet the assumptions of three-way decomposition, a causal model must have 1) no unmeasured confounders for the exposure and outcome relationship, 2) no unmeasured confounders for the mediator and outcome relationship, 3) no unmeasured confounders for the exposure and mediator relationship and 4) have no exposure-induced mediator-outcome confounding (Greenland & Robins, 1992; Pearl, 2001; VanderWeele, 2013). As seen in Figure 2, when an exposure-induced mediator-outcome confounder is present, the exposure is a cause of the confounder, and as a result, the confounder can be found on the exposure-outcome causal pathway (Pearl, 2001; VanderWeele, 2013; Yung et al., 2018). In regard to the fourth assumption, if this assumption were to be met, we could assume that none of the mediator-outcome confounders would be located on the causal pathway between the intersectional group exposure and the cognitive functioning outcomes (LaMorte, 2016; Steen & Vansteelandt, 2018).
3.4.3 Directed acyclic graphs

A Directed Acyclic Graph (DAG) is conceptual model used a-priori assumptions to visualize the causal relationship between exposures, outcomes and their confounders (Glymour, 2006). DAGs graphically display the causal relationships between dependent and independent variables in a hypothesized association, the relationship between covariates, and the relationship between covariates and the dependent and independent variables. Through the a-priori use of DAGs, researchers can observe the various pathways that may lead to bias through confounding (Dawid, 2008). Using the software DAGitty, a DAG was created for the purpose of a-priori examination of the association between the intersectional groups, loneliness and cognitive decline, as well as potential covariates that may bias the proposed associations (see Figure 3) (Textor et al., 2016).

DAGs can be used to investigate whether the hypothesized association upholds or violates statistical model assumptions. Using DAGs, we were able to determine that the exposure-induced mediator-outcome confounding assumption has been violated. As shown in Figure 3, age, one of three variables used to create the intersectional group variable, is a risk factor influencing all mediator-outcome confounders in the hypothetical model. For example, as age increases the risk for chronic illness, stroke, and poor physical functional status increases (Boehme et al., 2017; Jaul & Barron, 2017). In like manner, as age increases, social participation decreases (Bukov et al., 2002).
Figure 3

Directed acyclic graph (DAG) of the association between intersectional grouping and cognitive functioning, mediated by loneliness
DAGs can also be used to identify minimally sufficient adjustment sets, the minimum number of covariates that need to be controlled for in a statistical analysis in order to estimate a causal relationship without the bias of confounding (Foraita et al., 2014). When outlining our causal model, we sought to determine the minimally sufficient adjustment sets for the exposure-mediation and exposure-outcome models in order to find a shared minimally sufficient adjustment set that would work for both models. Furthermore, we also sought to determine a set of exposure-mediation confounders that could be controlled for without blocking the exposure-outcome and exposure-mediation pathways. However, due to the fact that all mediator-outcome confounders in the model were induced by the exposure, it was not possible to control for any mediator-outcome confounders without blocking the exposure-mediation and exposure-outcome pathways. Resultingly, it was not possible to control for the mediator-outcome confounders without blocking an undetermined portion of the causal effect. In the end, we decided to proceed with this analysis using the variables childhood experiences of abuse, childhood social status, immigration status and ethnicity as they shared a minimally sufficient adjustment set for the exposure-mediation-outcome.

3.5 Data considerations

3.5.1 Sample weights

Longitudinal sample weights were used in all descriptive and analytic analyses to account for the unique weighting for the longitudinal sample, and to reduce biases that may have been introduced into the study due to non-response to the survey in specific subgroups of the sample population based on factors such as age and sex (Natcen Social Research, 2018a; Steptoe et al., 2013).

The longitudinal survey sampling weights used in the analysis were calculated based on the core member sample recruited at Wave 1 and 2, and refreshment sample members at Wave 3 and 4. In order to receive a sample weight, a survey respondent had to have participated in the study for 5 consecutive waves, from Wave 4 (Time 1 of the present study) to Wave 8 (Time 2 of this study). Study participants had to have continued to live in a private household over that time period. Overall, the survey weights were calculated
based on the total longitudinal sample of 5,623 core members (Natcen Social Research, 2018a). Sample weights for the complete case population ranged from approximately 0.34 to 4.02.

3.5.2 Sample design variables

In order to account for ELSA’s complex survey design, strata and cluster variables were used in all regression analyses. A cluster variable was used to account for the two-stage clustering design used in the ELSA survey. The cluster variable used in analysis was based on the Wave 8 survey sample (Natcen Social Research, 2018a). In total there were 2,207 unique clusters within the final analytic sample. A stratum variable was used to account for the stratification used in the survey design. The stratum variable used in analysis was also based on the Wave 8 sample (Natcen Social Research, 2018a) There were 11 unique strata within the final analytic sample.

3.5.3 Missing data

Overall, 9.60% of the total sample was missing at least one exposure, outcome, mediator or covariate datum value. As seen in Table 3, the missingness for each individual variable was either null or low.

Per Table 3 the percent missing for the present study was low, ranging between 0.00% and 6.39%. Age, sex, immigration status, and ethnicity had no missing values. This may be due to the fact that they are derived variables using multiple variables, and multiple data collection periods as data sources. Although the values are still relatively low, the loneliness score questions had the highest percentage of missingness, 6.23% for question 1, 6.36% for question 2, and 6.39% for question 3. Missingness for this module may have been slightly higher than other variables used in study as it was collected without supervision using a self-completion questionnaire package.
Table 3

Count and percentage of missing values for the exposure, outcome, mediator and confounder variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Missing Observations (n)</th>
<th>Percent Missingness (%) *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>3</td>
<td>0.09</td>
</tr>
<tr>
<td>Age</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Sex</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Loneliness: Question 1</td>
<td>198</td>
<td>6.23</td>
</tr>
<tr>
<td>Loneliness: Question 2</td>
<td>202</td>
<td>6.36</td>
</tr>
<tr>
<td>Loneliness: Question 3</td>
<td>203</td>
<td>6.39</td>
</tr>
<tr>
<td>Memory Function Score 1 Wave 4</td>
<td>8</td>
<td>0.25</td>
</tr>
<tr>
<td>Memory Function Score 1 Wave 8</td>
<td>3</td>
<td>0.09</td>
</tr>
<tr>
<td>Memory Function Score 2 Wave 4</td>
<td>11</td>
<td>0.35</td>
</tr>
<tr>
<td>Memory Function Score 2 Wave 8</td>
<td>23</td>
<td>0.72</td>
</tr>
<tr>
<td>Executive Function Score Wave 4</td>
<td>10</td>
<td>0.31</td>
</tr>
<tr>
<td>Executive Function Score Wave 8</td>
<td>3</td>
<td>0.09</td>
</tr>
<tr>
<td>Childhood experience of abuse</td>
<td>59</td>
<td>1.86</td>
</tr>
<tr>
<td>Social class at 14</td>
<td>13</td>
<td>0.41</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Immigration status</td>
<td>0</td>
<td>0.10</td>
</tr>
</tbody>
</table>

*Percent missingness was calculated using a denominator value of 3,176. This sample size reflects the sample who had not been excluded for proxy responses, presence of Alzheimer’s disease and Dementia, or non-participation in the survey Wave 3 self-complete questionnaire package.

The datum was analysed using a complete case analysis. All observations with missing values for the key outcome, exposure, mediator and confounder variables were removed using listwise deletion. Listwise deletion was used to handle missing data in this study due to the low rate of missing variables, specifically research suggests that a missingness rates under 10% is not likely to bias statistical inferences (Bennett, 2001). After baseline exclusion, and before sample members with missing values were removed, the sample size was 3,176. After deletion the sample size decreased to 2,871.
3.5.4 Current applications of VanderWeele’s three-way decomposition

VanderWeele’s three-way decomposition has been used in various areas of research, including population health and social science, to examine mediation models (Mazidi et al., 2018; Merchant & Pitiphat, 2015; Ojha et al., 2015). Authors Ojha et al. (2020) used the model to examine vaccine related concerns as a mediator of the association between racial disparities and influenza vaccine uptake. VanderWeele’s three-way decomposition analysis has been applied to intersectional quantitative research. Researchers Bauer & Scheim (2019) conducted an illustrative analysis examining the mediating role of psychological distress on the association between ethno-racial group and sexual or gender minority status and day-to-day discrimination. Bauer and Scheim provided strategies for causal mediation analysis with intersectional groupings, as well as a guide for interpreting the results using an intersectional lens.

VanderWeele’s three-way decomposition analysis can be conducted manually using syntax, or through procedures available through statistical packages such as SAS and Stata. The syntax provided for VanderWeele’s causal mediation analysis for linear outcomes is not designed to handle data that has been collected through complex sampling methods which include weights and cluster or stratum variables, and as a result, they cannot provide measures of variances that account for design effect. The statistical applications available are also not designed to account for complex survey sampling. Specifically in SAS, three-way causal mediation analyses can be conducted using PROC CAUSALMED. While the PROC CAUSALMED procedure allows researchers to used sample weights, it is not possible to specify cluster or stratum variables. The analysis as is cannot accurately approximate design-based measures of variance.

There is one known published example of the application of VanderWeele’s three-way decomposition method to complex survey data. Specifically, researchers Vijayaraghavan et al. (2018) examined data from two longitudinal surveys with a study sample derived from a complex multi-stage probability sample. The researchers briefly describe that they used the results of two logistic regressions to manually compute point estimates, and the bootstrap replication method to calculate measures of variance for each point estimate.
(Vijayaraghavan et al., 2018). Similar research conducted examining mediation effects in complex survey data has also used sandwich variance estimator methods to compute the confidence intervals for their point estimates (Rudolph et al., 2019). There is a need for the identification of the appropriate tools needed to conduct a causal mediation using data from a complex probability sample, as well as a detailed outline of the steps needed specifically for models with linear outcomes and intersectional exposure categories.

3.6 Statistical analysis

All statistical analyses for this study were completed using SAS 9.4.

3.6.1 Objective 1: Descriptive statistics

Weighted mean and standard error measures were calculated for the continuous variables. PROC SURVEYMEANS was used to calculate the mean loneliness score, executive function score and overall memory function score at Time 1 for each of the eight intersectional groups using the sample longitudinal weights. Weighted measures of frequency were computed for the binary and categorical variables. PROC SURVEYFREQ was used to examine the distribution of binary and categorical variables in the sample for the entire sample, and for each of the eight intersectional groupings using longitudinal weights.

3.6.2 Objective 2: Multiple linear regression

PROC SURVEYREG was used to conduct simple linear regressions to examine the association between intersectional group membership and the 8-year change in score for the cognitive functioning domains. PROC SURVEYREG was also used to conduct simple linear regressions to examine the association between the confounder variables and the 8-year change in score for the cognitive functioning domains. PROC SURVEYREG was then used to conduct multiple linear regressions to examine the associations while adjusting for confounders. The intersectional group Males 50 to 64 with low educational attainment was used as the reference group for the multiple linear regression analyses.
3.6.3 Objective 3: Causal mediation analysis

Three-way decomposition procedures were performed using a modified version of VanderWeele’s three-way decomposition statistical code, altered to take factors such as strata and clusters into consideration (VanderWeele, 2014). To conduct the analysis, each intersectional group had to be converted into a subsample in order to directly compare each intersectional group to a reference group. Each subsample was comprised of one intersectional group and the reference group (Bauer & Scheim, 2019). For each subsample, dummy binary variables were created (the number of subsamples required is equal to the number categories in the intersectional group variable minus one), with *Males 50 to 64 years of age with high level education* used as the reference group. Due to the model specifications, categorical confounder variables were also converted into dummy variables.

For each cognitive function domain PROC SURVEYREG was used to model the association between the change in outcome, and the dummy exposure variable denoting intersectional group membership, adjusting for confounders. Equation (3) shows the multiple linear regressions equation that was used in the present study to model the relationship between the exposure and outcome, in the presence of the mediator and confounders.

\[
Y = \theta_0 + \theta_1 a + \theta_2 m + \theta_3 am + \theta_4 c_1 + \theta_5 c_2 + \theta_6 c_3 + \theta_7 c_4 + \theta_8 c_5 + \theta_9 c_6 + \theta_{10} c_7 \quad (3)
\]

PROC SURVEYREG was then used to model the association between the mediator, loneliness score, and the binary intersectional group membership variable, adjusting for confounders. *Error! Reference source not found.* shows the multiple linear regression equation that was used to model the relationship between the exposure and mediator, in the presence of confounders.

\[
M = \beta_0 + \beta_1 a + \beta_2 c_1 + \beta_3 c_2 + \beta_4 c_3 + \beta_5 c_4 + \beta_6 c_5 + \beta_7 c_6 + \beta_8 c_7 \quad (4)
\]

In order to evaluate the point estimates, the level of each confounder needed to be set. Based on the PROC CAUSALMED guidelines for three-way decomposition in SAS, the level of the confounder was to be set to the mean value of the confounder, calculated
separately for each subsample (SAS institute Inc., 2017). Here, the level of the confounder was set to the weighted mean of the intervention group (reference group). The three-way decomposition effect measures NDE, PIE, INT\textsubscript{MED}, and TE were computed using the following equations (see Equations (5) through (9)):

\[
PIE = \left( (\theta_2 \beta_1 + \theta_3 \beta_1 \cdot a^0) \cdot (a^1 - a^0) \right) \tag{5}
\]

\[
INT\textsubscript{MED} = (\theta_3 \beta_1 \cdot (a^1 - a^0) \cdot (a^1 - a^0)) \tag{6}
\]

\[
BCC = \beta_2 c_1 + \beta_3 c_2 + \beta_4 c_3 + \beta_5 c_4 + \beta_6 c_5 + \beta_7 c_6 + \beta_8 c_7 \tag{7}
\]

\[
NDE = ((\theta_1 \cdot (a^1 - a^0)) + (\theta_3 \cdot (a^1 - a^0)) \cdot ((\beta_0 + (\beta_1 a^0)) + BCC)) \tag{8}
\]

\[
TE = PIE + NDE + INT\textsubscript{MED} \tag{9}
\]

Equation (7) for the BCC, the sum of products of the estimated coefficient and the confounders when the confounder is set to the mean value, is a value used to calculate the NDE. Notation for the three-way decomposition equations can be found in Table 4.

**Table 4**

*Notation for the three-way decomposition equations*

<table>
<thead>
<tr>
<th>Notation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c_n)</td>
<td>Represents the confounder variable set to the mean of the subsample</td>
</tr>
<tr>
<td>(a^0)</td>
<td>The value assigned to reference intersectional group</td>
</tr>
<tr>
<td>(a^1)</td>
<td>The value assigned to the comparison intersectional group</td>
</tr>
<tr>
<td>(\theta_n)</td>
<td>Standardized coefficients computed from the model representing the exposure-outcome association, given the presence of the mediator and the confounders</td>
</tr>
<tr>
<td>(\beta_n)</td>
<td>Standardized coefficients computed from the model representing the exposure-mediator association, given the presence of the confounders</td>
</tr>
</tbody>
</table>

Notation refers to Equations (5) through (9)

Balance repeated replication is an analytic method used to estimate measures of uncertainty for an estimate, in such cases where traditional methods used to compute measures of variance are unavailable or would be unreliable due to the violation of theoretical assumptions (Vittinghoff et al., 2011). Balanced repeated replication is a replication weight technique specifically designed to compute measures of variance for
full data samples containing multiple strata. The method requires that each stratum contains exactly two clusters per stratum, however this method can be modified for stratum containing more than two clusters (Lohr, 2019; Lumley, 2008). Balanced replicate samples of the full sample dataset are created through the use of the Hadamard matrix, where one cluster per stratum is excluded and is assigned a weight of zero, and the second remaining cluster is given a replicate weight equal to two times the value of the original full sample adjustment weight (Lumley, 2008). The total number of balanced replicate samples formed for the full sample dataset will be equal to the first multiple of four greater than the number of strata in the total sample (Lewis, 2016). The weighted total sample size for each replicate sample is approximately equal to the total weighted sample size of the full sample (Kolenikov, 2010). Equation (10) shows that the standard error for a point estimate is calculated using the point estimates for the full sample and the point estimates for each of the replicate groups (Lewis, 2016). As shown in (11) the confidence interval for the desired \( \alpha \) value is then calculated using the standard error and the Z value for the confidence level \( \alpha \). Notation for (10) and (11) is displayed in Table 5.

\[
SE_{BRR}(PE) = \sqrt{\frac{1}{R} \sum_{r=1}^{R} (PE_r - PE)^2} \quad \text{where } (r = 1, 2 \ldots R) \quad (10)
\]

\[
\text{Confidence Interval} = PE \pm Z_\frac{\alpha}{2} (SE) \quad (11)
\]

Table 5

<table>
<thead>
<tr>
<th>Notation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>( SE )</td>
<td>Standard error for the point estimate</td>
</tr>
<tr>
<td>( R )</td>
<td>The total number of balanced repeated replicates created from the full sample dataset</td>
</tr>
<tr>
<td>( r )</td>
<td>Replicate group, where ( r = (1, 2 \ldots, R) )</td>
</tr>
<tr>
<td>( PE_r )</td>
<td>The replicate specific point estimate, calculated using the balanced repeated replication weight for the replicate group ( r )</td>
</tr>
<tr>
<td>( PE )</td>
<td>The full sample point estimate, calculated using the original full sample adjustment weight</td>
</tr>
<tr>
<td>( Z_\frac{\alpha}{2} )</td>
<td>The standardized normal distribution for the confidence level ( \alpha )</td>
</tr>
</tbody>
</table>

Notation refers to Equation (10) and (11)
Balanced repeated replications were used in this analysis to estimate the standard error and the confidence intervals around the point estimates TE, NDE, PIE and INT MED. This method was selected to be used because the manual method used to calculate three-way decomposition was not capable of approximating variance estimates. Balanced repeated replications were selected over other popular methods for estimating variances as it was best suited for the survey sampling design used in the ELSA study. Specifically, the naïve finite bootstrapping method is not compatible for use with finite population samples that have been derived through the use of complex sampling designs (SAS institute Inc., 2019). Moreover, when compared to variance estimation methods compatible with complex survey data, studies have shown that balance repeated replication provides more precise variance estimates for cluster stratified multistage samples when compared to bootstrapping replication weights and the jackknife methods (Lewis, 2016; Rao & Shao, 1999). The method is also advantageous as it can be used for a wide range of survey statistics, and can provide variance estimates for more complex point estimates, like the ones used in this analysis (CDC, n.d.; Lewis, 2016).

The data used in this analysis contained more than two clusters per stratum. In order to meet the assumptions of the analysis, the group balanced half samples method was implemented, where for each stratum, clusters were randomly assigned into two pseudo-cluster groups, denoted by the values of 0 and 1 (Mukhopadhyay et al., 2008). Due to small sample size within stratum, the three smallest strata were collapsed into a pseudo-stratum. PROC SURVEYMEANS with the pseudo-strata, pseudo-cluster and weight variables specified was used to create balanced repeated replication weights. Overall, 12 sets of replication weights were created for each subsample. Using PROC SURVEYREG, Equations (5) through (9) were then used to calculate the point estimates PIE, NDE, INT MED and TE. The full sample point estimates were computed using the full sample longitudinal weight variable, and the mean mediator and mean confounder values for the reference group in the total population. The replicate point estimates were then calculated 12 additional times, using each of the 12 BRR replication weights and the mean mediator and mean confounder values specific to each of the BRR replicates. Equation (10) and (11) were used to calculate the standard error and confidence interval around the point estimates.
Chapter 4

4 Results

This chapter describes the sample characteristic results for the total sample and for each of the 8 intersectional groups, the 8-year change in score for cognitive functioning domains executive function and memory function, as well as the results for the simple and multiple linear regressions for the total sample population. This chapter will also present the results for the three-way decomposition for the association between intersectional group membership, loneliness score and each cognitive functioning outcome.

4.1 Objective 1: Sample characteristics

The following section presents the descriptive statistical results for the total analytic sample and by intersectional group membership. The mean values for the outcomes 8-year change in memory functioning, and 8-year change in executive functioning are also presented.

4.1.1 Descriptive statistics for the total analytic sample

Descriptive statistics for the total weighted analytic sample population measured at Wave 4 are reported in Table 6. The total unweighted analytic sample consisted of 2,871 individuals. The weighted sample was representative of 2,787 longitudinal cohort participants age 50 years and older residing in the community setting in England.

More than half of the longitudinal cohort were male (54.1% \(n_{\text{weighted}}=1,508\)), and approximately half of the cohort were in the lowest age bracket, reported to be 50 to 64 years (53.2%, \(n_{\text{weighted}}=1,481\)) at Time 1. The longitudinal cohort largely identified as ethnically white (97.8%, \(n_{\text{weighted}}=2,724\)) and was primarily comprised on non-immigrants with 90.1% of the longitudinal cohort reporting being born in the United Kingdom (\(n_{\text{weighted}}=2,514\)). In terms of educational attainment, 61.3% of the cohort reported that they had attained less than an O-level educational qualification.
At Wave 4, the weighted mean memory function score for the longitudinal cohort was 10.98 (SE=0.07). At Wave 8, the weighted mean memory function score decreased to 10.19 (SE=0.08). Change in executive functioning appeared to follow a similar trend. The weighted mean executive functioning score was 21.61 (SE=0.14) at Wave 4, decreasing to 20.98 (SE=0.15) by Wave 8. Measured on a 9-point scale, the weighted mean for loneliness score at Wave 4 was 4.09 (SE=0.03).
Table 6

*Weighted characteristics for the total analytic longitudinal sample*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total analytic sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory function score (Time 1) (n±SE)</td>
<td>10.98 (±0.07)</td>
</tr>
<tr>
<td>Memory function score (Time 2) (n±SE)</td>
<td>10.19 (±0.08)</td>
</tr>
<tr>
<td>Executive function score (Time 1) (n±SE)</td>
<td>21.61 (±0.14)</td>
</tr>
<tr>
<td>Executive function score (Time 2) (n±SE)</td>
<td>20.98 (±0.15)</td>
</tr>
<tr>
<td>Loneliness score (Time 1) (n±SE)</td>
<td>4.09 (±0.03)</td>
</tr>
<tr>
<td>Age (n (%))</td>
<td></td>
</tr>
<tr>
<td>50 to 64 years old</td>
<td>1481 (53.2%)</td>
</tr>
<tr>
<td>65 years and above</td>
<td>1305 (46.8%)</td>
</tr>
<tr>
<td>Biological sex (n (%))</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1278 (45.9%)</td>
</tr>
<tr>
<td>Male</td>
<td>1508 (54.1%)</td>
</tr>
<tr>
<td>Education attainment (n (%))</td>
<td></td>
</tr>
<tr>
<td>O-level qualification and above</td>
<td>1077 (38.7%)</td>
</tr>
<tr>
<td>Less than O-level qualification</td>
<td>1709 (61.3%)</td>
</tr>
<tr>
<td>Ethnicity (n (%))</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>2724 (97.8%)</td>
</tr>
<tr>
<td>Ethnic minority</td>
<td>62 (2.2%)</td>
</tr>
<tr>
<td>Immigration status (n (%))</td>
<td></td>
</tr>
<tr>
<td>Born in the UK</td>
<td>2514 (90.2%)</td>
</tr>
<tr>
<td>Not born in the UK</td>
<td>272 (9.8%)</td>
</tr>
<tr>
<td>Childhood experiences of abuse (n (%))</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>232 (8.3%)</td>
</tr>
<tr>
<td>No</td>
<td>2554 (91.7%)</td>
</tr>
<tr>
<td>Childhood social status (n (%))</td>
<td></td>
</tr>
<tr>
<td>High managerial, administrative, and professional occupations</td>
<td>809 (29.0%)</td>
</tr>
<tr>
<td>Intermediate occupations</td>
<td>332 (12.0%)</td>
</tr>
<tr>
<td>Routine and manual occupations</td>
<td>1115 (40.0%)</td>
</tr>
<tr>
<td>Other labour occupations</td>
<td>530 (19.0%)</td>
</tr>
</tbody>
</table>

The sample characteristics were calculated based on the weighted analytic sample equal to 2,787 individuals.

4.1.2 Descriptive statistics by intersectional group membership

Based on the intersection of age, biological sex, and educational attainment, 8 distinct intersectional groups were defined in the study sample. 18.4% of the unweighted cohort sample belonged to the intersectional group of *Females 65 years and older with low*
educational attainment, and 16.5% were Females 50 to 64 years of age with low educational attainment. 10.0% of the unweighted sample were Male 65 years and older with high educational attainment, and approximately, 8.7% of the unweighted sample were Females 65 years and older with high educational attainment. The weighted and unweighted frequency and proportions of the total sample by intersectional group membership is presented in Table 7 (See Appendix A for weighted sample descriptive statistic information).

Table 7

Frequency and proportion of intersectional group membership within the total sample

<table>
<thead>
<tr>
<th>Intersectional group membership</th>
<th>Unweighted sample size (n)</th>
<th>Percentage of total unweighted sample (%)</th>
<th>Weighted sample size (nweighted)</th>
<th>Percentage of total weighted sample (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males 50 to 64 years old with low educational attainment</td>
<td>260</td>
<td>9.1</td>
<td>324</td>
<td>11.6</td>
</tr>
<tr>
<td>Males 65 years and older with low educational attainment</td>
<td>291</td>
<td>10.1</td>
<td>337</td>
<td>12.1</td>
</tr>
<tr>
<td>Females 50 to 64 years old with low educational attainment</td>
<td>475</td>
<td>16.5</td>
<td>485</td>
<td>17.4</td>
</tr>
<tr>
<td>Females 65 years and older with low educational attainment</td>
<td>527</td>
<td>18.4</td>
<td>563</td>
<td>20.2</td>
</tr>
<tr>
<td>Males 50 to 64 years old with high educational attainment</td>
<td>421</td>
<td>14.7</td>
<td>387</td>
<td>13.9</td>
</tr>
<tr>
<td>Males 65 years and older with high educational attainment</td>
<td>288</td>
<td>10.0</td>
<td>230</td>
<td>8.3</td>
</tr>
<tr>
<td>Females 50 to 64 years old with high educational attainment</td>
<td>360</td>
<td>12.5</td>
<td>285</td>
<td>10.2</td>
</tr>
<tr>
<td>Females 65 years and older with high educational attainment</td>
<td>249</td>
<td>8.7</td>
<td>176</td>
<td>6.3</td>
</tr>
<tr>
<td>Total population</td>
<td>2871</td>
<td></td>
<td>2787</td>
<td></td>
</tr>
</tbody>
</table>

The mean memory score at Time 1 was the highest for Females 50 to 64 years of age with high educational attainment, with a score of 13.40 (SE=0.16) and the lowest for those categorized as Male age 65 years and older with low educational attainment, with a weighted mean score of 9.25 (SE=0.18). There was a statistically significant difference in the weighted mean memory function score by intersectional group membership (F=70.42, p<0.0001). The weighted mean executive function score at Time 1 was the highest for Females 50 to 64 years old with high educational attainment, with a score of 25.41 (SE=0.39) while Females 65 years and older with low educational attainment were
observed to have the lowest mean executive function score, with a score of 18.60 (SE=0.27). The weighted mean executive function score also significantly differed by intersectional group membership (F=52.03, p<0.0001). *Females 65 years and older with low educational attainment* were observed to have the highest reported level of loneliness, with a mean loneliness score of 4.44 (SE=0.08). The intersection of *Males 65 years and older with high educational attainment* were reported to have the lowest level of loneliness, with a weighted mean score of 3.71 (SE=0.07). Loneliness score differed significantly by intersectional group membership (F=9.65, p<0.0001). The results for the weighted mean memory function score, executive function score and loneliness score by intersectional group membership is presented in Table 8.
Table 8

Memory function score, executive function score, and baseline loneliness score by intersectional group membership

<table>
<thead>
<tr>
<th>Intersectional group membership</th>
<th>Memory function score (Time 1) Mean\text{weighted} (±SE)</th>
<th>F statistic</th>
<th>Baseline executive function score (Time 1) Mean\text{weighted} (±SE)</th>
<th>F statistic</th>
<th>Baseline loneliness score (Time 1) Mean\text{weighted} (±SE)</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males 50 to 64 years old years old with low educational attainment</td>
<td>10.55 0.18</td>
<td>70.42*</td>
<td>22.03 0.44</td>
<td>52.03*</td>
<td>4.18 0.10</td>
<td>9.65*</td>
</tr>
<tr>
<td>Males 65 years and older with low educational attainment</td>
<td>9.25 0.18</td>
<td></td>
<td>19.56 0.40</td>
<td></td>
<td>3.87 0.09</td>
<td></td>
</tr>
<tr>
<td>Females 50 to 64 years old with low educational attainment</td>
<td>11.68 0.14</td>
<td></td>
<td>21.46 0.27</td>
<td></td>
<td>4.16 0.07</td>
<td></td>
</tr>
<tr>
<td>Females 65 years and older with low educational attainment</td>
<td>9.90 0.15</td>
<td></td>
<td>18.60 0.27</td>
<td></td>
<td>4.44 0.08</td>
<td></td>
</tr>
<tr>
<td>Males 50 to 64 years old with high educational attainment</td>
<td>12.00 0.14</td>
<td></td>
<td>24.32 0.33</td>
<td></td>
<td>3.89 0.07</td>
<td></td>
</tr>
<tr>
<td>Males 65 years and older with high educational attainment</td>
<td>10.24 0.18</td>
<td></td>
<td>21.62 0.40</td>
<td></td>
<td>3.71 0.07</td>
<td></td>
</tr>
<tr>
<td>Females 50 to 64 years old with high educational attainment</td>
<td>13.40 0.16</td>
<td></td>
<td>25.41 0.39</td>
<td></td>
<td>4.02 0.07</td>
<td></td>
</tr>
<tr>
<td>Females 65 years and older with high educational attainment</td>
<td>11.49 0.20</td>
<td></td>
<td>22.70 0.42</td>
<td></td>
<td>4.02 0.10</td>
<td></td>
</tr>
</tbody>
</table>
4.1.3 8-year change in cognitive outcomes

4.1.3.1 8-year change in memory function

The weighted mean changes in memory function over the 8-year study period for the intersectional groups all showed a declining trend, with declines in scores ranging from -0.07 to -1.67 points over the 8-year period. The weighted mean values for change in memory functioning by intersectional group are reported in Table 9. The mean decline in memory function was largest for *Females age 65 years and older with low educational attainment*. The group had an average decrease in memory score equal to 1.67 points (SE=0.16) over the 8-year period. *Females age 50 to 64 years old with high educational attainment* saw a mean decrease in memory function of -0.19 (SE=0.17) points. *Males 50 to 64 years old with low educational attainment* had the lowest weighted mean decline, on average, with a decrease of 0.07 (SE=0.21) points from baseline to follow-up. The difference in the change in memory function among the intersectional groups was statistically significant (F=13.49, p<0.0001).

4.1.3.2 8-year change in executive function

The weighted mean change in executive function score was largest for *Females 65 years and older with high educational attainment* intersectional group, with a decline of 1.74 (SE=0.47) points over the 8-year period (See Table 9). *Males 65 years and older with low educational attainment* were observed to have a weighted mean decline in score of 1.40 (SE=0.45) point from baseline to follow-up. The intersectional group of *Males 50 to 64 years of age with low educational attainment* saw an improvement in executive functioning over time, on average, with an 0.08 (SE=0.45) point increase in score over the 8-year period. The difference in the change for executive function score among the intersectional groups was statistically significant (F=5.25, p<0.0001).
Table 9

Change for executive function and memory function from Wave 4 through 8, by intersectional group

<table>
<thead>
<tr>
<th>Intersectional group membership</th>
<th>Mean 8-year change in memory function Mean weighted (±SE)</th>
<th>F statistic</th>
<th>Mean 8-year change for executive function Mean weighted (±SE)</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males 50 to 64 years old with low educational attainment</td>
<td>-0.07 0.21</td>
<td>13.49*</td>
<td>0.08 0.45</td>
<td>5.25*</td>
</tr>
<tr>
<td>Males 65 years and older with low educational attainment</td>
<td>-1.42 0.21</td>
<td></td>
<td>-1.40 0.45</td>
<td></td>
</tr>
<tr>
<td>Females 50 to 64 years old with low educational attainment</td>
<td>-0.46 0.15</td>
<td></td>
<td>-0.46 0.29</td>
<td></td>
</tr>
<tr>
<td>Females 65 years and older with low educational attainment</td>
<td>-1.67 0.16</td>
<td></td>
<td>-1.27 0.34</td>
<td></td>
</tr>
<tr>
<td>Males 50 to 64 years old with high educational attainment</td>
<td>-0.27 0.17</td>
<td></td>
<td>-0.15 0.31</td>
<td></td>
</tr>
<tr>
<td>Males 65 years and older with high educational attainment</td>
<td>-1.06 0.20</td>
<td></td>
<td>-1.32 0.43</td>
<td></td>
</tr>
<tr>
<td>Females 50 to 64 years old with high educational attainment</td>
<td>-0.19 0.17</td>
<td></td>
<td>-0.59 0.39</td>
<td></td>
</tr>
<tr>
<td>Females 65 years and older with high educational attainment</td>
<td>-0.92 0.26</td>
<td></td>
<td>-1.74 0.47</td>
<td></td>
</tr>
</tbody>
</table>

F values were calculated using one-way ANOVA
* denotes F values that were found to be statistically significant with p value < 0.0001

4.2 Objective 2: Regression analysis

4.2.1 8-year change in memory function

4.2.1.1 Bivariate analysis

The results of the simple linear regression analyses between the dependent variable, 8-year change in memory function, and intersectional group membership and covariates are reported in Table 10. The intersectional group Males 50 to 64 years with low educational attainment was selected as the reference group as they had the lowest mean 8-year change in memory function among all intersectional groups.
Intersectional group membership was significantly associated with the 8-year change in memory functioning (F=10.77, p<0.0001). The intersectional categories *Males 65 years and older with low educational attainment*, *Females 65 years and older with low educational attainment*, *Males 65 years and older with high educational attainment*, and *Females 65 years and older with high educational attainment* were significantly associated with 8-year change in memory functioning, when compared to the reference group *Males 50 to 64 years with low educational attainment*.

Over the 8-year period, *Males 65 years and older with high educational attainment* on average had a 1.35-point greater decrease in memory score when compared to *Males 50 to 64 years with low educational attainment*. (b=-1.35, p<0.0001) For *Females 65 years and older with low educational attainment*, decline in memory score was on average 1.59 point greater when compared to the reference group (b=-1.59, p<0.0001). Moreover, decline in memory score was 0.98 points larger for *Males 65 years and older with high educational attainment* (b=-0.98, p=0.0009), and 0.84 points larger for those categorized as *Female 65 years and older and high educational attainment* (b=-0.84, p=0.0123), when compared to the reference group.

There were no significant bivariate associations between childhood experiences of abuse (p=0.2424), childhood social status (p=0.6200), ethnicity (p=0.9844), or immigration status (p=0.2839), and 8-year change in memory functioning score.

### 4.2.1.2 Multiple linear regression

In order to examine the association between intersectional group membership and the decline in memory functioning over the 8-year period, multiple linear regression analysis was conducted, controlling for the covariate’s childhood social status, childhood experiences of abuse, ethnicity, and immigration status. Results for the analysis are reported in Table 10. The overall model was significant (F=6.09, P<0.0001). Similar to the bivariate analyses, after adjusting for confounders there were no observed associations between childhood experiences of abuse (p=0.7945), childhood social status (p=0.8565), immigration status (p=0.0903) or ethnicity (p=0.6704), and the decline in memory functioning over time.
After adjusting for covariates, the overall model effect for the association between intersectional group membership and the decline for memory functioning was significant (F=10.78, p<0.0001). Similar to the bivariate analysis, when compared to the reference group of Males 50 to 64 years with low educational attainment, there were significant associations between the intersectional group and decline in memory functioning for the intersectional categories of Males 65 years and older with low educational attainment, Females 65 years and older with low educational attainment, Males 65 years and older with high educational attainment, and Females 65 years and older with high educational attainment when compared to the reference category.

Controlling for covariates did not appear to have an impact on the values of the estimate, as the estimates remained relatively unchanged. After adjustment, the results show that Males 65 years and older with low educational attainment on average had a 1.33-point larger decrease in memory score in comparison to Males 50 to 64 years old with low educational attainment (b=-1.33, p<0.0001). After controlling for confounders, on average, Females age 65 years and older with low educational attainment had a 1.60 greater decline in memory score (b=-1.60, p<0.0001) in comparison to the reference, while Males age 65 years and older with high educational attainment had a 0.99 larger decline in memory score (b=-0.99, p=0.0009) in comparison to the reference. Lastly, after adjustment Females 65 years and older with high educational attainment on average had a significantly greater decrease in score over the 8-year period in comparison to Males 50 to 64 years old with low educational attainment (-0.84, p=0.0128).
Table 10

Bivariate and multivariate comparisons between independent variables and change in memory functioning over time

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bivariate Association</th>
<th>Multivariate association</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>Standard error</td>
</tr>
<tr>
<td>Intersectional group membership</td>
<td>10.77</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Males 50 to 64 years old with low educational attainment</td>
<td>Reference group</td>
<td></td>
</tr>
<tr>
<td>Males 65 years and older with low educational attainment</td>
<td>-1.35</td>
<td>0.30</td>
</tr>
<tr>
<td>Females 50 to 64 years old with low educational attainment</td>
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<td>0.26</td>
</tr>
<tr>
<td>Females 65 years and older with low educational attainment</td>
<td>-1.59</td>
<td>0.27</td>
</tr>
<tr>
<td>Males 50 to 64 years old with high educational attainment</td>
<td>-0.20</td>
<td>0.27</td>
</tr>
<tr>
<td>Males 65 years and older with high educational attainment</td>
<td>-0.98</td>
<td>0.30</td>
</tr>
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<td>Females 50 to 64 years old with high educational attainment</td>
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<td>0.27</td>
</tr>
<tr>
<td>Females 65 years and older with high educational attainment</td>
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<td>0.34</td>
</tr>
<tr>
<td>Childhood experiences of abuse</td>
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<td>0.2424</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
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</tr>
<tr>
<td>----------------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Ethnicty</td>
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<tr>
<td>Ethnic minority</td>
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<tr>
<td>White</td>
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<td></td>
</tr>
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<td>Immigration status</td>
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<td>0.23</td>
</tr>
<tr>
<td>Born in the U.K.</td>
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<td></td>
</tr>
<tr>
<td>Childhood social status</td>
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<td></td>
</tr>
<tr>
<td>High managerial, administrative, and professional occupations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate occupation</td>
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</tr>
<tr>
<td>Manual occupations</td>
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<td>0.16</td>
</tr>
<tr>
<td>Other occupations</td>
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<td>0.20</td>
</tr>
<tr>
<td>Intercept</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Model effect F=6.09, p<.0001
4.2.2 8-year change in executive functioning

4.2.2.1 Bivariate analysis

Simple linear regressions were conducted in order to examine the associations between the exposure and confounder variables with the outcome 8-year change in executive functioning. The intersectional group *Males 50 to 64 years with low educational attainment* was selected as the reference group as they had the lowest mean 8-year change in executive functioning among all intersectional groups. The results of the bivariate analyses are reported in Table 11. There were no statistically significant bivariate associations between childhood experiences of abuse (p=0.5831), ethnicity (p=0.8734) or immigration status (p=0.2106) and 8-year change in executive functioning in the simple linear regression analyses.

Intersectional group membership was significantly associated with executive function change (F=4.55, p<0.0001). When compared to the reference group *Males 50 to 64 years old with low educational attainment*, *Males 65 years and older with low educational attainment* had a 1.48 greater decrease in executive functioning score over the 8-year period (b=−1.48, p<0.0192). The association between *Females 65 years and older with low educational attainment* and 8-year change in executive functioning was also significant. *Females 65 years and older with low educational attainment* had a 1.35 greater decrease in executive functioning when compared to the reference group (b=−1.35, p=0.0163). *Males 65 years and older with high educational attainment* had a 1.40 significantly larger decrease in executive functioning (b=−1.40, p<0.0236), while *Females 65 years and older with high educational attainment* were observed to on average have a 1.82 significantly larger decrease in functioning when compared to the reference group (b=−1.82, p=0.0050).

Childhood social status was associated with the 8-year change in executive functioning (F=3.52, p=0.0153). Those who were in the intermediate occupational social class during childhood on average had a 0.99 greater decrease in score over the 8-year period in comparison to those who were in the high managerial, administrative, and professional occupational social class (b=−0.99, p=0.0249). Moreover, in comparison to the reference
category, those who were in the routine or manual occupational class during childhood on average had a 1.07 larger decrease in executive functioning score from baseline to follow up (b=-1.07, p=0.0019). The association between other social occupation class during childhood and change in executive functioning score was not significant when compared to the reference group (b=-0.66, p=0.1130).

4.2.2.2 Multiple linear regression

After controlling for childhood experiences of abuse, ethnicity, immigration status, and childhood social status, the overall model effect for the association between intersectional group membership and change in executive function was significant (F=4.91, p<0.0001). After adjustment, there were no observed associations between childhood experiences of abuse (p=0.9164), ethnicity (p=0.6771) or immigration status (p=0.2896) with the 8-year change in executive functioning.

Similar to the bivariate analysis, the association between intersectional membership and 8-year change in executive functioning was significant for **Males 65 years and older with low educational attainment** (b=-1.47, p=0.0190), and **Males 65 years and older with high educational attainment** (b=-1.57, p=0.0117) in comparison to the reference group after adjustment for confounders. **Females 65 years and older with low educational attainment** had 1.40 greater decrease in 8-year executive functioning when compared to **Males 50 to 64 years old with low educational attainment** (b=-1.40, p=0.0126). Moreover, after adjustment **Females 65 years and older high educational attainment** on average had a 2.08 significantly greater decline in executive functioning when compared to the reference group (b=-2.08, p=0.0013). Complete results for the adjusted analysis can be found in Table 11.

After adjustment there was also a significant association between childhood social status and 8-year change in executive functioning score (F=3.88, p=0.0088). In comparison to the reference category, high managerial, administrative, and professional occupational social class, those who were in the routine or manual occupational class during childhood on average had a 1.14 statistically significantly larger decrease in memory score from baseline to follow up (b=-1.14, p=0.0010). After adjustment, individuals who were in the
intermediate social occupational class were observed to have a 0.99 greater decrease in score over the follow up period in comparison to the reference category (b=-0.99, p=0.0243) Like in the bivariate analysis, there was no significant association between the other social occupation categorization and the outcome (b=-0.71, p=0.0900).
### Table 11

**Bivariate and Multivariate regressions examining the association between the decline in executive function, independent variables and covariates**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bivariate Association</th>
<th>Multivariate association</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate (b)</td>
<td>Standard error</td>
</tr>
<tr>
<td>Intersectional group membership</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males 50 to 64 years old with low educational attainment</td>
<td>Reference group</td>
<td></td>
</tr>
<tr>
<td>Males 65 years and older with low educational attainment</td>
<td>-1.48</td>
<td>0.63</td>
</tr>
<tr>
<td>Females 50 to 64 years old with low educational attainment</td>
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<td>0.53</td>
</tr>
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<td>0.56</td>
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</tr>
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</tr>
<tr>
<td>Females 65 years and older with high educational attainment</td>
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</tr>
<tr>
<td>Childhood experience of abuse</td>
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<td>0.5831</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------</td>
<td>--------</td>
</tr>
<tr>
<td>Experienced abuse</td>
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<td>0.54</td>
</tr>
<tr>
<td>No history of abuse</td>
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<tr>
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<td>Reference group</td>
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</tr>
<tr>
<td>Childhood social status</td>
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<td>0.0153</td>
</tr>
<tr>
<td>High managerial, administrative, and professional occupations</td>
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<td>Intermediate occupation</td>
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<td>Routine or manual occupations</td>
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<td>Other occupations</td>
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</tr>
<tr>
<td>Intercept</td>
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<td>0.52</td>
</tr>
</tbody>
</table>

Model effect $F=4.91, p<.0001$
4.3 Objective 3: three-way decomposition analysis

For objective 3, we used three-way decomposition of the total effect to examine the relationship between intersectional group membership and change in executive function over time, further looking at the influence of the mediator loneliness score on the relationship. A loneliness score of 3.71, associated with the mean loneliness score for the reference group of *Males 50 to 64 years with high education attainment* was used as the target mediator level in the three-way decomposition analyses. This reference group was selected as it represented the lowest recorded mean level of loneliness amongst the eight intersectional groups, therefore the most advantageous level of loneliness amongst the groups.

The set level of the confounders for the estimation of the point estimates were equal to the weighted mean level of each covariate for the reference group. In this case the mean value for the binary variables were used. Resultingly, for all of the comparisons, the mean values of the confounders were set to a level that represented 0.10 for childhood experiences of abuse, 0.04 for ethnicity, 0.12 for immigration status, 0.14 for intermediate social occupational class, 0.38 for routine and manual social occupational class and 0.14 for other social occupational class. The following section summarizes the results for the three-way decomposition analysis regressions, and the decomposition of the total effects for each comparison group.

4.3.1 Association between intersectional group membership and loneliness score

The association between intersectional group membership and loneliness score was examined for each of the seven comparisons and was then later used to derive the three-way decomposition estimates for the memory functioning outcome and executive functioning outcome. After adjustment for confounders, the results indicate no significant associations between intersectional group membership and loneliness score for any of the separate comparisons with the reference group.
4.3.2 Decomposition of the total effect of intersectional group membership and decline for memory function over time, with loneliness score as a mediator

Table 12 highlights the point estimates for the TE, NDE, PIE, and INTMED for each of the 7 comparison groups for the outcomes 8-year change in memory function and 8-year change in executive functioning. With loneliness score used as the mediator set to the score of 3.71, there were observed significant total effects for the association between intersectional group and decline in memory functioning for four intersectional group comparisons. The total effect for the overall association between the intersectional group and 8-year change in memory function was significant for the separate comparisons between Males 65 years and older with low educational attainment (TE=1.15 (-1.93, -0.37)), Females 65 years and older with low educational attainment (TE=1.35 (-1.76, -0.95)), Males 65 years and older with high education (TE=0.78 (-1.12, -0.43)), Females 65 years and older with high educational attainment (TE=0.65 (-1.29, -0.01)) and the reference intersection, Males 50 to 64 years old with high educational attainment.

The NDE, the portion of the total effect of the association caused by intersectional group membership alone was significant for the separate comparisons between Males 65 years and older with low educational attainment (NDE=1.15 (-1.94, -0.36)), Females 65 years and older with low educational attainment (NDE=1.32 (-1.77, -0.88)), Males 65 years and older with high education (NDE=0.80 (-1.15, -0.46)), and the reference intersection, Males 50 to 64 years old with high educational attainment.

The PIE, the portion of the total association attributed to the mediator, was also significant only for the comparison between Females 65 years and over with low educational attainment and the reference group (PIE=0.14 (0.03, 0.24)). 0.14 of the association could be attributed to the presence of the loneliness mediator.

The INTMED, the value attributed to the interaction between loneliness score and intersectional group membership was not significant for any of the intersectional group comparisons.
Table 12

*Three-way decomposition point estimates for decline in memory function and decline in executive function*

<table>
<thead>
<tr>
<th>Comparisons</th>
<th>Decline in Memory function</th>
<th></th>
<th></th>
<th>Decline in executive functioning</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural direct effect (NDE)</td>
<td>Mediated Interaction (INT\textsubscript{MED})</td>
<td>Pure Indirect Effect (PIE)</td>
<td>Total Effect (TE)</td>
<td>Natural direct effect (NDE)</td>
<td>Mediated Interaction (INT\textsubscript{MED})</td>
<td>Pure Indirect Effect (PIE)</td>
<td>Total Effect (TE)</td>
</tr>
<tr>
<td>Males 50 to 64 years old with low educational attainment</td>
<td>0.23</td>
<td>-0.10</td>
<td>0.07</td>
<td>0.20</td>
<td>0.11</td>
<td>0.24</td>
<td>-0.05</td>
<td>0.30</td>
</tr>
<tr>
<td>Males 65 years and older with low educational attainment</td>
<td>-1.15</td>
<td>0.00</td>
<td>-0.00</td>
<td>-1.15</td>
<td>-1.22</td>
<td>-0.00</td>
<td>0.00</td>
<td>-1.22</td>
</tr>
<tr>
<td>Females 50 to 64 years old with low educational attainment</td>
<td>-0.15</td>
<td>-0.07</td>
<td>0.07</td>
<td>-0.14</td>
<td>0.76</td>
<td>-0.00</td>
<td>-0.05</td>
<td>0.71</td>
</tr>
<tr>
<td>Dataset Description</td>
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<td>Lower CI</td>
<td>Upper CI</td>
<td>Estimate</td>
<td>Lower CI</td>
<td>Upper CI</td>
<td>Estimate</td>
<td>Lower CI</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>----------</td>
<td>----------</td>
<td>------------</td>
<td>----------</td>
<td>----------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>Females 65 years and older with low educational attainment</td>
<td>-1.32</td>
<td>(-1.77, 0.88)</td>
<td></td>
<td>-0.17</td>
<td>(-0.36, 0.03)</td>
<td></td>
<td>0.14</td>
<td>(0.03, 0.24)</td>
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<tr>
<td>Males 65 years and older with high educational attainment</td>
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<td>(-1.15, 0.46)</td>
<td></td>
<td>0.07</td>
<td>(-0.00, 0.13)</td>
<td></td>
<td>-0.04</td>
<td>(-0.09, 0.01)</td>
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<tr>
<td>Females 50 to 64 years old with high educational attainment</td>
<td>0.14</td>
<td>(-0.35, 0.63)</td>
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<td>(-0.18, 0.07)</td>
<td></td>
<td>0.03</td>
<td>(-0.03, 0.09)</td>
</tr>
<tr>
<td>Females 65 years and older with high educational attainment</td>
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<td>(-1.26, 0.02)</td>
<td></td>
<td>-0.07</td>
<td>(-0.16, 0.01)</td>
<td></td>
<td>0.04</td>
<td>(-0.03, 0.11)</td>
</tr>
</tbody>
</table>

Point estimates were calculated using the intersectional group *Males 50 to 64 years old with high educational attainment* as the reference group. The mediator was set to a loneliness score of 3.71, the mean score for the reference group. Precision estimates were calculated using balance repeated replications.
4.3.3 Decomposition of the total effect of intersectional group membership and the decline for executive function over time, with loneliness score as a mediator

The results for the three-way decomposition examining the relationship between intersectional group membership, loneliness score, and decline in executive functioning score over time are reported in Table 12. Based on the results of the subsequent regression analyses, the total effect for the overall intersectional group and 8-year change for executive functioning association was significant for the separate comparisons between the reference group and *Males 65 years and older with low educational attainment* (TE=-1.22 (-2.22, -0.22)), *Females 50 to 64 years old with low educational attainment* (TE=0.71 (0.08, 1.33)), *Males 65 years and older with high educational attainment* (TE=-1.16 (-1.77, -0.55)) and *Females 65 years and older with high educational attainment* (TE=-1.67 (-2.57, -0.76)).

Similarly, the portion of the total effect caused by intersectional group membership alone was significant for the separate comparisons between *Males 65 years and older with low educational attainment* (NDE=-1.22 (-2.21, -0.22)), *Females 50 to 64 years old with low educational attainment* (NDE=0.76 (0.13, 1.39)), *Males 65 years and older with high educational attainment* (NDE=-1.15 (-1.75, -0.55)), *Females 65 years and older with high educational attainment* (NDE=-1.57 (-2.55, -0.60)) and the reference intersectional group.

No values for the PIE or INT_{MED} in the three-way decomposition were determined to be significant for any of the intersectional group comparisons.
Chapter 5

5 Discussion

Using the intersectional framework, this chapter will discuss the key findings of the descriptive and analytic statistical data analyses, and their implications on health research. This chapter will also discuss the strengths and limitations of the study, as well as directions for future research.

5.1 Summation of study findings

5.1.1 Descriptive characteristics of older adults in England

We first sought to examine the characteristics of adults age 50 years and older residing in England. Using data from Wave 4 and Wave 8 of the ELSA study we examined sample characteristic for the overall longitudinal cohort and by intersectional group membership.

When the total longitudinal sample was examined based on intersectional group membership, there was observed heterogeneity in cognitive functioning scores at Time 1. For memory functioning and executive functioning there were statistically significant differences in scores among the intersectional groups. *Females 50 to 64 years old with high educational attainment* scored highest in Time 1 cognitive scores for both domains. Meanwhile *Females 65 years and older with low educational attainment* were observed to have the lowest baseline score for executive functioning and the second lowest score for baseline memory functioning.

Given that this thesis is the first known study of its kind observing intersections of sex, education and age and their relation to cognitive functioning, we are not able to directly compare the findings to those of previous research conducted in this field. If we were to compare our findings to non-intersectional research conducted on the singular axes, we might expect that individuals at the intersection of female sex, high educational attainment and middle age would have a perceived advantage for baseline cognitive functioning when compared to women at the intersection of female sex, low educational attainment, and old age. Female sex, young age and above high school level educational attainment have all individually been observed to be positively associated with baseline
general cognition scores (Karlamangla et al., 2009; Reas et al., 2017). From an intersectional approach, we could theorize that women at the intersection of high education and middle age may experience multiple buffers that work together to maintain a higher level of cognitive functioning at baseline.

When examining sample characteristics for the total population, the longitudinal cohort appeared to have low levels of perceived loneliness (mean_{weighted}=4.04). When loneliness was examined in the sample by intersectional group membership, there was an observed statistically significant difference in scores amongst the eight intersectional groups. These findings suggest that there may be heterogeneity in the level of loneliness for individuals at different social locations. While there is a lack of consensus on the presence of gender differences in perceived loneliness in adult populations, previous research examining educational differences and age differences in loneliness on singular axes suggested that individuals with high educational attainment and those categorized in the lowest age group would have lower levels of loneliness (Alma et al., 2011; Drennan et al., 2008). Based on this one could theorise that males or females age 50 to 64 with high educational attainment would have the most advantageous loneliness scores. However, here when examining the longitudinal cohort using an intersectional approach the findings suggest that loneliness was the lowest for individuals at the intersection of Males age 65 and older with high educational attainment. It is important to note that while the differences in loneliness were statistically different for the intersectional groups, the differences in score would not be considered meaningful. The mean weighted loneliness scores for all intersectional groups would be considered low based on pre-established cut-off points that consider a score of 6 through 9 to be a high level of loneliness (Hughes et al., 2004).

5.1.2 Association between intersectional group membership and cognitive functioning

The research study also sought to examine the association between intersectional group membership based on education, age, and sex, and 8-year change in cognitive function for memory function and executive function domains. For the purpose of the regression analyses, the intersectional group of Males 50 to 64 years old with low educational attainment was used as a reference comparison group.
We observed associations between intersectional groups and both cognitive functioning outcomes. We found a significant association between intersectional group membership and 8-year change in memory functioning, with declines in memory functioning over time observed to be the largest for *Females 65 years and older with low educational attainment* and *Males 65 years and older with low educational attainment*. There was also a significant association between intersectional group membership and 8-year change in executive functioning. Specifically, the intersections of *Males 65 years and older with low educational attainment*, *Females 65 years and older with low educational attainment*, *Males 65 years and older with high educational attainment*, and *Females 65 years and older with high educational attainment* were shown to have significantly larger decreases in executive functioning over time when compared to the reference group. If examined on singular axes with non-intersectional assumptions, it would be expected that older adult men with low educational attainment would have been the group that would have experienced the largest decline in executive function in comparison to the reference group. Here the decline in executive function was the largest for individuals at the intersection of *Females 65 years and older with high educational attainment*, who after adjustment for confounders were observed to have a greater than 2-point reduction in executive function score over the 8-year study period. This decline was 0.5 points larger than the group that saw the second largest decline, *Males 65 years and older with high educational attainment*. Based on our findings being at the intersection of female sex, high educational attainment and old age might potentially accelerate the impact of decline in executive function. Our findings are different than what would have been expected if an additive non-intersectional approach would have been utilized. When the assumption of additivity is used the social positions are assumed to act independently of each other (Bowleg, 2008). The additive approach is reliant on the assumption that belonging to the greatest number of disadvantaged social groups results in the most disadvantaged outcomes (Bowleg, 2008; Purdie-Vaughns & Eibach, 2008). As our findings show, that assumption is not always correct. Using an intersectional approach in quantitative research allows us to observe the unique ways in which multiple interlocking social positions, as well as their processes, work together to impact health outcomes. The
intersectional approach allows us to highlight heterogeneity that would have been otherwise hidden through additive assumptions.

When comparing the difference in change in executive function between the two groups that saw the largest decline, it could be argued that gendered-socioeconomic inequity in old age may influence the differences that we observed. While older men and women are less likely to be participating in the labour force at 65 years and older, men may have larger state pensions, and as a result, larger economic resources post retirement due to their access to higher paying jobs in their working years. A recent report found that the average pension wealth for men and women differed significantly. It is estimated that men receive 18 percent more in pension yearly that women in the United Kingdom (Pensions Policy Institute, 2019). It is also estimated that for England in 2019 the average pension wealth for individuals 60 to 64 years of age was £51,100 for women. The value is more than three times higher for men, estimated at £156,500 (Foster & Heneghan, 2018). This is driven particularly by gender differences in the accumulation of state pension caused by historically large gendered pay gaps, and the disadvantage of lower paying gendered work for women (Foster & Heneghan, 2018). Women also may have experienced the financial repercussions of time away from the workforce due to familial obligations. Maternity leave legislations and employment protection was introduced in England in 1975 (Anitha & Pearson, 2013). However due to stringent employment requirements, for the first 15 years after the introduction of the legislations only approximately half of the women participating in the labour force met the qualifications required to access the benefits (Anitha & Pearson, 2013). Resultingly, older educated women exiting the workforce may potentially see a larger decline in socioeconomic resources when compared to older educated men. This reduced access to economic resources may impact older women’s ability to participate in their typical health seeking behaviours, or to participate in lifestyle and behavioural activities that stimulate the late life maintenance of cognitive health. Senior women are also more likely to report a higher severity of physical disability in comparison to men (Naumann Murtagh & Hubert, 2004). The presence of physical disability in old age may further hinder their ability to participate in cognitive stimulating activities such as exercise and leisure activities.
5.1.2.1 Childhood experience of abuse

In the separate bivariate and adjusted models, Childhood experience of abuse was not observed to have an association with the outcomes of 8-year change in memory function or 8-year change in executive functioning. There is a lack of evidence supporting a direct association between childhood experiences of abuse and executive functioning or memory functioning change over time in the longitudinal cohort sample population. These findings conflict with the growing body of evidence suggesting that experiences of childhood violence are correlated with poor cognitive outcomes due to high levels of stress that impair brain development during key growth periods (Bishop et al., 2010). For example, a 2013 cohort study examining individuals who had experiences of abuse in the first decade of life found that experiences of childhood violence predicted poor executive functioning in middle adulthood (Nikulina & Widom, 2013). Research has suggested that individuals who exhibit poor cognitive outcomes in mid-life are at a higher risk for accelerated cognitive decline in old age (Hughes et al., 2018).

5.1.2.2 Ethnicity

In the separate bivariate and adjusted models, ethnicity was not observed to have an association with the outcomes of 8-year change in memory function or 8-year change in executive functioning score. The findings differ from current research that has observed larger decreases in cognitive functioning for racialized older adults (Karlamangla et al., 2009; Levine et al., 2018). Previous research suggesting racial differences in cognitive functioning were conducted in older adult populations residing in the United States and have highlighted that educational differences were potential drivers of the association. Factors such as regional differences in level of access to education by ethnic group may influence the external validity of previous research conducted in the United States and may impact its applicability to ethnic populations in the United Kingdom. Similarly, due to the small number of minority individuals available in the study sample it is possible that the effect measures in the model for ethnicity were underestimated.
5.1.2.3 Immigration status

Similar to the ethnicity variable, no differences were observed in the bivariate or adjusted model for change in memory function or change in executive function outcomes over time. There is limited to no previous research involving the direct association between immigration status and change in cognitive functioning over time in older adult populations, and as a result we did not have specific expectations for an association between immigration status and the outcomes of interest. However, the lack of observed association could also be a result of imprecise estimates due to small cell sizes, specifically for those in the sample born outside of the United Kingdom. As a result, estimates for this group may have been imprecise for both cognitive functioning outcomes.

5.1.2.4 Childhood social status

In the bivariate and adjusted model, childhood social status was significantly associated with 8-year change in executive functioning but was not significantly associated with change in memory functioning. Childhood social status has generally been observed to predict health in older adulthood. High levels of stress during childhood have been hypothesized to negatively impact brain development. Moreover, disparities in access to early childhood resources due to lack of income could negatively impact a child’s ability to develop self-regulation and reasoning skills, as well as their access to education, a key predictor of decline in cognitive function, over the life course (Blair, 2016).

5.2 Mediating role of perceived loneliness

For Objective 3 of the study, we sought to examine if loneliness mediated the association between intersectional group membership and the cognitive functioning outcomes, using three-way decomposition analysis modified to take survey design factors such as weights, clustering, and stratification into account.
5.2.1.1 Mediating role of perceived loneliness on the association between intersectional groups and 8-year change in memory functioning

For the memory functioning domain, results for the total effect of the association between exposure and outcome reflected the existing inequity in cognitive health outcomes within older adult populations. When considering the overall total effect of the intersectional groups on change in functioning over the period of eight years, the overall effect was significant and negative for individuals at the intersection comparisons between the reference group, Males 50 to 64 years old with high educational attainment, and the intersectional categories of Males 65 years and older with low educational attainment, Females 65 years and older with low educational attainment, Males 65 years and older with high educational attainment, and Females 65 years and older with high educational attainment. This observation highlights significantly higher levels of decline for memory function amongst these groups.

When examining the natural direct effects, we observed a significant association between the comparison intersections and eight-year change in memory function under a theoretical intervention where the mediator was set to the level held by the reference group, the lowest observed mean perceived loneliness score held amongst the intersection groups (3.71). Based on the study findings, if the intersectional groups of Females 65 years and older with low educational attainment, Males 65 years and older with low educational attainment, and Males 65 years and older with high educational attainment were to experience the same reduced level of loneliness as the reference group Males 50 to 64 years with high educational attainment there would still be negative and significant residual inequalities present in the association between intersectional group membership and eight-year change in memory function. The results show that even if the excess loneliness were to be removed, the heterogeneity in effect for decline in memory functioning would be expected to still continue to exist with little change.

On the indirect pathway, the study found evidence of effect on the outcome due to mediation alone, i.e., due to differences in levels of loneliness, but for only those at a single intersection. The findings suggest that if the effect of perceived loneliness was set
to the same strength and direction for *Females 65 years and older with low educational attainment* as that of the reference group, there would be a positive and significant difference in change in memory over time. This highlights the potential for intervention, specifically, a targeted intervention towards the intersectional group of *Females 65 years and older with low educational attainment* could result in an observed improvement in change in cognition over time. However, it is important to note that due to the large amount of comparison tests conducted for the decomposition analysis, it is possible that these results were observed to be statistically significant due to chance. These results should be interpreted with caution and should require future examinations to confirm the results. Lastly, we did not observe any statistically significant mediated interactions for any intersections, meaning that we found no evidence that effects of loneliness on change in memory may vary across intersections.

### 5.2.1.2 Mediating role of perceived loneliness on the association between intersectional groups and 8-year change in executive functioning

For the executive functioning domain, when considering the overall total effect of the intersectional groups on change in functioning over the period of 8 years, the total effect was significant for individuals at the intersection of *Males 65 years and older with low educational attainment*, *Males 65 years and older with high educational attainment*, *Females 50 to 64 years old with low educational attainment*, and *Females 65 years and older with high educational attainment*.

When considering the natural direct effect, the findings highlight that if loneliness was set to the lower level of the more-advantaged reference group there would continue to be significant associations between each of the four intersectional comparison groups and the reference group with regard to changes in executive functioning outcome. Based on these findings, if loneliness was set to the lower level of 3.71, the natural direct effect would be negative and significant and nearly identical to the total effect for the comparisons between the reference group and the three older age (age 65 years and older) intersectional comparison groups. Hence, there would still be evidence of residual inequalities with advantageous levels of loneliness for the comparison groups.
The study did not find evidence of an effect due to mediation alone on the indirect pathway, i.e., due to excess levels of loneliness, in that the pure indirect effects were not shown to be statistically significant for any of the seven intersectional group comparisons. This can be interpreted as when perceived loneliness was set to the lower mean score found for the reference group *Males 50 to 64 years old with high educational attainment*, there was no observed difference in 8-year change executive function. Similar to 8-year change in memory score, the mediator’s effect of the outcome was also shown to not vary amongst the comparison groups, in that there were no statistically significant mediated interactions. Therefore, for all comparison groups the additional effect of the perceived loneliness on the 8-year change in executive functioning was not observed to be significantly different for the comparison and the reference intersectional groups.

5.3 Study strengths

The use of the ELSA survey is a strength of this study. The longitudinal prospective cohort design of the ELSA data allowed for examinations of changes in cognitive health over time, to better establish causal inferences. Moreover, the ELSA research study provided a large sample of the older adult population in England that was advantageously collected through multistage survey sampling methods.

This study is the first known research study of its kind to use the intersectional approach in cognitive health research, and as a result it addresses gaps in knowledge in regard to the intersectional differences in the functional health of older adult populations. There has been a call for more studies that examine the impact of social factors on cognitive health over the life course. The use of the intersectional approach in this study allows for three social positions that have historically been examined on the singular axis to be examined using methods that better allow for the identification of heterogeneity within subgroups of the population. Similarly, while the association between loneliness and cognitive health have previously been explored, this study is novel as it was able to explore disparities in the impact of loneliness on change in cognition. Through the use of intersectionality, this study allowed us to better consider the way that individuals in marginalized positions in society experienced changes in cognitive health over time.
This study employed current intersectional methods in quantitative intersectionality research. It can also be used as an example of the practicality of VanderWeele’s three-way decomposition as a method in intersectionality research (VanderWeele, 2013). The methodology used in this study provides guidance for the use of three-way decomposition in complex survey data, specifically allowing for the inclusion of strata and clusters into the statistical data analysis. This study also makes a substantive contribution to the research in methodology for quantitative intersectionality, as it provides a guide for calculating measures of variance for three-way decomposition estimates. Existing guidance on using this method in intersectional applications (Bauer & Scheim, 2019) used variance estimation methods that assume a random sample, though the method is best suited for large population data sets, which are nearly universally collected through multistage sampling methods. This work will allow other researchers to strengthen their applications of this method in realistic data scenarios.

5.4 Study limitations

While the use of ELSA was beneficial, it is important to note that there was clear underrepresentation of minority social positions within the sample population. The lack of representation may limit the generalizability of our finding to specific subgroups of the population. Specifically, there was an underrepresentation of racial and ethnic minority groups within the ELSA study (Steptoe et al., 2013). The 2011 UK National Census estimated that 14.0% of the population of England and Wales identified as an ethnic minority; 7.5% Asian, 3.3% Black and 3.2% of mixed race or categorized as another ethnicity (Office for National Statistics, 2018). However, in this sample only 2.2% of the population was an ethnic minority. As a result, it is unclear if the results of this study can be extrapolated to the ethnic minority older adult population residing in England.

Similarly, there was an underrepresentation of immigrants born outside of the United Kingdom. It is estimated that 14% of the population in the United Kingdom are immigrants, however in this sample only 9% indicated that they were born outside of the United Kingdom (Vargras-Silva & Rienzo, 2019). Due to small cell size, we were not able to incorporate ethnic minority classifications or immigration classifications into the
analytic intersections, and even the main effects in our statistical analysis may have had insufficient power and imprecise estimates.

Due to the presence of exposure-induced mediator-outcome confounding in the DAG model, there were confounder variables in the model that could not be sufficiently adjusted for without blocking the causal pathway. We can only truly answer questions regarding the effect of the intersections on the loneliness variable, and the effect of the intersections on the cognitive functioning outcomes through the examination of pathways other than variables that cannot be effectively controlled for, including poor physical functioning, stroke, alcohol consumption, smoking and chronic illnesses such as cardiovascular disease. This also suggests that residual confounding is present in our analysis as some variables identified as confounders cannot be effectively adjusted for. Residual confounding may also be present due to errors in the measurement for the confounding variables like childhood social status that required retrospective recall. There is also always the potential that there may have been unidentified confounding variables that were not considered in the model. As a result, there may be residual differences between intersectional groups that still remain, that in turn may bias the observed associations.

Another major limitation in the study is due to the potential presence of selection bias in the form of survival bias and loss to follow-up (Banack et al., 2019). Selection bias is especially prevalent in research involving participants in old age. ELSA study specifically used a longitudinal approach to examine health in middle to older adult populations 50 years and older. In the selection of the sample, healthier old age participants are more likely to be selected; Researchers have found that individuals who experience disparities throughout the life-course are more likely to experience morbidity and mortality at younger ages, in comparison to those who have not faced disparities (Zajacova & Burgard, 2013). Given that cognitive aging is a predictor of illness and mortality in older adult populations, individuals with low baseline levels of cognitive functioning may have been less likely to have survived to participate in the study or conversely, not be well enough to volunteer participation. Moreover, loss to follow-up is another major limitation. Due to limited dropout data on the sample population, it was not
possible to account for individuals who may have been lost to follow-up due to poor functional ability or death. Again, particularly in populations age 80 and older, the older high functioning study subjects would be more likely to remain in the study in comparison to those with lower function (Banack et al., 2019). Overall, selection bias may alter the measure of effect for the observed exposure-mediator-outcome association.

Lastly, there are potential concerns with measurement validity. In terms of the measurement of the cognitive functioning outcome, researchers previously noted potential issues regarding performance validity. While the questions were changed for each study wave, the format of the test remained the same. As a result, the study participants may have gained an advantage in performance at each additional administration of the test due to the knowledge of the structure of the test (Bertua et al., 2005). Moreover, variables related to sensitive topics may have been underreported in the ELSA study, potentially biasing our results. Specifically, childhood experiences of abuse and violence are commonly underreported in self-report surveys, due to fear of social stigma, lack of familiarity with interviewers, or difficulty recalling traumatic events experienced in childhood due to memory repression (McKinney et al., 2009). There may also have been misclassification by educational status. Educational attainment was measured at Wave 4 (Time 1) and did not account for participants who may have moved from the ‘low educational attainment’ to ‘high educational attainment’ categorization if they had received additional training over the course of the study period, though most education would be expected to have occurred at younger ages.

### 5.5 Future research directions

This study identified intersectional differences in memory functioning and executive functioning in the older adult populations residing in England. It is recommended that future studies continue to use quantitative intersectional approaches to examine cognitive health over the life course. Future research can also use intersectional approaches to examine other important but lesser explored aspects of cognitive health such as lifelong learning in senior populations, as well as complex attention which has been observed to have significant declines in older adult populations (Glisky, 2019). As well, while we did not find evidence that loneliness served as a driver of the intersectional differences in
cognitive functioning decline, researchers can examine other modifiable social and behavioural factors that may mediate associations between intersectional groups and cognitive functioning outcomes.

With the increase interest of cognitive health in older adult populations, research studies such as ELSA and HRS have provided congruent and standardized measures for domains in cognitive health (Program of Global Aging, 2020). Through this, there is the potential for cross-country comparisons of the exposure-mediator-outcome relationship to examine intersectional differences within countries, and further examinations of how additional intersections such as geographical or regional disparities in health policy and access to care differentially impact cognitive health.

Lastly, in order to develop a more nuanced understanding of the role of power and heterogeneity in older adult populations, researchers should further explore cognitive health at different marginalized intersections in the population, for example, at the intersection of race, ethnicity, and social class. However, this will require future studies, especially those examining cognitive functioning in older adult populations, to seek to include more representative samples of the population (Gill & Redwood, 2013; Salkind, 2012; Steptoe et al., 2013). A greater capacity for intersectional research could potentially be established through the inclusion of oversampling, or the use of complex survey methods that are stratified by underrepresented social identities (Kalton, 2009).
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Appendices

Appendix A. Sample characteristic of the analytic population, by intersectional group membership

Table A. Sample Characteristics by Intersectional group membership

<table>
<thead>
<tr>
<th>Sample Characteristic</th>
<th>Intersectional Group 1 (n=324)</th>
<th>Intersectional Group 2 (n=337)</th>
<th>Intersectional Group 3 (n=485)</th>
<th>Intersectional Group 4 (n=563)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Memory function score (t=1) (n=±SE)</td>
<td>10.55 (±0.18)</td>
<td>9.25 (±0.18)</td>
<td>11.68 (±0.14)</td>
<td>9.90 (±0.15)</td>
</tr>
<tr>
<td>Memory function score (t=5) (n=±SE)</td>
<td>10.49 (±0.20)</td>
<td>7.83 (±0.21)</td>
<td>11.22 (±0.16)</td>
<td>8.24 (±0.18)</td>
</tr>
<tr>
<td>Baseline Executive function score (t=1) (n=±SE)</td>
<td>22.03 (±0.44)</td>
<td>19.56 (±0.40)</td>
<td>21.46 (±0.27)</td>
<td>18.60 (±0.27)</td>
</tr>
<tr>
<td>Executive function score (t=4) (n=±SE)</td>
<td>22.11 (±0.46)</td>
<td>18.16 (±0.39)</td>
<td>21.92 (±0.32)</td>
<td>17.32 (±0.33)</td>
</tr>
<tr>
<td>Baseline loneliness score (n=±SE)</td>
<td>4.18 (±0.10)</td>
<td>3.87 (±0.09)</td>
<td>4.16 (±0.07)</td>
<td>4.44 (±0.08)</td>
</tr>
<tr>
<td>Ethnicity (n (%))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>319 (98.46%)</td>
<td>331 (98.22%)</td>
<td>479 (98.76%)</td>
<td>552 (98.05%)</td>
</tr>
<tr>
<td>Ethnic Minority</td>
<td>5 (1.54%)</td>
<td>6 (1.78%)</td>
<td>6 (1.24%)</td>
<td>11 (1.95%)</td>
</tr>
<tr>
<td>Immigration status (n (%))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Born in the UK</td>
<td>301 (92.90%)</td>
<td>303 (89.91%)</td>
<td>440 (90.53%)</td>
<td>528 (93.78%)</td>
</tr>
<tr>
<td>Not born in the UK</td>
<td>23 (7.10%)</td>
<td>34 (10.09%)</td>
<td>45 (9.26%)</td>
<td>35 (6.22%)</td>
</tr>
<tr>
<td>Childhood experiences of abuse (n (%))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>31 (9.57%)</td>
<td>14 (4.15%)</td>
<td>54 (11.11%)</td>
<td>28 (4.97%)</td>
</tr>
<tr>
<td>No</td>
<td>293 (90.43%)</td>
<td>323 (95.85%)</td>
<td>432 (88.89%)</td>
<td>534 (94.85%)</td>
</tr>
<tr>
<td>Childhood social status (n (%))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High managerial, administrative, and professional occupations</td>
<td>62 (19.14%)</td>
<td>58 (17.21%)</td>
<td>126 (25.93%)</td>
<td>139 (24.69%)</td>
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<tr>
<td>Intermediate occupations</td>
<td>38 (11.73%)</td>
<td>39 (11.57%)</td>
<td>48 (9.88%)</td>
<td>65 (11.55%)</td>
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<tr>
<td>Routine and manual occupations</td>
<td>145 (44.75%)</td>
<td>152 (45.10%)</td>
<td>219 (45.06%)</td>
<td>230 (40.85%)</td>
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<tr>
<td>Other labour</td>
<td>79 (24.38%)</td>
<td>88 (26.11%)</td>
<td>93 (19.14%)</td>
<td>129 (22.91%)</td>
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<table>
<thead>
<tr>
<th>Sample Characteristic</th>
<th>Intersectional Group 5 (n=387)</th>
<th>Intersectional Group 6 (n=230)</th>
<th>Intersectional Group 7 (n=285)</th>
<th>Intersectional Group 8 (n=176)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Memory function score (t=1) (n ±SE)</td>
<td>12.00 (±0.14)</td>
<td>10.24 (±0.18)</td>
<td>13.40 (±0.16)</td>
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<td>Memory function score (t=5) (n ±SE)</td>
<td>11.72 (±0.17)</td>
<td>9.18 (±0.22)</td>
<td>13.21 (±0.17)</td>
<td>10.57 (±0.25)</td>
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<td>Baseline Executive function score (t=1) (n ±SE)</td>
<td>24.32 (±0.33)</td>
<td>21.62 (±0.40)</td>
<td>25.41 (±0.39)</td>
<td>22.70 (±0.42)</td>
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<td>Executive function score (t=4) (n ±SE)</td>
<td>24.17 (±0.34)</td>
<td>20.29 (±0.44)</td>
<td>24.82 (±0.37)</td>
<td>20.96 (±0.45)</td>
</tr>
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<td>Baseline loneliness score (n ±SE)</td>
<td>3.89 (±0.07)</td>
<td>3.71 (±0.07)</td>
<td>4.02 (±0.07)</td>
<td>4.02 (±0.10)</td>
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<tr>
<td>Ethnicity (n (%))</td>
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<td></td>
</tr>
<tr>
<td>White</td>
<td>372 (96.12%)</td>
<td>224 (97.39%)</td>
<td>274 (96.14%)</td>
<td>173 (98.30%)</td>
</tr>
<tr>
<td>Ethnic Minority</td>
<td>15 (3.88%)</td>
<td>6 (2.61%)</td>
<td>11 (3.86%)</td>
<td>3 (1.70%)</td>
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<td>Immigration status (n (%))</td>
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<tr>
<td>Born in the UK</td>
<td>341 (88.11%)</td>
<td>203 (88.26%)</td>
<td>247 (86.67%)</td>
<td>151 (85.80%)</td>
</tr>
<tr>
<td>Not born in the UK</td>
<td>46 (11.89%)</td>
<td>27 (11.74%)</td>
<td>38 (13.33%)</td>
<td>25 (14.20%)</td>
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<td>Childhood experiences of abuse (n (%))</td>
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<tr>
<td>Yes</td>
<td>37 (9.56%)</td>
<td>15 (6.52%)</td>
<td>37 (12.98%)</td>
<td>16 (9.09%)</td>
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<tr>
<td>No</td>
<td>350 (90.44%)</td>
<td>215 (93.48%)</td>
<td>248 (87.02%)</td>
<td>160 (90.91%)</td>
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<td>Childhood social status (n (%))</td>
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<td></td>
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<tr>
<td>High managerial, administrative and professional occupations</td>
<td>135 (34.88%)</td>
<td>84 (36.52%)</td>
<td>128 (44.91%)</td>
<td>77 (43.75%)</td>
</tr>
<tr>
<td>Intermediate occupations</td>
<td>52 (13.44%)</td>
<td>31 (13.48%)</td>
<td>34 (11.93%)</td>
<td>24 (13.64%)</td>
</tr>
<tr>
<td>Routine and manual occupations</td>
<td>145 (37.47%)</td>
<td>84 (36.52%)</td>
<td>88 (30.88%)</td>
<td>53 (30.11%)</td>
</tr>
<tr>
<td>Other labour</td>
<td>55 (14.21%)</td>
<td>31 (13.48%)</td>
<td>33 (11.58%)</td>
<td>22 (12.50%)</td>
</tr>
</tbody>
</table>
Appendix B. Curriculum Vitae

Curriculum Vitae

Name: Chantel Walwyn

Post-secondary Education and Degrees: Western University
London, Ontario, Canada
2017-2021 MSc

Brock University
St. Catharines, Ontario, Canada
2012-2016 BPH

Honours and Awards: Queen Elizabeth II Graduate Scholarship
in Science and Technology
2018-2019

Related Work Experience: Graduate Research Assistant
Western University
2017-2020

Publications:
Niagara Region Public Health (2016). Niagara Region Village of 100. Available at
https://www.niagararegion.ca/health/statistics/demographics/default.aspx