Linking Social, Psychological and Lifestyle Factors to Cognitive Decline in Aging: Pathways and Challenges to Optimal Function

by

Cassandra Lynn Brown

Master of Science, University of Victoria, 2012
Bachelor of Science, Queen's University, 2008

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Supervisory Committee

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Dr. Andrea Piccinin, (Department of Psychology)
Supervisor

Dr. Mauricio A. Garcia-Barrera, (Department of Psychology)
Departmental Member

Dr. Karen Kobayashi, (Department of Sociology)
Outside Member

Abstract

The possibility that lifestyle factors may delay or accelerate cognitive decline in aging has garnered significant attention and a considerable body of research has formed. However, investigating the relations between social engagement and cognitive function in aging have been somewhat equivocal in their findings and there is a lack of understanding of the mechanisms by which social engagement may impact cognitive function and the role of factors limiting social engagement. The aim of this dissertation was to build on current understanding of how specific aspects of social relationships relate to cognitive functioning in older adulthood and how these aspects are affected by challenges and barriers to social participation. This dissertation is comprised of three studies addressing several specific research questions. Study one (Chapter 2) examined whether relations with cognitive performance over time differ for structural aspects of social relationships (social network and social contact) versus functional/subjective aspects of social relationships (loneliness and social support) and whether the associations are between cognitive performance and stable, "trait-like" components of social relationships or fluctuating "state-like" components of these constructs, using autoregressive latent trajectory modeling of data from the Health and Retirement Study. Study two (Chapter 3) used a multilevel modeling approach to examine whether the spouses/partners of individuals diagnosed with Alzheimer's disease or dementia experience a within person decline in cognitive performance and whether changes in structural and functional/subjective aspects of social relationships interacted with a spouses' diagnosis of memory disease to predict within person change in cognitive performance. Study three (Chapter 4) investigated whether rejection sensitivity, social avoidance, and fears of negative social evaluations were predictive of lack of social participation and loneliness in a sample of Vancouver Island older

adults. These factors have previously been investigated in younger adults as risk factors for loneliness and social withdrawal, but social isolation in older adulthood is often attributed to lack of social opportunities. This dissertation demonstrates the importance of considering precise aspects of social relationships, including barriers to social participation, and their relations to cognitive functioning.

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Dedication

To my family, your unwavering support and encouragement has carried me through.

Chapter 1: Introduction

Developed nations around the world are experiencing unprecedented population aging, in part because over the last 100 years life expectancy has increased and individuals with chronic conditions are living longer (Crimmins & Beltrán-Sánchez, 2011). Increased age remains the main risk factor for many of the most common diseases in developed nations, including cancer, cardiovascular disease and neurodegenerative disease, thus as the population age increases so does the prevalence of these conditions (Niccoli & Partridge, 2012). Shifting demographics and concerns about increasing prevalence of chronic diseases and related functional disability has sparked great interest in reducing periods of morbidity and improving quality of life in older adulthood, themes that have been incorporated into concepts such as healthspan (Crimmins, 2015), morbidity compression (Crimmins & Beltrán-Sánchez, 2011; Fries, 2002), and successful aging (Rowe & Kahn, 1997). Compressing the period of morbidity at the end of life has important implications at the individual level and large implications at the epidemiological level for the total burden of disease. This is particularly true for cognitive decline where even mild cognitive impairments are associated with a decline in functional capacity (Burton, Strauss, Bunce, Hunter, & Hultsch, 2009).

Neuroanatomical and neurophysiological changes in the aging brain and the increasing prevalence of neurofibrillary tangles and amyloid plaques, neuropathologies considered the hallmarks of Alzheimer's disease, have been forwarded as possible reasons for age-related cognitive decline (Glisky, 2007; Park & Reuter-Lorenz, 2009; Snowdon, 2003). Yet, despite such changes, many adults retain functional capacity well into old age and observations of neuroplasticity in older adult brains suggest that even improvements in cognitive functioning are possible (Hertzog, Kramer, Wilson, & Lindenberger, 2008; Lövdén, Bäckman, Lindenberger,

Schaefer, & Schmiedek, 2010). Thus, the mechanisms of age-related cognitive declines are likely multifactorial and the observed cognitive performance of older adults a result of both neurocognitive changes and compensatory processes (Park & Reuter-Lorenz, 2009). This, combined with increasing knowledge of links between cognitive function and factors, such as cardiovascular health, that are amenable to lifestyle changes, provides a theoretical basis for the idea that lifestyle changes may lead to better maintenance of cognitive function in older adulthood (Ballesteros, Kraft, Santana, & Tziraki, 2015; Hertzog et al., 2008). This has become a very active area of research that garners considerable interest from the public (Hertzog et al., 2008).

Social activity or engagement is one of the lifestyle factors most commonly investigated as possibly important for cognitive function in older adulthood (Ballesteros et al., 2015; Hertzog et al., 2008). Maintaining interpersonal relationships is considered a key component of successful aging and its importance stressed as part of general advice on aging (Rowe & Kahn, 1997). However, studies investigating the relations between social engagement and cognitive function in aging have been somewhat equivocal in their findings and there is a lack of understanding of the mechanisms by which social engagement may impact cognitive function (James, Wilson, Barnes, & Bennett, 2011). Characterizing the social worlds of individuals is complex and multidimensional, including both objective components, such as social network size and frequency of social activity engagement, as well as subjective components such as satisfaction with one's social relationships and perceptions of how well one's social needs are met. Further, the objective and subjective components are known to be interrelated, but the strength and directionality of this relation is unclear. Only rarely are multiple social dimensions considered simultaneously in studies investigating the relations between social factors and

cognitive function, and different social dimensions may relate to cognitive function through different mechanistic pathways.

The present dissertation focuses on pathways of association between objective social factors, subjective social factors, lifestyle, and cognitive outcomes. This dissertation is comprised of three related studies. First, the different ways social factors are conceptualized and measured, the current state of research on associations between social factors and cognitive function, and evidence for possible pathways by which social factors and cognitive outcomes may be related will be reviewed. Aspects of physical health are considered in so far as physical health changes may represent a pathway through which social factors impact cognitive changes in aging but are otherwise not a specific focus.

Social Factors

Social relationships are complex and influenced by various aspects at the level of the individual (e.g., personality), their environment (e.g., social opportunities) and the larger social structures within a given region and culture (e.g., social cohesion). In the present dissertation 'social factors' is used as an umbrella term to refer to social variables investigated at the individual level as this was the focus of investigation. At the level of the individual, several social factors are most commonly investigated including social networks, social activity or social engagement, and social support. Social networks are defined as the social contacts one has access to, and may be quantified by the structure of the network and sometimes frequency of interaction (Ballesteros et al., 2015; Berkman, Glass, Brissette, & Seeman, 2000). Social activity, also referred to as social integration or social engagement (Ramsay et al., 2008), is a measure of the degree of participation within personal, social, or community networks (Berkman et al., 2000;

Sheldon Cohen, 2004). Here social activity is used specifically to describe the quantification of how many social activities (e.g., dinner with friends) an individual is participating in. Social support is both the perception and actuality that support, including instrumental (e.g., help with tasks), informational (e.g., advice), and emotional (e.g., a sense that one is cared for), is available from others. These aspects of social support can be measured as one's perception about available support or as a report of actual instances of received support (Schwarzer, Knoll, & Rieckmann, 2004). Loneliness refers to the set of feelings in reaction to perceptions of not having one's intimate and social needs met (Ernst & Cacioppo, 2000). Sometimes loneliness is divided into social and emotional loneliness, with the former related to feelings of not having a social group in which one is valued and can have shared experiences, and the latter referring to feelings of lacking a significant attachment relationship (Ernst & Cacioppo, 2000). Although these definitions will be used consistently throughout this dissertation, across the extant literature, even when the same social factor is considered, different studies often use slightly different conceptualizations and different measures.

Cognitive Function

As with social factors, cognitive function is also used in throughout this dissertation as an umbrella term with the recognition that cognitive function is not unitary construct. It is well established that different domains of cognitive function show differential relationships with age, with processing speed, working memory, and free recall relatively more affected in normative aging than stores of existing knowledge such as vocabulary, or recognition memory (Horn, 1982; Horn & Cattel, 1967). Similarly, different domains of cognitive function are known to be differentially affected by neurological and psychological changes. Importantly for the present

investigations, chronic stress has been suggested to impact cognition through neuroendocrine dysregulation which have been shown to affect episodic memory, processing speed, and some executive functions such as set-shifting, while abilities such as vocabulary are relatively spared (Franz et al., 2011; Head, Singh, & Bugg, 2012). Mental health conditions such as anxiety are more likely associated with transient changes in cognitive performance (as opposed to long-lasting changes in cognitive ability) due to difficulties with attentional control that would be expected to affect performance on tasks sensitive to this, such as attention, inhibition, or set-shifting tasks (Eysenck, Derakshan, Santos, & Calvo, 2007). The cognitive functions investigated in this dissertation were limited by available measures but include outcomes that may arguably be more sensitive (i.e., episodic memory operationalized as immediate and delayed free recall) and less sensitive (i.e., overall mental status). Although episodic memory and mental status are the cognitive outcomes in this dissertation, in the extant literature other cognitive outcomes have been examined in relation to social factors and are reviewed as available. In addition, many studies do use screening measures such as the Mini-Mental Status Exam (MMSE; Folstein, Folstein & McHugh, 1975) as an overall cognitive outcome measure.

Social Network and Cognitive Function

Overall, social network characteristics have shown inconsistent relations to indicators of cognitive function in older adulthood even when the same cognitive outcome is examined (Agüero-Torres, von Strauss, Viitanen, Winblad, & Fratiglioni, 2001; Green, Rebok, & Lyketsos, 2008; Holtzman et al., 2004; Seeman, Lusignolo, Albert, & Berkman, 2001; Zunzunegui, Alvarado, Del Ser, & Otero, 2003). Some studies have found protective effects of increased social network size (Holtzman et al., 2004; Zunzunegui et al., 2003) while others have

failed to find such effects (e.g.,(Agüero-Torres et al., 2001). Holtzman (2004) examined maintenance of MMSE performance among a group of adults over 50 years old and found that those with larger social networks at baseline had reduced odds of decline by the third wave of assessment (Holtzman et al., 2004). However, Green et al. (2008) found that social network size was not protective against later overall cognitive decline as measured by the MMSE performance and a delayed recall task. In the same study, frequency of interactions with social network members and emotional support received were also examined and no associations between these variables and change in MMSE or delayed recall performance over time was found (Green et al., 2008).

Social Activity/Engagement and Cognitive Function

Social activity participation has also shown mixed relations with cognitive decline in aging. James et al. (2011) found social activity participation predicted rate of change in multi-test composite scores of perceptual speed, visuospatial ability, working memory, semantic memory, and episodic memory. Higher levels of social activity were found to predict less than the population average decline in perceptual speed over a subsequent two-year period using a univariate dual change score model (Lövdén, Ghisletta, & Lindenberger, 2005). Bielak, Gerstorf, Anstey, and Luszcz (2014) found an association between rate of change in one-on-one social activity and rate of change in immediate episodic memory performance using a bivariate latent growth model. However, within the same study, no association was found between rate of change in social activity and rate of change in perceptual speed or delayed episodic memory performance (Bielak et al., 2014). In a coordinated analysis of four longitudinal studies, change in social activity since baseline was related to rate of change in immediate episodic memory and

in reasoning performance in three of the four studies included (Brown et al., 2012). The exception was the Long Beach Longitudinal Study which, unlike the other three studies, showed little change or variance in change among participants in social activity over time. No significant relation was found between social activity and change in vocabulary performance across any of the four studies, whereas the relationship between social activity change and change over time in fluency performance was found in all three of the samples with a measure of fluency (Brown et al., 2012). Overall, change in social activity has been most consistently related to rate of change in episodic memory and reasoning performance, and less consistently associated with change in vocabulary performance, and processing speed (Aartsen, Smits, van Tilburg, Knipscheer, & Deeg, 2002; Bielak et al., 2014; Brown et al., 2012; Ghisletta, Bickel, & Lövdén, 2006; James et al., 2011; Lövdén et al., 2005). In one study, examining only baseline associations, a relationship between baseline social activity and a baseline global cognitive performance composite score was found but baseline social activity did not predict change in global cognitive performance over time (McGue & Christensen, 2007).

Several studies have found little evidence of any relationship between social activity and cognitive change. Kåreholt, Lennartsson, Gatz, & Parker (2011) found that baseline social activity had no significant association with mini-mental status exam score. Using bivariate dual change score models to investigate associations over a one year period, no significant coupling of social activity participation and perceptual speed or verbal fluency were found, whereas levels of media and leisure activities were associated with slower perceptual speed but not verbal fluency performance (Ghisletta et al., 2006). Aartsen et al. (2002) found that none of three everyday activity types investigated, social, experiential, and developmental, predicted

performance in any of the cognitive domains examined six years later including mental status, word list learning and memory, non-verbal reasoning, or processing speed.

Social support and Cognitive function

Interestingly, fewer studies have investigated the relations between social support and cognitive function and several of those that have, included it as part of a larger group of social measures (Hertzog et al., 2008). In one cross-sectional study with a sample of 482 participants aged 55 plus, from the NIH Toolbox normative study, a significant association was found between emotional support and executive function and processing speed, controlling for a variety of covariates including general health status, education, negative affect and a number of indicators of positive affect (Zahodne, Nowinski, Gershon, & Manly, 2014). However, no associations were found between emotional support and working memory and episodic memory. Self-efficacy was associated with better working memory. No other psychological or social variables examined (life satisfaction, positive affect, friendship, loneliness, instrumental support or negative affective) were related to any of the cognitive domains examined after accounting for other variables included in the model. The authors note that this pattern was maintained even after restricting the sample to what is typically considered older adults (age 65 plus) (Zahodne et al., 2014).

Loneliness and Cognition Function

Although relatively fewer studies have examined the relations between social support and cognitive function in older adulthood, loneliness has been increasingly examined. Ellwardt, Aartsen, and Deeg (2013) investigated the longitudinal relations between emotional and

instrumental support, loneliness, and cognitive function using data from the Longitudinal Study of Aging Amsterdam (LASA). They found longitudinal relations such that an increase in received emotional support was related to an increase in cognitive functioning and a decrease in loneliness. They hypothesized an indirect effect of emotional support on cognition through loneliness, but this was not supported by study results. The effect of increased emotional support had a larger and more direct effect on cognitive functioning than an initially high level (intercept) of emotional support. Interestingly, increased instrumental support was actually related to a decrease in cognitive functioning (Ellwardt et al., 2013). In another study, greater baseline loneliness was found to be a significant predictor of global cognitive decline from baseline at 10 year follow up (RR = 3.0, 95% CI = 1.4–6.8) (Tilvis et al., 2004).

Studies examining associations between loneliness and specific domains of cognitive function have showed more mixed results. Lonelier individuals showed poorer immediate recall in some cross-sectional studies (Gilmour, 2012), but other studies failed to find a significant relationship (O'Luanaigh et al., 2012; Schnittger, Wherton, Prendergast, & Lawlor, 2012). Loneliness was also related to delayed recall in some (O'Luanaigh et al., 2012) but not all studies (Gilmour, 2012; Schnittger et al., 2012). In their cross-sectional study, O'Luanaigh et al. (2012) also reported no significant associations between verbal fluency and loneliness when controlling for depression, social networks, and a range of demographic factors. Relations between loneliness and executive functions have also been examined cross-sectionally. Although a negative association between loneliness and executive function was found, in a multivariate model that included social interaction the association was no longer significant (Gilmour, 2012). Another study also reported a negative correlation between loneliness and executive function but found that in a multiple linear regression model that included depression, neuroticism, perceived

stress, solitary living, and accommodation status the association was no longer significant (Schnittger, Wherton, Prendergast, & Lawlor, 2012). One consistent finding is the negative association between loneliness and processing speed that remains even after controlling for relevant confounds such as depression, social network, and other cognitive and demographic factors (Boss, Kang, & Branson, 2015; Gilmour, 2012; O'Luanaigh et al., 2012).

Several studies have also examined longitudinal associations between loneliness and cognitive function. In a prospective study with 4 years of follow-up, immediate and delayed recall performance were significantly and negatively associated with loneliness at baseline and four-year follow-up (Shankar, Hamer, McMunn, & Steptoe, 2013). However, for delayed recall, higher levels of isolation and loneliness were associated with poorer recall in individuals with lower levels of education only. Greater loneliness was also significantly associated with low levels of verbal fluency at baseline, but not at follow-up (Shankar et al., 2013). Wilson et al. (2007) found that those reporting greater loneliness at baseline had lower episodic, semantic, and working memory performance at baseline. However only the relations between semantic memory and baseline loneliness was significant at the fourth year follow-up when controlling for age, gender, and level of education. Schnittger et al. (2012) reported that verbal fluency was a significant risk factor of social loneliness.

Loneliness has also been associated with increased risk of developing Alzheimer's disease or dementia. Holwerda et al. (2014) found that lonelier individuals at baseline had increased odds of Alzheimer's disease or dementia 3 years later (OR = 2.56, 95% CI = 1.82–3.61) even after controlling for demographic, somatic, and psychiatric risk factors. In a study using data from the Rush Memory and Aging Project (MAP), the relation between loneliness, cognitive outcomes, and Alzheimer Disease (AD) pathology was examined (Wilson et al., 2007).

For the over 800 participants who completed the loneliness scale, loneliness was related to the development of incident AD and to rate of cognitive decline. This remained true after controlling for numerous other factors including social networks, social, cognitive and physical activities, disability, and depressive symptoms. As part of participation in MAP individuals are asked to donate their brain and spinal tissue to the study for autopsy. Over the study period examined, 135 people came to autopsy. In this group loneliness was not related to amyloid load or tangle density, or cerebral infarctions (Wilson et al., 2007). The authors interpret this as indicating that loneliness is related to whether or not cognitive deficits are expressed in the presence of amyloid plaques and tau tangles but not to the development of these pathologies.

Composite Social Measures and Cognitive Function

Although so far, evidence for relations between individual social factors and cognitive functioning among older adulthood has been reviewed separately, social factors are also partially interdependent. Larger social networks are associated with increased activity participation, possibly because social networks enable access to opportunities for social activities and other social resources such as social support (Berkman et al., 2000; Litwin & Stoeckel, 2016). Several studies have attempted to account for the complexity of social relations and inter-relations by using composite indices of various social factors or examining multiple factors. Using data from the Paquid cohort, a longitudinal study of aging with up to 20 years of follow up, the relations between social factors (social engagement, social network size, satisfaction with social relationships, and a perception of feeling understood) and cognitive decline and dementia risk were examined. Social engagement was found to predict only baseline level of cognitive functioning but not rate of change (Marioni et al., 2015). However, feeling well understood was

related to both baseline, and rate of change, in cognitive function while neither social network size, nor satisfaction with social network was related to baseline or rate of change in cognitive functioning (Marioni et al., 2015). Cognitive functioning was a factor composed of MMSE, verbal fluency, Wechsler Similarities, episodic memory and learning (Wechsler Paired Associate Test), processing speed, and immediate visual memory scores. In another study, baseline social integration (a composite of marital status, contact with parents/children/neighbours, and volunteer activities) was related to a slower rate of memory decline over the 6 year follow up period (Ertel, Glymour, & Berkman, 2008). Bassuk, Glass, and Berkman, (1999) found in their sample of 2, 812 American's aged 65 and older that participants with higher engagement showed less decline in mental status. They used a composite index including a number of social activity and social network items (e.g., monthly contact with at least three friends or relatives) and cognition, measured as mental status, with four waves of assessment over a 12-year period. Similarly, poor social connections, infrequent participation in social activities, and social disengagement was found to predict risk of decline in cognitive function as measured by a short mental status questionnaire and a story recall test, among a group of community dwelling Spanish adults aged 65 and older (Zunzunegui et al., 2003).

Pathways

Commonly cited explanations for disparate results are different theoretical conceptualizations and/or operationalization of social factors as well as differences in the measurement of cognitive function and what specific domains are examined, or because different statistical methodologies are employed. As reviewed above, in many cases even among studies using a similar conceptualization (e.g., social activity), comparing similar cognitive outcomes

(e.g., mental status) results are not consistent. Different studies have used different statistical models which may account for some of the variability in results (Ghisletta et al., 2006; Hertzog et al., 2008; Hultsch et al., 1999). As even models that appear similar often have a different set of assumptions, include different covariates, differ in their treatment of change, and in whether or not between person and within person affects are conflated or modeled. All of these factors likely account for some of the inconsistencies. However, even when the relations between social activity and four domains of cognitive function were examined in four different longitudinal samples using the same statistical model with the same covariates there was some inconsistency in the results between samples for the majority of cognitive domains (Brown et al., 2012). This may reflect a number of factors, one being sample differences as not all samples showed change is social activity over time, or differences in measurement approaches. It may be that social activity, when examined independently, is a proxy for other factors that show a stronger relationship with cognitive decline in aging. In a follow up study, it was found that within person change in social activity significantly predicted within person cognitive activity which in turn predicted within person change in cognitive performance (Brown et al., 2016). Thus, it is important to consider possible pathways through which social factors may be related to cognitive function as finding more proximal factors may be important in understanding the relations.

Current hypotheses on how social factors may impact age-related cognitive decline have origins both in the literature on social impacts on health and the literature on "lifestyle", "engagement" or "enrichment" effects on cognitive decline. One of most comprehensive models of the influence of social factors on health outcomes is Berkman and colleague's (2000) model which outlines a "cascading causal process" through which social integration affects health. The model delineates four pathways through which social networks influence behaviour: provision of

social support, social influence, social engagement and attachment, and access to resources and material goods (Berkman et al., 2000). Moving further down the cascade, four, more proximate, pathways through which the above psychosocial and behavioral factors affect health status are outlined as: physiological stress responses, psychological states and traits (e.g., self-esteem, self-efficacy, security), health-damaging behaviors such as tobacco consumption or high-risk sexual activity, health promoting behavior such as appropriate health service utilization, medical adherence, and exercise, and lastly through exposure to infectious disease agents such as HIV, other sexually transmitted diseases or tuberculosis (Berkman et al., 2000). Others group them differently but highlight a similar set of pathways (Deindl, Brandt, & Hank, 2016; Fiorillo & Sabatini, 2011). These frameworks focus on how social factors influence health, and while some pathways may be equally relevant for cognitive function, others such as through infectious disease, may be related to cognitive function in only very specific cases and are unlikely to explain a large proportion of the association in population-based studies. Drawing from these frameworks and the literature on enrichment effects and cognitive decline, evidence for two specific pathways for the association between social factors and cognitive function specifically is reviewed.

Psychosocial Factors

Social factors may be associated with cognitive function in aging through psychological pathways. Links between social factors and psychological well-being in older adulthood are well established with both cross-sectional and longitudinal associations found in the literature. Those who report greater social support are less likely to suffer from depression (Blazer & Hybels; Cherry et al., 2013; Lin & Dean, 1984), while those with lower social support report greater

psychological distress (Couture, Larivière, & Lefrançois; Cruza-Guet, Spokane, Caskie, Brown, & Szapocznik, 2008; Matt & Dean, 1993). Matt and Dean (1993) found a cross-lagged effect over a 22-month period such that, for those aged 71 or older, higher received social support from friends predicted lower psychological distress. Notably, higher psychological distress also predicted lower social support for the oldest group, but for the group aged 50 to 70 years old, this cross-lagged effect was not found (Matt & Dean, 1993). Similarly, older adult's perception of having someone to have fun with predicts lower psychological distress two years later (Robitaille, Orpana, & McIntosh, 2012). Although much of the research has focused on social support, social activity participation has also been related to decreases in depressive symptoms and increased positive affect (Chao, 2016; Hong, Hasche, & Bowland, 2009). In a longitudinal study including over 5,000 older adults, those who were consistently more socially active were less likely to be initially depressed and their depressive symptoms decreased across time (Hong et al., 2009). In a longitudinal study of older adults in Taiwan, those who increased their intellectual, social and physical activities between waves reported fewer depressive symptoms at follow-up compared to those who maintained the same activity level. Increased social activity was independently related to depressive symptoms and increases in social activity participation were also related to higher positive affect at follow up (Chao et al., 2016). Thus, although there is likely a reciprocal relationship, with individuals who are depressed being less likely to participate in social activities, there is evidence that social activity can be a precipitating factor. Deficits in concentration, learning, and episodic memory, and executive functions have been identified as cognitive features of depression (Austin, Mitchell, & Goodwin, 2001). Further, baseline positive affect independently predicts risk of cognitive decline (Dolcos, MacDonald, Braslavsky, Camicioli, & Dixon, 2012). When considering the impact of social factors on

psychological pathways the quality or perceptions of social relations may be more important than simply social network numbers, as several studies have found that unsupportive social relationships do not confer psychological benefits, and relationships high in strain are actually related to greater psychological distress (Uchino, Holt-Lunstad, Smith, & Bloor, 2004). For older adults, better quality of family relationships including satisfaction with one's marital situation and the quality of relationships with children and extended family members, was significantly related to better psychological well-being, but quantity of social ties alone did not relate to psychological well-being (Ryan & Willits, 2007). Strained relationships have been related to lower life satisfaction and poorer mental health, an effect that is particularly strong for strained spousal relationships (Carr, Cornman, & Freedman, 2016; Lee & Szinovacz, 2016). Thus, it is important to consider perceived social support or relationship quality.

Two theories for how social support impacts health are the stress-buffering model and the main-effects model, which may also be pathways through which social support is related to cognitive function. The stress-buffering model proposes that social support reduces the impact of stressful experiences by enabling effective coping strategies and encouraging less threatening interpretations of events (Cohen, 1988). Social contacts may provide emotional support, information, and resources necessary to moderate how an event is viewed, attenuating or eliminating negative reactions (Cohen, 1988). Social contacts may also provide social support that enables individuals to better adapt following a traumatic or stressful event (Charuvastra & Cloitre, 2008; Kawachi & Berkman, 2001; Mancini & Bonanno, 2009). The buffering hypothesis proposes an interaction whereby social factors are particularly important and become activated under conditions of stress. Given, that chronic stress has been associated with episodic memory and some executive functions, social factors may also be particularly important for these

cognitive functions if the stress-buffering hypothesis were supported (Franz et al., 2011; Head et al., 2012). Alternatively, in the main effect model, social support, regardless of current stress, is suggested to promote positive psychological states such as self-esteem, self-efficacy, security, and lower risk of depressive symptomatology (Berkman et al., 2000; Sheldon Cohen, 2004; Hertzog et al., 2008).

Lifestyle Activity Factors

Social engagement, considered a key component (along with physical and cognitively stimulating activities) of an enriched or active lifestyle, has been hypothesized to decrease age-related cognitive decline and lower the likelihood of AD (Hertzog et al., 2008). The premise that cognitive function in older adulthood can be maintained through continuing to engage in cognitively stimulating activities has also been described as the "use it or lose it" principle (Bielak, 2010; Hertzog et al., 2008; Hultsch et al., 1999) and the cognitive reserve hypothesis (Stern, 2002). "Use it or lose it" is a principle of experience-dependent brain plasticity such that synaptic connections that are not sufficiently engaged will weaken and be lost over time (Kleim & Jones, 2008). When cognitive abilities are used and challenged, the synaptic connections enabling those abilities will become stronger and more efficient over time enabling improved plasticity in conditions of challenge (i.e., "use it and improve it":(Kleim & Jones, 2008; Lövdén et al., 2010). Similarly, the cognitive reserve hypothesis proposes that continued engagement in cognitively complex activities builds up a reserve of compensatory resources that allow for maintained cognitive function even in the presence of neurological damage or disease (Park & Reuter-Lorenz, 2009; Stern, 2002). Social factors may benefit cognitive function in older adulthood because maintaining social ties and engaging in social interactions is cognitively

complex, because many activities with a social component also include a cognitive component (e.g., card games), or because the social component provides motivation for participation in more cognitively stimulating activities.

Several studies have used longitudinal designs to investigate the associations between activity engagement and cognitive change. Mackinnon, Christensen, Hofer, Korten, and Jorm, (2003) found in a sample of 294 adults over 70 years old that deterioration in activity levels over the three-year study period (including a variety of cognitive, social and physical activities) was correlated with deterioration in multi-test indices of cognitive speed, memory and crystallized intelligence. However, they note that cognitive decline across domains was also observed in those who showed no decline in activity participation and that the rate of cognitive decline did not differ between those who showed activity decline and those who did not. Another study investigating the associations between social, fitness, and cognitive activities and risk of cognitive decline found that increased engagement in leisure activities was associated with an approximately 40% reduction in risk of cognitive decline by follow up one to two years later, independent of age, gender, education, and other confounding risk factors (Niti, Yap, Kua, Tan, & Ng, 2008). Interestingly they found that "productive" activities showed the strongest inverse association with cognitive decline while the association between physical activity and cognitive decline became non-significant once other activity types (i.e., social and productive) were taken into account. The association between leisure activity and cognitive decline was more pronounced among APOE-ε4 carriers (Niti et al., 2008). However, their assessment of cognitive decline was operationalized as a one or more point decline in MMSE score, a limited measure. Newson and Kemps (2005) found that greater participation in lifestyle activities, including household maintenance, domestic chores, social activities and service to others (e.g., volunteer

work) at baseline was associated with higher levels of current cognitive functioning and predicted change scores 6 years later for processing speed, picture naming, and incidental recall. However, lifestyle activity participation did not predict change in verbal fluency. There is some evidence suggesting that activity participation and social network factors may interact in their associations with cognitive function (Litwin & Stoeckel, 2016). Litwin et al (2016) found that activity engagement showed a stronger positive association with cognitive recall (B = .191) than social network resources (B=.073) when each was examined in the absence of the other. However, the two interacted such that the association between activity participation and cognitive recall decreased as social network resources increased controlling for age, socioeconomic characteristics, country, and health.

Social factors may also motivate other healthy behaviors which in turn benefits cognitive function (Berkman et al., 2000; Kuiper et al., 2015). Being involved within religious groups has been linked to lower levels of tobacco and alcohol use in adults (Krause, 2008) as well as greater physical activity and exercise (Idler & Kasl, 1997). Community involvement such as being involved in volunteer work and community organizations has been associated with healthier lifestyles (Musick & Wilson, 2007). Conversely, the loss of important relationships is related to less healthy lifestyles. Being widowed is associated with unhealthy weight loss (Eng, Kawachi, Fitzmaurice, & Rimm, 2005; Umberson, Liu, & Powers, 2009), more smoking, and a more sedentary lifestyle (Wilcox et al., 2003). However, some research has found that the decline in health that typically follows widowhood does not occur when other social ties step up, possibly because social control from multiple sources can influence health habits (Williams & Umberson, 2004). However, the influence of social ties on lifestyle is not always positive (Christakis & Fowler, 2007).

Linking Social factors, Cognitive Function, and the Brain

Cognitive performance in aging is increasingly constrained by biology as neuroanatomical and neurophysiological changes occur (Glisky, 2007). However, despite these limitations on the upper limits of performance, neuroplasticity is possible throughout the lifespan and there is often room for improvement (Hertzog et al., 2008; Lövdén et al., 2010). Although some changes such as decreased brain volume are typically observed in aging, there are differences between individuals (and brain regions) in the rates of change (Raz, Ghisletta, Rodrigue, Kennedy, & Lindenberger, 2010). Further, the formation of neuropathologies such as neurofibrillary plaques and tangles, and micro-infarcts are increasingly common with age but also show individual differences in extent and frequency of pathology. In theory, social factors may interact with these age-related physical process (e.g., neurotransmitter function, formation of neuropathology) or features of the brain (e.g., structural features, cerebrovascular health) to affect change in cognition in a number of ways. Bennett, Arnold, Valenzuela, Brayne, and Schneider (2014) outline three pathways linking lifestyle factors to cognitive function through physical measures in the brain. The first is that a lifestyle factor may be directly related to more or less neuropathology. The second is "a modulatory effect such that the lifestyle factor alters the relation of pathology to cognition, i.e., increases or decreases the probability of dementia for a given level of neuropathology" (Bennett et al., 2014). The third possibility is a relationship between lifestyle, cognition, and other indices such as neuronal density or structural markers such as cortical thickness (Bennett et al., 2014).

To date there has been little evidence to suggest that any social factors are directly related to Alzheimer's disease pathology (Bennett et al., 2014). Social network size was not found predictive of either cognition proximate to death or amyloid load or tangle density (Bennett,

Schneider, Tang, Arnold, & Wilson, 2006). However, social networks modified the relation of both amyloid and tangles with cognition such that amyloid and tangles had little effect on cognition in the presence of a large network even after controlling for cognitive, physical, and social activity, depressive symptoms, and number of chronic diseases (Bennett et al., 2006). Thus, those with larger social networks are better able to functionally compensate for disease pathology. This is consistent with the cognitive reserve hypothesis (Mortimer, Snowdon, & Markesbery, 2003). However, the neurobiologic basis of these plastic responses remains to be determined (Bennett et al., 2014).

There is also some evidence of associations between social factors and structural brain markers. One study of neuronal density and cortical thickness matched pairs of high and low engagement participants (engagement was based on a composite of educational attainment, occupational complexity, and social engagement), and found that the more engaged group had a higher neuronal density and greater cortical thickness (Valenzuela, Brayne, Sachdev, & Wilcock, 2011). Further, although not a direct pathway, social support may impact structure and function of the brain through stress, which, has been related to social support and psychological factors.

Allostasis means "maintaining stability (homeostasis) through change and has been used to refer to the neuroendocrine response to stress (McEwen & Wingfield, 2003). During stressful experiences glucocorticoid hormones and catecholamines are secreted by the adrenal glands and these hormones regulate the body's response the stressor and influence cognitive functions (de Kloet, Oitzl, & Joëls, 1999; Roozendaal, 2002; Sapolsky, Romero, & Munck, 2000). Allostatic load refers to the 'wear and tear' that occurs with repeated cycles of allostasis and/or inefficient turning off of the response (McEwen, 1998; McEwen & Stellar, 1993). The accumulation of physiological wear and tear has been suggested as the casual pathway through which stress

impacts cognitive function. Higher allostatic load has been associated with greater cognitive decline (Karlamangla, Singer, McEwen, Rowe, & Seeman, 2002). Prolonged hypercortisolism is associated with smaller hippocampal volume and slower brain glucose metabolism (Sapolsky et al., 2000). Chronic hypercortisolism is also associated with altered cognitive function, particularly memory and frontal-striatal mediated abilities such as executive functioning, and increased risk for dementia and Alzheimer's disease (Epel, 2009; Franz et al., 2011). Other markers of the stress response may also provide insights in the links between stress and cognitive function. The occurrence of multiple daily stressors is associated with elevated systemic interleukin-6 (IL-6) and C-reactive protein levels, both markers of chronic inflammation. Elevations in indicators of inflammation, specifically IL-6 and C-reactive protein (CRP) levels, have been associated with increased incidence of depression, cardiovascular disorder, diabetes, certain cancers, autoimmune diseases, frailty, and mortality (Maggio, Guralnik, Longo, & Ferrucci, 2006). Incidence of depression and psychiatric illness has been consistently associated with chronic stress which may further affect HPA axis regulation, and compromise individuals' responses to stress (Marin et al., 2011).

There is considerable overlap between the proposed pathways through which social factors influence cognitive function and pathways through which social factors may impact various other aspects of health. Various social factors have been related to aspects of health. Satisfaction with one's relationships with friends significantly predicted self-rated health over and above the impact of frequency of interactions, and participation in various social activities (Fiorillo & Sabatini, 2011). Single or divorced older adults showed poorer performance on basic measures of physical functioning than their partnered counterparts (Clouston, Lawlor, & Verdery, 2014) while being dissatisfied with one's social network and having fewer social ties outside of one's

partnership were also associated with poorer respiratory function (Clouston et al., 2014). Lonely older adults are also more likely to present alterations in the immunological system (Hawkley & Cacioppo, 2004), smoke, be obese (Lauder, Mummery, Jones, & Caperchione, 2006) and have lower health status (Rico-Uribe et al., 2016). There is also increasing evidence linking physical health and disease to cognitive function (Hertzog et al., 2008). Even in the absence of disease, measures of cardiovascular health have been linked to cognitive function through their relationship with cerebrovascular health (Qiu & Fratiglioni, 2015). Thus, it is possible that both pathways proposed for the impact of social factors on cognitive function, through lifestyle and through psychological factors, overlap with pathways by which social factors influence health which also impact cognitive functioning.

Issues in the Study of Social Factors and Cognitive Function

There are a number of challenges to clarifying pathways of association between social factors and cognitive function. First, the temporal course through which social factors may influence psychological, lifestyle factors, and cognitive function are not well understood. Early life social experiences, such as the emotional support received from one's parents, continue to impact social and psychological functioning across the lifespan through relatively stable traits like personality and interpersonal style (Gallo & Smith, 1999). In turn, certain interpersonal styles, such as hostility, are reciprocally associated with worsening social relations over time while warmth is associated with better interpersonal relations (Gallo & Smith, 1999). Neuroticism is a relatively stable trait suggested to be a good indicator of the cumulative level of psychological distress that an older adult has experienced over their life course because of its high association with negative emotions and negative life events (Hertzog et al., 2008). Similar

to psychological distress, neuroticism has been associated with increased incidence of Alzheimer's disease and mild cognitive impairment in old age and higher neuroticism predicts a more rapid cognitive decline. This is particularly true among the oldest age groups (>70) as these relations were not found in studies including a younger cohort (mean age <70) (Hertzog et al., 2008). Hertzog et al. (2008) suggest that this is consistent with the premise that psychological distress and depression are damaging to cognition when accumulated over long periods of time. Similarly, it remains unclear over what time frame lifestyle factors that may confer cognitive reserve operate. It may be that reserve is accumulated over the lifespan or that benefits can be reaped relatively quickly with lifestyle changes. Examining cross-sectional, or baseline associations as well as associations with changes over time are crucial for differentiating these two possibilities.

Another substantial challenge is the possibility for reverse causality and reciprocal relations. One alternative hypothesis is that cognitive decline reduces social functioning, and prompts individuals to withdraw socially as they find the cognitive demands increasingly difficult to manage (Washburn, Sands, & Walton, 2003). Few studies have examined dynamic associations between social factors and cognition. However, those that have had found mixed evidence with one study finding evidence that men withdraw from social opportunities due to cognitive decline, but supported the premise of social causation for cognitive decline in women (Thomas, 2011). Others have found evidence of bidirectional associations between social networks and cognitive function and for social factors as the causal influence (Ellwardt et al., 2015; Li & Zhang, 2015). There is also evidence that cognitive function impacts social and psychological factors over the lifespan. For example, lower estimated IQ was associated with greater loneliness (O'Launaigh et al., 2012). Individuals who showed greater change in IQ

between childhood and age 79 were lonelier than those who showed less change in IQ (Gow et al., 2007).

A Framework for the Relations between Social Factors, Psychological Factors, and Cognitive Function

Building on the reviewed theories and evidence, Figure 1 presents a general conceptual framework for the impact of social factors on cognitive function in older adulthood. Social factors, such as social network, social support, and social engagement are dynamically linked to psychological factors, lifestyle factors, health, and cognitive function. Direct and indirect relations between all components are possible. It is also assumed that there is at least the possibility for reciprocal causal relations, for example, with social network impacting lifestyle factors (e.g., other activity participation) while activity participation may also increase social network size through providing opportunities for social connections. Within the broad categories included in the framework it is assumed that there are subcategories that may show differential relations to other subcategories. Another key point is that the psychobiological pathways of relations may differ between the different pathways and perhaps by subcategory. For example, as reviewed above, the weight of the evidence suggests that a cognitively engaged lifestyle is protective against cognitive decline through the conference of cognitive reserve (rather than a reduction in Alzheimer's disease pathology) (Bennett et al., 2014). Whereas loneliness may affect specific domains of cognitive function primarily through an interaction with the stress-response. Finally, it is acknowledged that this conceptual model of relations is situated within the individual's broader social and economic circumstances and that the relative strengths and directions of relations may be influenced by such factors that are not included in this model.

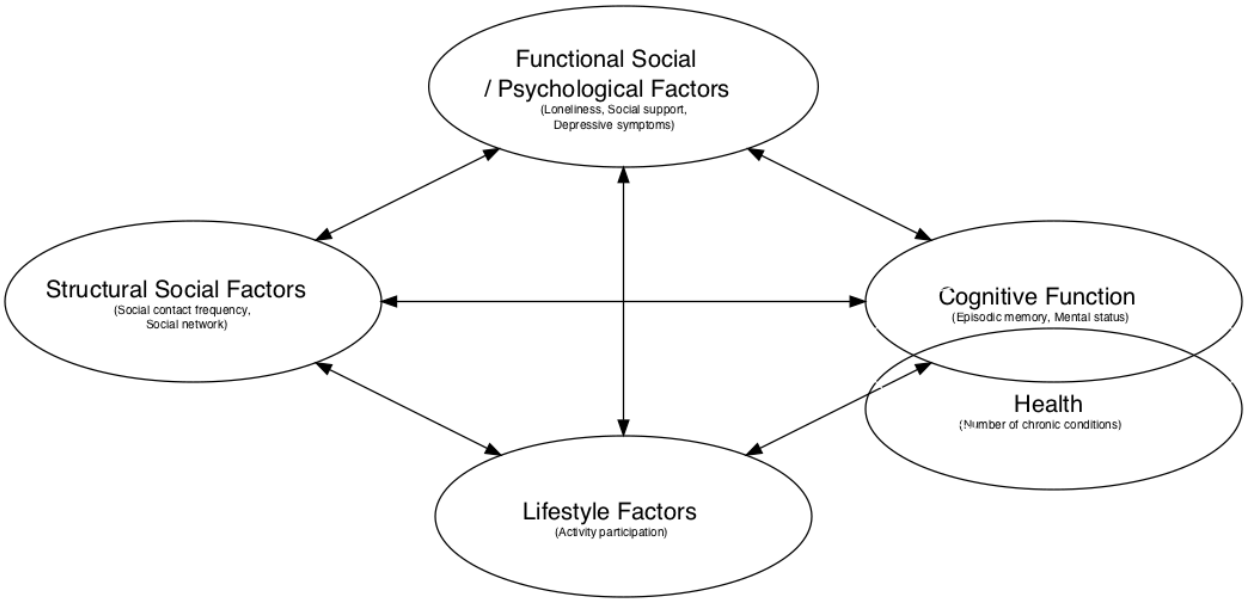

Figure 1. A model of pathways of association between social factors and cognitive function with corresponding specific variables in parenthesis.

Testing Particular Pathways of the Model

The model proposes that the more structural aspects of social relations (i.e., social network, social contacts) and functional/psychological aspects (i.e., loneliness) are dynamically linked and these may have differential relations to different cognitive outcomes. It may be that social isolation leads to loneliness and loneliness leads to social isolation, and both lead to cognitive declines with the relative order of each being inconsequential. However, if this is the case, there are implications for intervention because individuals at risk of social isolation due to environmental factors rather than psychological ones (e.g., caregivers) may become at risk for negative psychological sequalae. The first study focuses on the specific pathways between structural social factors and cognitive functions and functional social/psychological factors and cognitive functions (see Figure 2), and the second study also focuses on these pathways but examines whether changes occur as with when caregiving status changes. The third study

focuses on the relations between social and psychological factors, specifically examining the hypothesis that psychological factors, including social anxiety, fear of negative evaluation, and rejection sensitivity, will be related to loneliness and social activity participation (see Figure 3).

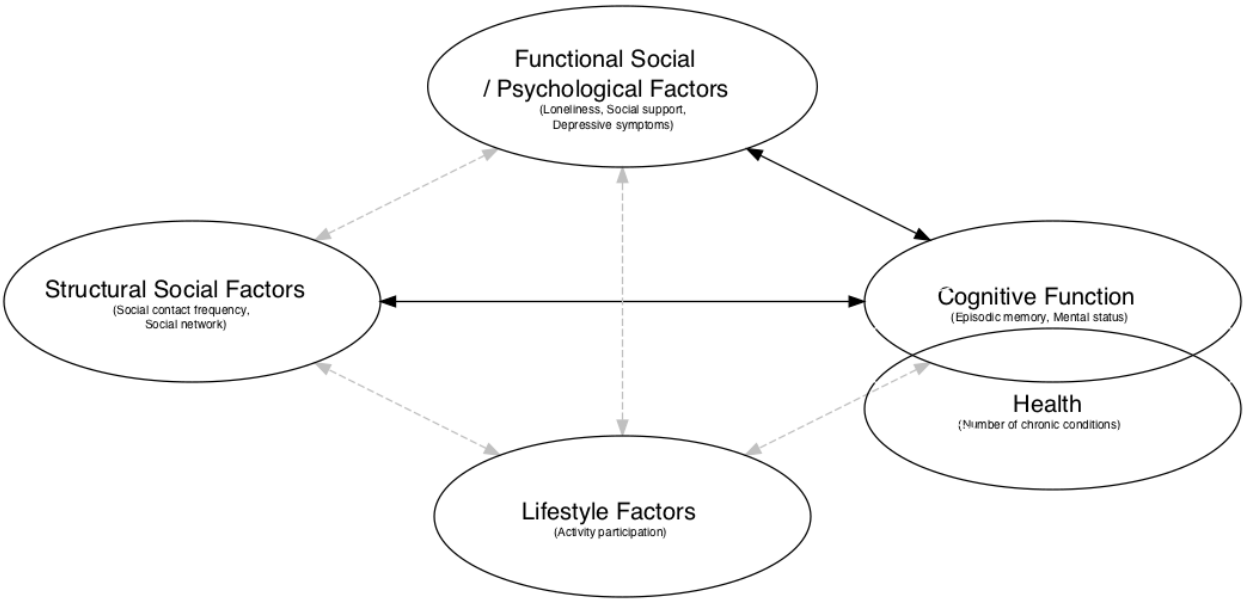

Figure 2. Specific pathways of the model examined in studies one and two. Unexamined pathways illustrated with dotted grey lines.

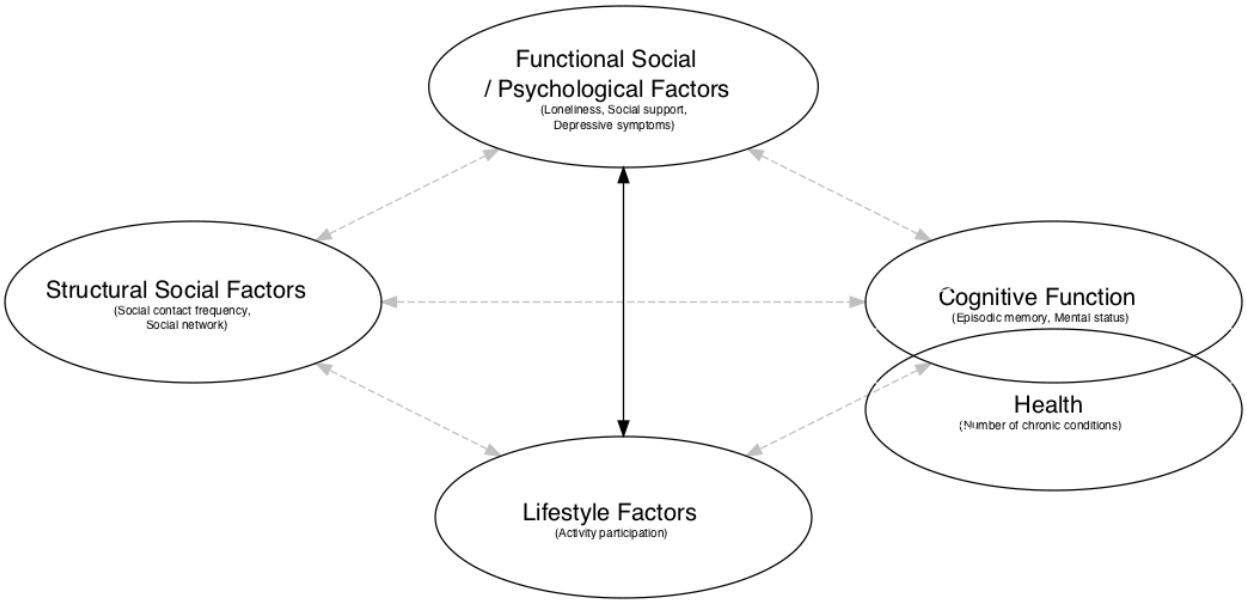

Figure 3. Specific pathways of the model examined in study three. Unexamined pathways illustrated with dotted grey lines.

Chapter 2: Structural and Functional Aspects of Social Relationships and Cognition in Aging

Abstract

Objective: Links between social relationships and maintenance of cognitive functioning in older adulthood is a topic of considerable interest. Yet important questions remain about the presence and nature of associations. This investigation aims to address several of these questions. First, we evaluate whether relations with cognitive performance over time differ for structural versus functional/subjective aspects of social relationships (i.e., social network and social contact versus loneliness and social support). Second, we investigate whether associations are primarily between stable, "trait-like" components of social relationships and cognitive performance or whether fluctuations "i.e., state-like" components of these constructs are more consistently related. Third, we examine the direction of the relations between components of cognitive and social factors. Fourth, the impacts of age, education, gender, cohort, and health conditions on these relations are considered.

Method: The sample included up to 5810 participants from each of six waves, in years 2004 and later, of the Health and Retirement Study. Those who were 65 years old or older in 2004 (mean 2004 age = 72.12 years, SD = 5.82) and had data for at least one wave of cognitive and psychosocial variables were included. Autoregressive latent trajectory (ALT) models were used to investigate whether social network, social contact, social support, and loneliness were related to memory (immediate and delayed) and mental status. Separate models for each social and cognitive variable combination were estimated.

Results: Comparisons of fit indices of bivariate ALT models favored models with level, linear change, and autoregressive parameters of cognitive variables estimated but only level and autoregressive parameters of social variables. Associations between overall levels of cognitive performance and social factors were not found, indicating that "trait-like" components are not

related. However, reciprocal cross-lagged relations were common between social factors and cognitive performance, specifically memory and mental status.

Conclusion: There was little support for a link between “trait-like” level of social variables and “trait-like” levels of cognitive performance. However, there was evidence of a reciprocal link between fluctuations in cognitive performance and social factors. These results are novel in applying ALT models to examine the relations between state- and trait-like components of both structural and functional aspects of social relationships over time.

Introduction

With great gains in life expectancy and those over 80 representing the fastest growing age group in several developed nations (He et al., 2016), identifying factors that contribute to successful aging is of key importance. Social isolation in older adulthood is an increasingly prominent issue in light of evidence that many older adults are socially isolated, which has implications for quality of life and wellbeing (Chen & Freely, 2014). Further, the link between social relationships and mortality risk is robust and well established (Holt-Lunstad et al., 2010). Cognitive changes in older adulthood are one of the major sources of declining functioning and most likely reasons for an older person to require extended care (Agüero-Torres, von Strauss, Viitanen, Winblad, & Fratiglioni, 2001). Although some research has suggested that social relationships are related to cognitive decline in older adulthood, current evidence is mixed and important questions remain.

Social relationships are complex and involve many facets that can be measured in different ways. It is not clear if different aspects of social relations are differentially related to different cognitive functions. A broad distinction is made between functional and structural aspects of social relationships. Functional aspects of social relationships include elements such as the provision of social support and relationship quality (i.e., how well the relationship is meeting needs), while structural aspects include social network size and frequency of contact with others which indicate the presence of social ties but not necessarily perceptions of quality (Holt-Lunstad et al., 2010).

Overall, social network characteristics have shown inconsistent relations to indicators of cognitive change in older adulthood (Agüero-Torres et al., 2001; Green et al., 2008; Holtzman et

al., 2004; Seeman et al., 2001; Zunzunegui et al., 2003). Some studies have found protective effects of greater social network size on mental status (Holtzman et al., 2004; Zunzunegui et al., 2003) while others have failed to find such effects (e.g., Green et al., 2008). Holtzman and colleagues (2004) examined maintenance of Mini-Mental Status Exam (MMSE; Folstein, Folstein, and McHugh, 1975) performance among a group of adults over 50 years old and found that those with larger social networks at baseline had reduced odds of decline by the third wave of assessment. However, Green et al. (2008) found that social network size was not protective against later cognitive decline as measured by the MMSE performance and a delayed recall task. Notably, these studies investigated the relations between baseline social network and change in mental status but did not examine whether changes in social network and changes in mental status co-occur.

It may be that actual social contact is a more direct protective factor against cognitive decline than simple counts of social network members. However, studies investigating social contact have also shown mixed results. In one study, frequency of interactions with social network members and emotional support received were both examined; no associations between these variables and change in MMSE or delayed recall performance over time was found (Green et al., 2008). Yet in another study investigating social contact, Beland (2005) found that older adults (over 65 years old) with higher levels of family ties and social engagement with relatives maintained better cognitive function up until 80 years of age, though after 80 the difference diminished. In this study, social relationship variables were included as time-varying predictors of cognitive function, with age as the temporal variable.

It may be that it is subjective evaluations of one's social relationships and whether one perceives one's social relationships as meeting needs that is related to cognitive function. Overall fewer studies have investigated the relations between social support and cognitive function and several of those that have included it as part of a larger group of social measures (Hertzog et al., 2008). In one cross-sectional study, including individuals over age 55 who participated in the NIH Toolbox normative study, a significant association was found between emotional support and executive function and processing speed, controlling for a variety of covariates including general health status, education, negative affect and a number of indicators of positive affect (Zahodne et al., 2014). However, no associations were found between emotional support and working or episodic memory. No other psychosocial variables examined (life satisfaction, positive affect, friendship, loneliness, instrumental support or negative affect) were related to any of the cognitive domains after accounting for other variables in the model. The authors note that this pattern was maintained even after restricting the sample to what is typically considered older adults (age 65 plus) (Zahodne et al., 2014). Ellwardt et al. (2015) investigated the longitudinal relations between emotional and instrumental support, loneliness, and cognitive function using data from the Longitudinal Study of Aging Amsterdam (LASA). They found that an increase in received emotional support over time was related to an increase in cognitive functioning and a decrease in loneliness. However, a mediation analysis, did not reveal an indirect effect of emotional support on cognition through loneliness. The effect of increased emotional support over time had a larger and more direct effect on cognitive functioning than an initially high level (intercept) of emotional support. Interestingly, increased instrumental support was related to a decrease in cognitive functioning perhaps reflecting social network members recognition of increased need for instrumental support due to declining cognitive function (Ellwardt et al.,

2015). In another study, greater baseline loneliness was found to be a significant predictor of global cognitive decline from baseline at 10 year follow up (RR = 3.0, 95% CI = 1.4–6.8) (Tilvis et al., 2004).

Even studies examining cross-sectional, single time point, associations between loneliness and specific domains of cognitive function have showed more mixed results. Lonelier individuals showed poorer immediate recall in some cross-sectional studies (Gilmour, 2011), but other studies failed to find a significant relationship (O'Luanaigh et al., 2012; Schnittger et al., 2012). Loneliness was also related to delayed recall in some (O'Luanaigh et al., 2012) but not all studies (Gilmour, 2011; Schnittger et al., 2012). In their cross-sectional study, O'Luanaigh et al. (2012) also reported no significant associations between verbal fluency and loneliness when controlling for depression, social networks, and a range of demographic factors. Relations between loneliness and executive functions have also been examined cross-sectionally. Although a negative association between loneliness and semantic fluency, which can be considered a measure of executive functioning, was found, in a multivariable model that included social interaction the association was no longer significant (Gilmour, 2011). Another study also reported a negative correlation between loneliness and executive function but found that in a multiple linear regression model that included depression, neuroticism, perceived stress, solitary living, and accommodation status the association was no longer significant. This suggests that impact of loneliness on executive function may not be a unique contribution, but rather overlaps with other constructs, such as psychological distress, or lack of cognitively stimulating activities that are also related to executive functioning. One consistent finding is the negative association between loneliness and processing speed that remains even after controlling for relevant

confounds such as depression, social network, and other cognitive and demographic factors (Boss et al., 2015; Gilmour, 2012; O'Luanaigh et al., 2012).

Several studies have used longitudinal data to examine associations between loneliness and cognitive function but fewer conducted longitudinal analysis and, although baseline (cross-sectional) associations were common, few longitudinal associations were found. In a longitudinal study with 4 years of follow-up, immediate and delayed recall performance were significantly and negatively associated with loneliness at baseline and four-year follow-up (Shankar et al., 2013). However, for delayed recall, higher levels of isolation and loneliness were associated with poorer recall in individuals with lower levels of education only. Greater loneliness was also significantly associated with low levels of verbal fluency at baseline ($p < 0.001$), but not at follow-up (Shankar et al., 2013). Wilson et al. (2007) found that those reporting greater loneliness at baseline had lower episodic, semantic, and working memory performance at baseline. However only the relations between semantic memory and baseline loneliness was significant at the fourth year follow-up when controlling for age, gender, and level of education. Schnittger et al. (2012) reported that verbal fluency was a significant risk factor of social loneliness.

Donovan et al. (2017) found that baseline loneliness significantly predicted cognitive decline over a 12 year period and that baseline cognitive function predicted greater odds of loneliness over the 12 year follow-up, but this relationship became non-significant when controlling for depression while baseline loneliness continued to predict cognitive decline with marginal significance. Gow and Mortenson (2016) found in a study using 30 years of data that marital status at ages 50 and 60 and loneliness at age 70 were associated with cognitive change over time whereas social contact and social support failed to predict cognitive change.

In the Rush Memory and Aging Project (MAP), the relation between loneliness, cognitive outcomes, and AD pathology was examined (Wilson et al., 2007). For the over 800 participants who completed the loneliness scale, loneliness was related to the development of incident AD and to rate of cognitive decline. This remained true after controlling for numerous other factors including social networks, social, cognitive and physical activities, disability, and depressive symptoms. As part of participation in MAP, individuals are asked to donate their brain and spinal tissue to the study for autopsy. Over the study period examined, 135 people came to autopsy. In this group loneliness was not related to amyloid load, tangle density, or cerebral infarctions (Wilson et al., 2007). The authors interpret this as indicating that loneliness is related to whether or not there was a clinical manifestation of Alzheimer disease, in the presence of disease pathology, but not to the pathology itself.

Thus, there is some evidence for associations between a variety of social relationship factors and cognitive change in aging but there is no clear pattern indicating which social relationship factors are related to what aspects of cognitive functioning in older adulthood, highlighting the need for further research. Identifying individual social relationship factors related to cognitive change in aging is important for several reasons. First, they have different implications for possible interventions. If objective/structural social relationship factors are important for cognitive function, then intervening at this level, by providing opportunities for social contact and increased social network size may reduce the severity of cognitive decline. However, interventions that target feelings of not being supported by ones' social network members, or feelings of loneliness may not be resolved by increasing social contact opportunities and these individuals may benefit from a more comprehensive intervention. Second, this distinction is important because the mechanistic pathways through which structural/objective social

relationship measures and functional/subjective social relationship measures are related to cognitive function may differ.

Many studies do not examine change in both social and cognitive measures and instead use baseline measures of social factors to predict trajectories of cognitive function. When a single measurement is taken at a particular occasion, both the relatively stable individual trait (e.g., general sociability, tendency to feel loneliness), and fluctuating components that may be more related to factors unique to that particular occasion are included in each person's score. This is true for each of social relationship factors discussed as well for cognitive functioning. Distinguishing between these components is important, as it is possible, and perhaps likely, that one has a relationship to cognitive performance while the other does not (Hoffman & Stawski, 2009). Further, relations between fluctuating "state-like" components have different implications than relations between relatively stable "trait-like" components. Stable "trait-like" or "level" components of social network, social contact, perceived social support, and loneliness likely reflect a myriad of factors including personality and socioeconomic status that may themselves be related to cognitive performance and risk of cognitive decline. In the present study examining the relations between both "trait-like" and "state-like" components provides a way of separating out the impact of relatively stable factors such as socioeconomic status. Within the social realm it is likely that an individual's general sociability and their present circumstance (e.g., access to social contacts, marital status, etc.) are components of any single assessment. Thus, predicting later cognitive changes from a single data point at baseline means it is difficult to disentangle in what way the social relationship factor is related to cognitive function many years later.

Much of the existing literature uses latent growth modeling (LGM) to examine intra-individual stability. The LGMs used in previous research do not provide information regarding autoregressive relationships or time-specific relationships. Autoregressive latent trajectory models allow for the examination of both state-like and trait-like components simultaneously. This means that a bivariate autoregressive latent trajectory model (ALT) can be used to examine relations between both components of each variable (Morin, Maiano, Marsh, Janosz, & Nagengast, 2011). Further, the ALT model can include cross-lagged components to allow examination of the dynamic interplay of social relationship and cognitive factors. This is an important advantage as the temporal relationship between social relationship factors and cognitive performance is unclear.

The present study aims to answer the following questions:

1. Do structural, specifically social network size and social contact, and functional, specifically social support and loneliness, social relationship factors show linear change over time?
2. Is there a relationship between levels of social relationship factors and levels of cognitive performance?
3. Is there a relationship between linear trajectories of social relationship factors and linear trajectories of cognitive performance?
4. What is the direction of the “state-like” relations between social relationship factors and cognitive performance?

Method

Participants

Participants were drawn from the 2004, 2006, 2008, 2010, 2012, and 2014 waves of the Health and Retirement Study (HRS). The HRS is a nationally representative longitudinal panel study of individuals over the age of 50 and their spouses of any age in the United States of America. Specifically, the RAND HRS data files (Bugliari et al., 2016) were used as they are more user-friendly. The HRS is supported by the National Institute on Aging (NIA U01AG009740) and the Social Security Administration. In 2004, the HRS piloted a self-completed psychosocial questionnaire administered to a random sample of respondents. Beginning in 2006, the HRS began enhanced face-to-face interviews on a rotating basis with 50% of the core panel. The respondent psychosocial questionnaire was administered to an alternating 50% of the core panel, every 2 years, resulting in longitudinal data for the same participants every 4 years. In the present analysis, participants were excluded if they did not have at least one wave of response data for all cognitive and social variables of interest, or if they reported ever having received a diagnosis of "memory-related disease", Alzheimer's disease, or dementia. Information was not included from participants if they were younger than 65.

Measures

Demographics. Age at each occasion, gender, race, and years of education were gathered based on self-report. There were six included cohorts based on birth year. Cohort was coded as a nominal variable.

Social network diversity. Respondents were asked four questions about their social network composition: specifically, whether they have spouses/partners, children, other family,

and friends (Smith et al., 2013). To each question they could respond yes ‘1’ or no ‘0’, for a maximum possible total of 4.

Social contact. Respondents were also asked the extent to which they are in contact with members in their social network (excluding spouses) (Smith et al., 2013). For each group (children, other family, and friends), participants responded to three questions regarding how often they ‘Meet up’, ‘Speak on the phone’, and ‘Write or email’. Responses were given on a 1 = Three or more times a week to 6 = Less than once a year or never, scale. Responses were reverse coded and a summed for a total score of overall contact with social network for a maximum possible total of 54.

Social support/relationship quality. Social support was measured by three items of a social support scale developed by Walen & Lachman (2000). Similar measurements used in previous studies were found to be reliable (e.g.,(Bertera, 2005). Three items assessing social support include: ‘‘How much do they really understand the way you feel about things?’’, ‘‘How much can you rely on them if you have a serious problem?’’ and ‘‘How much can you open up to them if you need to talk about your worries?’’. Items were asked in four loops in reference to participants’ spouse/partner, children, family members, and friends. The response options ranged from 1 (a lot), 2 (some), 3 (a little), to 4 (not at all). Items were re-coded so that a higher value indicates a higher level of social support. A total social support score was calculated by summing responses to the three social support questions for all social network categories (i.e., spouse/partner, children, family members, and friends) and dividing that by the social network total so that having social network members in more categories did not necessarily result in a higher social support score. Thus, social support indicates the extent to which individuals rate their existing social networks as supportive with a maximum possible score of 12.

Loneliness. The Revised University of California Los Angeles Loneliness Scale is a self-report measure of loneliness (Hughes, Waite, Hawkley, & Cacioppo, 2004; Russel, Peplau, & Cutrona, 1980). The Revised version of the UCLA Loneliness scale is a short form of the widely used original scale. Respondents were asked to rate, on a 3-point scale, how often they felt as if they (a) lacked companionship, (b) were left out, or (c) were isolated from others. To obtain an overall loneliness score, the mean of the three items was calculated, with a higher score representing greater loneliness (range 1–3).

General Health. General health is summarized by including a count of the number of medical conditions reported. The score is comprised of the most common medical conditions among older adults: hypertension, diabetes, cancer, lung disease, heart condition, arthritis and stroke each coded as 0 (absent) or 1 (present) for a total range of 0 –7 with higher numbers indicating a greater number of medical conditions.

Episodic Memory. Memory functioning was assessed either in a face-to-face interview or over the phone. The two modes are expected to result in comparable performance (Ofstedal, Fisher, & Herzog, 2005). Memory functioning in HRS was assessed with two memory tasks: 1) an immediate word recall task where respondents were aurally given a list of 10 nouns and asked to recall as many words as possible from the list in any order (range 0-10), and 2) a delayed verbal memory task where after 5 min of engaging in other survey questions, respondents were asked to repeat the list of nouns previously presented as part of the immediate recall task. In order to minimize the impact of prior experience with the material (at previous waves of assessment), four different lists of 10 words were constructed that contained different but equivalent nouns of one and two syllables with high frequency (Thorndike & Lorge, 1944), high imagery, and concreteness (6.0 or more according to the norms by Paivio, Yuille, & Madigan,

(1968)). Nouns meeting the conditions were ordered by recall-ability according to norms developed by Rubin (Rubin & Friendly, 1986) and distributed to six lists. The four lists used in HRS were selected for maximum equivalence in a pretest with 30 HRS respondents. The lists were randomly assigned to participants so that they were initially equal in frequency. Participants receive the lists in order so that each form will be given only once to each participant over four visits.

Mental Status. Mental status was assessed in all HRS participants aged 65 and older with a series of questions (Ofstedal et al., 2005). Respondents were asked to count backwards, as quickly as possible, for 10 continuous numbers starting at the number 20. Respondents were asked to give "today's date" including the month, day, year, and day of the week. Two object naming questions were asked "What do you usually use to cut paper?" and "What do you call the kind of prickly plant that grows in the desert?". Respondents were asked to give the name of the current President and Vice President of the United States. Responses to mental status questions were summed for a mental status total score (range 0-9).

Analytical Strategy

Autoregressive Latent Trajectory (ALT) models were proposed by Bollen and Curran (2004, 2006) to include the important features of autoregressive and latent curve models for longitudinal data analysis. In bivariate autoregressive models each subsequent time point is defined by the previous time point value on the same variable, the previous time point on a second variable, plus a random disturbance (Bollen & Curran, 2004). The first occasion of measurement is typically treated as exogenous (i.e., pre-existing and not influenced by other variables in the model) and the autoregressive and cross-lagged effects are assumed to be the same for each individual in the sample (Bollen & Curran, 2004). An example of the bivariate

autoregressive model is presented in Figure 4. Latent growth models use all observed time points to estimate a latent trajectory for each person, and deviations from one's predicted trajectory are treated as random errors (see Figure 5). In a bivariate latent growth model relations between intercept and slope factors are modeled. In autoregressive latent trajectory models these temporary "state-like" deviations from predicted trajectories can be of substantive interest and predicted from other variables in the model (Morin et al., 2011). To answer the proposed research questions, a progressive series of models was estimated, first to examine social and cognitive variables of interest individually, and then in bivariate models. Based on Bollen and Curran's (2004, 2006) recommendations, first the univariate unconditional autoregressive models, LGM, and ALT models were estimated for each cognitive and social variable to understand the trajectory and autoregressive relations of each variable individually. For ALT models, the first measurement point for all processes was included in the model as exogenous and predetermined and the time metric was study wave. LGMs are not technically nested within the ALT model because the first occasion of measurement in the ALT model is exogenous and thus not part of the estimated trajectory. To achieve a nested model, the first occasion of measurement must be modeled as exogenous then, when the cross-lagged parameters are fixed to zero; it is equivalent to a LGM nested within the ALT. Additional constraints were then added to the full ALT model: 1) fixing the slope factor's variance to zero, 2) excluding the slope factor, 3) constraining the autoregressive parameters to equality over time. Model fit was evaluated with multiple fit indices: the chi-squared likelihood ratio test, the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Standardized Root Mean Square Residual (SRMR) and the Root Mean Square Error of Approximation (RMSEA). Values greater than 0.95 indicate good fit for CFI with greater than 0.90 indicating adequate fit (Bollen, 1989). For RMSEA values smaller

than 0.08 or 0.06 are considered acceptable and good, respectively. For SRMR 0.10 and 0.08 are considered acceptable and good fit respectively (Bollen, 1989). Nested models were compared using the chi-square difference test (Bollen, 1989). The estimation of bivariate models followed a similar strategy with bivariate models estimated for each social-cognitive variable pair. For bivariate models the full ALT model was specified with correlations between the intercepts and first measurement points of the cognitive and social variable. In the full model, the autoregressive, cross-lagged parameters, and with time-specific correlations between the two processes were all modeled as unrestricted across time. In the bivariate model series restrictions were progressively added to the full ALT: (1) fixing the slope variance to zero; (2) excluding the slope factor; (3) constraining the time-specific uniqueness correlations to equality over time; (4) excluding the time-specific uniqueness correlations; (5) constraining the autoregressive parameters to equality over time (6) constraining the cross-lagged regression parameters to equality over time. The first three constraints were added first to the cognitive processes and then to the social process one at a time. In each case, if the more complex model did not result in a significantly better fit than the simpler model (i.e., the model with fewer parameters estimated or more constraints), the simpler model was retained and alternative constraints tested against this model. The CLUSTER option in Mplus was used to adjust for the cluster sampling of both spouses in HRS. All models were estimated with the MLR option for maximum likelihood estimation with robust standard errors in Mplus 7.4 (Muthen & Muthen, 2012-2015). Maximum likelihood estimation can handle even large proportions of missing data assuming missing at random, by using all available information from all cases (Muthen & Muthen, 2012-2015).

Once a final model was identified for each bivariate combination without covariates, the covariates were added to only that model. The intercept and slope parameters of each process

(the cognitive and social) and the first measurement point (specified as predetermined) were regressed on each covariate. In ALT models, because the first occasion of measurement is predetermined, the intercept is the portion of the Time-2 variable remaining unexplained by the Time-1 variable.

Results

The descriptive statistics for all included variables are presented in Table 1. Model fit indices are presented for each model series in Tables 2 through 12. Each process was investigated separately as a univariate model and then each cognitive - social combination was estimated. Univariate model results are presented in supplementary materials (Appendix A). First, the results from the process of model building for each bivariate combination are described. Then results describing each process individually (social and cognitive); including the intercept, first wave value, trajectory shape and autoregressive parameters, are summarized from the results of all final bivariate models in which that process was included. The features of each variable should remain very similar regardless of the other variable included in the model. Following the summary of each variable, the bivariate relations between variables will be presented for each bivariate model.

Initially the steps described in the analysis section for comparing a series of models were attempted for all bivariate cognitive – social combinations. However, in all bivariate combinations, convergence issues limited the number of models included in the model building process and only models that converged without issue could be included in model comparisons. In many cases this meant that the full ALT model could not actually be estimated. Estimating the slope parameter resulted in model convergence issues for at least some of the models in the series for each of the social variables, although, for some variable combinations it was possible

to estimate the social variable slope when other model constraints were added. These cases are specifically described below. Model convergence with slopes estimated was not an issue in the univariate models, and thus it is likely related to increased model complexity in the bivariate models. Many models without the slope term estimated for the cognitive variable did not properly converge, which may indicate model misspecification when the cognitive slope term was excluded, consistent with the expectation of change over time.

Loneliness Model Building Results

Full bivariate ALT models with loneliness did not converge when investigated with immediate or delayed word recall. When the slope term for loneliness was not estimated all models converged. Some models with the loneliness slope, and other model parameters constrained, did converge and so were included in model comparison.

With immediate recall. Model comparison results indicate that the slope of loneliness can be excluded, time-specific correlations can be removed, and autoregressive parameters for both immediate word recall and loneliness can be constrained to equality over time without a significant reduction in model fit (see Table 2) all other constraints resulted in poorer model fit. The final model had excellent model fit according to all fit indices.

With delayed recall. The model fit results of the bivariate ALT model of delayed word recall performance and loneliness are reported in Table 3. Model fit results show that the following constraints can be added without a reduction in model fit: the slope term for loneliness can be excluded, time-specific uniqueness correlations between delayed word recall performance and loneliness can be removed, and the autoregressive parameters for both processes can be fixed to equality over time. However, constraining the cross-lagged regression components to

being stationary over time resulted in significantly poorer model fit indicating they do change across occasions. Thus, the ALT model without the loneliness slope, time-specific correlations between delayed word recall and loneliness, and fixed autoregressions for both loneliness and delayed recall was retained. The final model had excellent model fit according to all fit indices.

With mental status. The results of the bivariate models with mental status and loneliness are presented in Table 4. This was the only bivariate model including loneliness where the full ALT model could be estimated. Progressive model constraints showed that the following constraints could be added without a significant reduction in model fit: the slope term for loneliness can be excluded, the time-specific uniqueness correlations between loneliness and mental status can be removed, and the autoregressive parameters of loneliness can be constrained to equality over time. Although models with the loneliness slope could be estimated in the models with mental status including the slope term did not improve model fit. The final model had excellent model fit according to all fit indices.

Social Contact Model Building Results

Social contact bivariate models did not converge when the slope of social contact was estimated so only models with intercept and autoregressive parameters for social contact were compared.

With immediate recall. Bivariate models indicate that time-specific correlations can be excluded, and the immediate word recall autoregressive components can be constrained to equality over time without a significant decrease in model fit according to the chi-square difference test (see Table 5). The final model, Model six, had excellent model fit according to all fit indices.

With delayed recall. The model fit results of the bivariate ALT model of delayed word recall performance and social contact are reported in Table 6. The bivariate model results showed that the time-specific correlations between delayed word recall and social contact can be excluded, and the autoregressive parameters of delayed word recall can be constrained to equality over time without a significant reduction in model fit. Model 6 is the best fitting model according to the $\Delta\chi 2$ and has excellent model fit according to all fit indices.

With mental status. The results of the bivariate mental status and social contact analysis are presented in Table 7. According to the $\Delta\chi 2$ the following constraints can be added without a significant reduction in model fit: excluding time-specific correlations between mental status and social contact and constraining autoregressive parameters of social contact to equality over time. The best fitting model and has excellent model fit according to all fit indices.

Social Support Model Building Results

The full ALT models with social support did not converge. However, for some variable combinations when other model constraints were added, models did converge with the social support slope estimated. These were included for model comparison purposes but for all combinations the models without a social support slope estimated were retained.

With immediate recall. The fit of all converged bivariate ALT models of immediate word recall performance and self-reported social support are reported in Table 8. According to the $\Delta\chi 2$, the following constraints can be applied without a significant change in model fit: the slope of social support can be excluded, the time-specific correlations between uniquenesses of immediate word recall performance and social support can be excluded, and the autoregressive parameters of both immediate word recall and social support can be constrained to equality over

time. All other constraints significantly decreased model fit. Model nine is retained as the most parsimonious and has excellent model fit according to all fit indices.

With delayed recall. The fit of bivariate models of delayed word recall and social supported that converged are presented in Table 9. The progressive addition of further constraints showed that the slope of social support could be excluded, the correlations of time-specific uniqueness of delayed word recall performance and social support could be excluded and the autoregressions of both delayed word recall and social support could be constrained to equality over time without a significant reduction in model fit. Model nine was retained and showed good model fit by all indices.

With mental status. The results of the bivariate mental status and social support models are presented in Table 10. Some models with a slope term for social support would not converge however, with other model constraints, a social support slope term could be estimated. However, the ALT model with only level of social support estimated, with the autoregressive parameters of social support constrained to be stationary over time, and time-specific correlations between mental status and social support excluded was the best fitting model according to $\chi 2$ difference testing and showed excellent model fit according to all indices.

Social Network Composition Results

Most social network composition models would not converge with a slope term estimated. Thus, models were specified with only intercept, first occasion of measurement, and autoregressive parameters for social network composition.

With immediate recall. Model fit indices and comparisons are presented in Table 11. The ALT model without time specific correlations between immediate word recall and social

network, and the slope of social network could be estimated. However, model comparison revealed that the slope of social network could be excluded, time-specific uniqueness correlations could be excluded, and the autoregressive parameters of immediate word recall constrained to be equal over time. This model showed good model fit according to all indices.

With delayed recall. The bivariate model fits for social network and delayed word recall are presented in Table 12. Model fit comparisons showed the following model constraints did not reduce model fit and so were retained in the final model: excluding time-specific correlations between social network size and delayed word recall and constraining the autoregressive parameters for delayed word recall to equality over time. This model showed good fit according to all indices.

With mental status. The results of the bivariate mental status and social network are presented in Table 13. Conducting a model fit comparison of only converged models with progressively added model constraints showed that the following constraints could be added without a significant decrease in model fit: the correlations of time-specific uniqueness can be excluded, the autoregressive parameters for social network can be constrained to equality over time. This model also showed good model fit by all other fit indices.

Univariate findings

The univariate results are summarized from each of the bivariate models and presented below. All results are from bivariate models estimated without a social variable slope. Note that the results generally did not differ for the same variable, as would be expected. Parameters are presented as one estimate or a range summarizing similar results from all bivariate models in which that variable was included.

Immediate word recall. Immediate word recall had a significant negative slope with a small but significant variance, consistent across all models and with the univariate immediate word recall results (β ranged from -0.15 to -0.08, *p's* ≤ .01, ψ = 0.00, *p* = .01). Further, the proportion of state-like deviations in immediate word recall performance explained by performance at the previous wave remained consistently not significant ($\rho_{t,t-1}$ = -0.02, *p* = n.s for all models) over time; allowing autoregressive parameters to vary over time did not significantly improve model fit (see Tables 2, Table 5, Table 8, Table 11).

Delayed word recall. When delayed word recall was examined in relation to the four social factors, the slope of delayed recall performance was consistently significant and negative with a small but significant variance parameter (range β = -0.18 to -0.07, *p's* ≤ .01, and ψ = 0.01, *p's* ≤ .01). Previous time-specific uniqueness in delayed word recall performance did not predict time-specific uniqueness in delayed word recall performance two years later ($\rho_{t,t-1}$ = -0.01, *p* = n.s).

Mental status. The slope of mental status was consistently significant and negative with a small but significance variance parameter (range β = -0.32 to -0.25, *p's* ≤.001; ψ = 0.01, *p's* ≤.001). The autoregressive parameters of mental status predicted mental status two years later, became larger over time, and reached significance by the third occasion (social network: ρ_{21} = -0.01, *p* =.67, ρ_{21} = 0.03, *p* = .23; ρ_{43} = 0.05, *p* = .01; ρ_{54} = 0.13, *p* ≤ .001; ρ_{65} = 0.18, *p* ≤ .001; social support: ρ_{21} = -0.04, *p* = .28 ρ_{32} = -0.00, *p* = .93; ρ_{32} = 0.05, *p* = .01; ρ_{54} = 0.12, *p* ≤ .001; ρ_{65} = 0.15, *p* ≤ .001; social contact: ρ_{21} = -0.04, *p* = .28, ρ_{32} = -0.00, *p* = .93; ρ_{43} = 0.05, *p* = .01; ρ_{54} = 0.12, *p* ≤ .001; ρ_{65} = 0.15, *p* ≤ .001; loneliness: ρ_{21} = -0.02 *p* = .50, ρ_{32} = 0.04, *p* = .09; ρ_{43} = 0.06, *p* <.001; ρ_{54} = 0.13, *p* < .001; ρ_{65} = 0.17, *p* <.001).

Loneliness. Loneliness was one of the few social variables that could be estimated with a slope term, however this was not the case for all variable combinations and did not improve model fit. The mean loneliness slope was significant in the immediate word recall model, but not in the delayed word recall or mental status models. The slope of loneliness was not included in any of the final models to which covariates were added. Across all models, model fit indices indicated that models with autoregressive parameters constrained to equality over time were superior and time-specific uniqueness in loneliness significantly predicted time-specific uniquenesses two years later: range $\rho_{t,t-1}$ = 0.17 to $\rho_{t,t-1}$ = 0.26, p 's < .01.

Social contact. For two of the three bivariate models with social contact (mental status and delayed word recall) the full ALT model was not estimable due to convergence problems. Models without a slope term of social contact converged without issue. In two of the three models (immediate recall and delayed recall) allowing the autoregressive parameters of social contact to vary over time significantly improved model fit. Across all three bivariate models, social contact significantly predicted social contact two years later across all occasions ($\rho_{t,t-1}$ = 0.26 to 0.30, *p's* <.01).

Social support. As in the univariate models, model fit was not significantly improved by allowing the autoregressive parameters of social support to vary over time in any of the bivariate models. Across all models, time-specific uniqueness in social support significantly predicted time-specific uniquenesses in social support two years later ($\rho_{t,t-1}$ = 0.28 to 0.30, p's <.01).

Social network composition. In all models, the autoregressive social network parameters were significant and positive such that time-specific uniquenesses in social network significantly predicted time-specific uniqueness in social network two years later ($\rho_{t,t-1}$ = 0.12 to 0.33, p's <.01).

Covariate effects.

The predictors were added directly to each of the final ALT models. Fit indices for the final models with covariates are presented in the final rows of Tables 2 through 13. Bivariate model results for the best fitting models with covariates are discussed below and presented in Figures 6 through 17. The relation of covariates to each process remained consistent across models and are thus presented in summary.

Age. Older individuals had significantly less social contact and smaller social networks overall across all occasions. However, older individuals also reported significantly higher initial levels of social support. Older individuals also had lower performance overall on all three cognitive measures, and a greater rate of decline over time in all three measures.

Gender. Women reported greater initial as well as overall loneliness despite reporting more social contact and greater social support initially as well as overall, across all occasions, compared to men. However, men had more diverse social network composition overall. Women had higher performance on immediate word recall, delayed word recall, and higher mental status scores both initially and overall across all occasions. Gender was not related to rate of change in any cognitive functions examined.

Years of education. Those with more education reported significantly lower levels of loneliness overall and lower initial levels of loneliness, larger social networks, more social contact initially and overall across time, but lower overall levels of social support. More years of education was related to better initial performance on all three cognitive measures, and better performance overall across all occasions.

Health conditions. Individuals with more health conditions reported greater levels of loneliness overall and greater initial levels of loneliness. Individuals with more health conditions reported lower levels social support at the first measurement point and across all occasions. Health conditions were not related to social network or social contact. Greater number of health conditions was associated with lower initial performance and lower performance overall on all three cognitive measures.

Cohort. Cohort was not significantly related to any of the social or cognitive variables but was retained as a control variable.

Bivariate Relations Between Social and Cognitive Variables

The results for the bivariate relationships between social and cognitive factors investigated are presented for each variable combination. Note that estimates for the final best fitting models for each combination are discussed followed by a brief discussion of the effect of including covariates. Note that the final models with covariates are presented for each variable combination with the estimates included in the figure in lieu of tables of all parameter estimates.

Loneliness and immediate recall. In the final model the correlation between the intercept factors (level of loneliness and immediate recall net the impact of the first occasion of measurement) was not significant (corr. = 0.00, p = .77) nor was the correlation between time one loneliness and time one immediate word recall (corr. = -0.01, p = .46). Further, that the time-specific correlations could be removed without changing the overall fit of the model indicates that the time-specific uniquenesses, after accounting for the slope of immediate word recall, were not related at any given time point. The cross-lagged regressions of loneliness on immediate word recall were all significant except state-like deviations in time two loneliness did not significantly predict state-like deviations in time three immediate word recall performance (ρ_{32} =

-0.08, p = .07). State-like deviations in immediate word recall performance significantly predicted state like deviations in loneliness across all occasions indicating a reciprocal relationship.

The predictors age, sex, years of education, cohort, and number of health conditions, were added to the final unconditional bivariate ALT model (see Figure 6). The model fit indices appear in the last row of Table 2 and show adequate fit by all indices. The addition of covariates did not substantially change the bivariate relations. When covariates were added to the model significant cross-lagged relations remained such that loneliness at time three, four, and five predicted immediate recall performance at time four, five, and six, respectively and immediate recall performance at all occasions significantly predicted loneliness two years later (see Figure 6). The relation was negative indicating that lower immediate recall predicts greater loneliness.

Loneliness and delayed recall. In the final unconditional model the correlation between initial delayed word recall performance and loneliness was significant (corr. = -0.05, p = .02). However, correlation between the intercept factors was not significant (corr. = 0.01, p = .47). There was a significant cross-lagged relationship such that state-like increases in loneliness, from overall level, predicted decreased delayed word recall performance two years later. Further, decreases in delayed word recall performance, over and above that predicted from overall linear change over time, predicted increases in loneliness two years later.

When covariates were included, only time one and time three loneliness significantly predicted delayed word recall two years later (see Figure 7). State-like deviations in delayed word recall predicted state-like deviations in loneliness two years later at all occasions except

time four delayed recall did not significantly predict time five loneliness. The negative correlation between intercept factors was also no longer significant.

Loneliness and mental status. In the final loneliness and mental status model the initial values of mental status and loneliness were not significantly correlated, (corr. = -0.01, p = .29). Intercept terms were not significantly correlated (corr. = -0.00, p = .68). The cross-lagged regressions indicated that state-like deviations in loneliness at time one and time two did not predict deviations in mental status two years later (mental status - on - loneliness $\beta = 0.03$, p = .30) but loneliness did significantly predict mental status two years later at the third occasion and later (-0.13, p = .002; -0.133, p = .006; -0.14, p = .03). In contrast, the loneliness - on - mental status cross-lagged regressions were consistently significant and negative, indicating that poorer mental status predicted greater loneliness two years later (loneliness-on-mental status = -0.05 to -0.01, p's < .01).

The effects of covariates were investigated in the final model (see Figure 8). With the addition of covariates, time specific uniqueness in mental status significantly predicted time specific uniqueness in loneliness two years later at each occasion such that lower mental status predicted higher loneliness. Whereas time specific deviations in loneliness at time three predicted time specific deviations in mental status at time four only.

Social contact and immediate recall. In the final unconditional model the correlation between initial immediate word recall performance and social contact was not significant (corr. = -0.30, p = 0.37) nor was the correlation between intercept terms (corr. = 0.27, p = .10). The social contact-on-immediate word recall regressions were consistently significant. The

immediate word recall-on-social contact cross-lagged regressions were also consistently significant, indicating a reciprocal relationship.

The effect of predictors age, years of education, cohort, and number of health conditions were added directly to the final model (see Figure 9). When the covariates were included, the state-like deviations in social contact were not significantly related to state-like deviations in immediate word recall two years later at any occasions. State-like deviations in immediate recall from time three onwards significantly predicted state-like deviations in social contact two years later.

Social contact and delayed recall. The results of this model show that the correlation between initial delayed word recall performance and initial social contact was not significant (corr. = 0.20, p = .60). The correlation between the intercept terms of delayed word recall and social contact was also not significant (corr. = 0.36, p = .06). Time-specific deviations from level of social contact at time one did not predict time-specific deviations from the predicted trajectory of delayed recall at time two. Time-specific deviations from level of social contact at all other occasions significantly predicted deviations from the linear trajectory of delayed word recall two years later. At all occasions, deviations in delayed word recall significantly predicted deviations from social contact two years later.

The correlation between the intercept terms of delayed word recall and social contact became significant with the addition of covariates (see Figure 10). In the final covariate model, state-like deviations in social contact fluctuations did not predict deviations in delayed word recall performance two years later at any occasion. However, deviations in delayed word recall

performance at time two, time three and time four did significantly predict fluctuations in social contact two years later.

Social contact and mental status. In the final unconditional model there was no relationship between levels (corr. = 0.07, p = .42) or between initial values (corr. = -0.06, p = .73) of mental status and social contact. There was a significant cross-lagged relationship such that social contact at all occasions, except time one, significantly and positively predicted mental status two years later, and occasion specific variations in mental status, after accounting for overall trajectory of mental status, significantly predicted occasion specific variations in social contact after accounting for overall level of social contact.

When covariates were added to the final model (see Figure 11), the correlation between intercepts and between the first occasions of mental status and social contact remained not significant. Time-specific deviations in social contact at time two and time three predicted time-specific deviations in mental status two years later at time three and time four, respectively, but this association decreased to non-significance over time. State-like deviations in mental status predicted social contact two years later at all occasions.

Social support and immediate recall. In the final unconditional model there was no relationship between initial values (corr. = 0.06, p = .26) or levels (corr. = 0.00, p = .96) of immediate word recall performance and social support. Examination of these parameters shows that only time-specific deviations in social support at time two predicted time-specific deviations in immediate word recall at time three. The association is positive indicating that, after accounting for level, higher reported social support at time two was associated with better immediate word recall two years later. No other cross-lagged associations were significant.

The effect of predictors age, years of education, cohort, and number of health conditions were added directly to the final model (see Figure 12). There were no changes in relations from the unconditional model.

Social support and delayed recall. The results of the unconditional model show that neither the correlation between initial delayed recall performance and self-reported social support (corr. = 0.01, p = .92) nor between the intercept terms was significant (corr. = -0.04, p = .18). State-like increases in social support at time one and time two significantly predicted state-like increases in delayed recall at time two and time three respectively. State-like deviations in delayed word recall did not significantly predict state like deviations two years later in social support at any occasion.

As in the unconditional model, the correlation between linear slope factors of delayed word recall and social support remained not significant once covariates were included in the model (see Figure 12). As in the unconditional model, state-deviations in social support showed a consistently positive relationship with delayed recall but only deviations from level of social support at time two significantly predicted deviations from the linear trajectory of delayed word recall at time three, whereas, in the unconditional model social support at time one also significantly predicted delayed word recall at time two.

Social support and mental status. In the final unconditional model, there was no significant relationship between the first occasions of mental status and social support (corr. = 0.01, p =.80 or between intercept terms (corr. = -0.01, p = .66). There was a significant decline in mental status over time with significant variance in the slope. Time-specific uniqueness in social support at time two significantly predicted mental status at time three (0.03, p = .004) but, time-

specific uniquenesses in social support did not predict later time-specific uniqueness in mental status at any other occasions. State-like deviations in mental status did not predict later state-like deviations in social support at any occasion.

As in the unconditional model, social support at time two significantly predicted mental status at time three only (0.03, $p < .001$) (see Figure 14). State-like deviations in mental status did not predict social support at any occasion.

Social network composition and immediate recall. In the final unconditional model the correlation between initial (corr. = 0.01, $p = .79$) and intercepts (corr. = 0.01, $p = .36$) of immediate word recall performance and social network were not significant. State-like deviations in social network predicted state-like deviations in immediate word recall two years later for all occasions except the first. Deviations from the linear slope in immediate word recall performance at the first, fourth, and fifth measurement occasions significantly predicted deviations from predicted level social network of size two years later (occasions two, five, and six).

Predictors age, years of education, cohort, and number of health conditions were added directly to the final model (see Figure 15). The lagged association of state-like deviations in social network at time three predicting state-like deviations in immediate recall at time four was no longer significant in the conditional model. State-like deviations in immediate recall at time one, four, and time five continued to predict state-like deviations in social network composition two years later. Thus, these associations were not accounted for by covariates.

Social network composition and delayed recall. In the final model, the correlation between initial delayed recall performance and initial social network composition was not

significant 0.03, $p = .33$) nor was the correlation between intercept terms (corr. = 0.03, $p = .05$). State-like deviations in social network composition at time one, time two, and time three did not predict state-like deviations in delayed word recall performance at time two, time three, and time four, respectively. However, state-like deviations at time four and time five in social network size did significantly predict state-like deviations in time five and time six delayed word recall performance. State-like deviations in delayed word recall performance at time one, time four, and time five significantly predicted state-like deviations in social network size at time two, time five, and time six, respectively.

Covariates were added to the final model (see Figure 16). State-like deviations in social network at time four no longer predicted state-like deviations in delayed recall two years later. Otherwise the addition of covariates did not alter any conclusions.

Social network and mental status. In the final unconditional model there was no significant correlation between the first included mental status and social network scores (corr. = -0.00, $p = .86$) or between intercept terms (corr. = -0.00, $p = .85$). Social network significantly predicted mental status two years later such that greater time-specific uniqueness in social network predicted greater time-specific uniqueness in mental status for all occasions except social network at time one did not predict mental status at time two. Mental status also significantly predicted greater social network size two years later at all occasions (0.06, $p's < .01$).

Covariates were added directly to the final model (see Figure 17). In this model state-like deviations in mental status at time four and time five no longer significantly predicted state-like

deviations in social network composition at time five and six, respectively. Otherwise, the inclusion of covariates did not alter the significance of relations.

Discussion

This investigation first examined whether structural aspects of social relationships (social network composition and social contact) and functional aspects (social support and loneliness) showed linear change over time. When social factors were investigated independently, functional aspects of social relations did not show a mean trend over time while structural social factors did show a small but significant trajectory of decline over time with significant variability between individuals. However, in the estimation of models including both cognitive and social factors, many models with a trajectory term for the social factor did not converge. This may be because including a trajectory term resulted in model misspecification. This attribution for models with structural factors is more difficult given the results of the univariate model and may reflect difficulties due to model complexity. Although this difference in univariate and bivariate model findings for structural social variables does suggest there are limitations in the interpretation of model findings, in supplementary analysis investigating predicted trajectories of social variables results were consistent. This means that in bivariate models including social network and social contact, the change in these variables was fully accounted for by the autoregressive component, whereas in the univariate models it was explained by both a slope (linear change) factor and the autoregressive components. Unlike cognitive variables there is no underlying theory to suggest that social network and social contact should show linear change over time.

This finding is consistent with the socio-emotional selectivity theory of social relationships in aging which suggests that older adults focus their social efforts on the most emotionally rewarding close relationships as social network ties decrease (Cartensen, 2006). As

would be predicted by the theory, although there was some evidence of systematic change in structural social factors, older adults did not show a linear decrease in perceptions of social support, or increases in loneliness. This is also mostly consistent with previous research finding that ratings of emotional support do not decrease in aging except for those who experience changes in their closest relationship (Liao et al., 2016).

Overall, there were few relations between overall levels of social factors and level of the cognitive performance measures examined. Social contact was the exception, with level of social contact related to overall level of immediate and delayed recall. Given that trajectories of change in social factors were not included in bivariate models, no relations between systematic change over time was found. Trajectories of change in immediate and delayed memory and mental status were not significantly predicted by the overall level of social network diversity, social contact, social support, or loneliness.

There were a number of significant relations where time-specific fluctuations in one variable, after accounting for level, and trajectory for the cognitive variables, was predictive of time-specific deviations in the other two years later. However, no clear differentiation between structural (social network composition and social contact) and functional (social support and loneliness) social factors and their relations to cognitive performance emerged. Specifically, in the final conditional models there was some evidence of a cross-lagged relationship between social network diversity and immediate and delayed recall that increased to become significant in later occasions, although this was less consistent for delayed recall where fluctuations in immediate recall performance predicted fluctuations in social network two years later at the first occasion and last two only. The relationship between social network composition fluctuations and mental status was consistently reciprocal.

State-like increases in immediate and delayed recall performance predicted state-like increases in social contact two years later from the third wave onwards. State-like increases in social contact were not predictive of state-like increases in immediate or delayed recall. State-like increases in mental status predicted state-like increases in social contact two years later at all occasions but the reverse was true only with time two and time three social contact predicting time three and time four state-like deviations in mental status, respectively. This provides little evidence that social contact itself is protective against decreases in memory or mental status, and instead suggests that older adults who are experiencing changes in memory or mental status are vulnerable to decreased social contact. This may be because change in these areas of cognitive function limit ability or motivation to participate socially.

Overall, there was little evidence for relations between social support and immediate recall, delayed recall, or mental status. This suggests that increasing social support is unlikely to benefit older adults in terms of cognitive functioning. However, positively, it suggests that individuals who are experiencing changes in memory and mental status, while at risk for decreased social contact, are not more likely to experience a loss of social support. Unfortunately, this was not true for loneliness, where although there were no relations between overall levels of loneliness and overall cognitive performance across any of the three domains, state-like decreases in immediate recall and state-like decreases in mental status consistently predicted increases in loneliness two years later. There was less consistent evidence for state-like changes in loneliness predicting state-like changes in cognitive performance.

Thus, there was little to suggest systematic relationships between structural or functional social factors and cognitive function, with the exception of social contact. In the present investigation social contact specifically excluded spouses, but included questions asking about

children, other family members, and friends. It may be that individuals with better memory overall are more likely to remember to maintain social contact and that decreases in memory leave one vulnerable to decreasing social contact because one simply forgets to make plans to meet up, call someone, or send a letter or email. It is also possible that social interactions with someone with poorer memory are perceived as less fulfilling by family and friends and so others decrease the frequency of social interaction. Lastly, because assessing social contact relied on self-report of the individual, whereas memory performance was objectively assessed, a bias may be introduced particular to those who have poorer memory or are experiencing a memory change. However, it is unclear why the inaccuracy would be limited to reporting fewer social contacts and not extend to other social factors examined, but it is possible that participants with poorer memory could not recall social interactions and so under-reported them.

As a whole, these findings do not suggest a differential relationship between structural and functional social factors. However, they do suggest that relationships differ by the specific social construct examined and type of change being examined. Specifically, it may be that state-like changes in cognitive function are actually a risk factor for later decreases in social contact and increases in loneliness. Interestingly, state-like changes in social network composition showed the most reciprocal relations across the memory and mental status domains examined, although inconsistently across time. This could be in part because of the way the variable was conceptualized in the present investigation as representing whether individuals had any individuals in four social categories (spouse/partner, children, other family, friends). Given the generality of this question it is possible that change in social network diversity is actually indicating significant loss, such as the loss of a spouse, the loss of an only or all children, or last remaining extended family or friends. Losses of this magnitude might reasonably predict state-

like changes in cognitive performance two years later due to psychological factors (Vidarsdottir et al., 2014). The converse, that changes in cognitive function predict social network losses at later occasions may reflect a causal relationship, possibly operating through social contact, or simply an artefact of both being more likely among the oldest old (Hofer, Berg & Era, 2003).

Of note, examining predicted trajectories of each cognitive variable individually (see supplementary materials) indicated the mean predicted difference between occasions was small. The difference in number of words recalled both immediately and after a delay from one occasion to the next was less than 0.40 and the overall mean predicted change across the 10 years of study to be just over one word. Loneliness changed by little more than one tenth of a point from one occasion to the next for most waves, with the predicted difference across all 10 years of the study less than one point, indicating not even a whole change in category of endorsement. Social support showed little predicted difference from one occasion to the next with less than one point different from the highest predicted value to the lowest across all 10 years of the study. A one-point difference might be selecting “a little” instead of “some” in response to how much you can rely on friends if you have a serious problem, although there was variability between individuals. Similarly, social network composition showed less than a point difference from the highest predicted value to the lowest over all 10 years of the study indicating that most individuals did not lose a spouse or partner, all children, all other family or friends from their social network. Social contact showed a greater predicted absolute difference from the first wave to the last but also had a larger scale. This is consistent with the small cross-lagged parameter estimates, indicating effects are likely small. Although, these findings provide interesting insights into the nature of the relations between structural and functional social factors and cognitive function, a number of important limitations should be considered. First, although the

longitudinal design of the Health and Retirement Study provides a wealth of information, the fact that cognitive performance was assessed every two years, and social variables investigated every four years, makes it difficult to determine the time-course of relations and contributed to the convergence issues in model estimation due to a high proportion of missing data.

Second, because scores were used, rather than latent indicators of each variable, "state-like" uniquenesses of each process from which the autoregressive and cross-lagged regressions are estimated combine measurement error and state-like deviations which confounds the unreliability of measurement with actual change in variables of interest.

Third, estimation of the models was limited by convergence issues that are somewhat difficult to interpret. One possibility, particularly for social network and social contact, was that state-like uniqueness are actually reflecting linear change over time. However, theoretically, a level only model, meaning that individuals have a typical level of social contact that likely reflects a combination of characterological and relatively stable circumstance factors (like socioeconomic status) as well as state-like fluctuations in social contact reflecting more short-term circumstance factors (perhaps periods where friends or family have moved or lost touch but new friends can be added or contact resumed) could accurately describe social contact. Social network may, similarly, be accurately captured by such a model.

Fourth, although an attempt was made to investigate the direction of relations, which is a step towards causal inference, it cannot be taken as indicating such. There is the possibility that unmeasured variables are influencing both processes and responsible for observed associations, for example changing health status. An attempt was made to control for the influence of common health conditions, but it could not be included as a time-varying covariate due to modeling limitations.

In conclusion, there was little support for a relationship of between person differences, (i.e., "trait-like" levels) in social variables with cognitive performance. Further, there was little evidence that functional and structural aspects of social relationships are differentially related to cognitive function. However, there was evidence that within person changes in cognitive performance and social factors are related, with more evidence for changes in cognitive ability occurring before changes in social contact and loneliness. This has implications for understanding the mechanisms through which social variables and cognitive performance are linked. Specifically, it suggests that although social engagement is often considered part of a healthy lifestyle those experiencing cognitive changes may actually be more at risk for social changes. Although, there is little support for functional and structural social factors as protective against cognitive decline in the present study, this is not suggest that social factors do not have other important health implications. Thus, individuals experiencing even the relatively subtle cognitive changes observed in the present study, those who developed dementia were excluded, may be at risk for decreased social contact and increased loneliness. Further, these results are novel in applying ALT models to examine the relations between state- and trait-like components of both structural and functional aspects of social relationships over time. Being more specific about what relations are being examined, between what aspects of older adult's social worlds and cognitive function is needed to clarify the mixed results of the current literature and elucidate mechanisms of association.

Table 1. *Descriptive statistics by year.*

	2004	2006	2008	2010	2012	2014
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
	n = 5531	n = 5720	n = 5810	n = 5698	n = 5165	n = 4454
Women (%)	59.68	51.21	50	50	50	50
Age	72.13 (5.82)	74.07 (5.83)	76.01 (5.85)	78.31 (5.77)	79.62 (5.47)	81.15 (5.26)
Yrs Education	12.38 (3.1)	12.38 (3.1)	12.38 (3.1)	12.38 (3.1)	12.38 (3.1)	12.38 (3.1)
Health Conditions	1.96 (1.19)	2.13 (1.22)	2.28 (1.23)	2.47 (1.25)	2.53 (1.26)	2.58 (1.26)
Mental status	8.53 (0.79)	8.51 (0.81)	8.44 (0.88)	8.07 (1.1)	8.09 (1.16)	7.97 (1.32)
Word recall immediate	5.45 (1.5)	5.31 (1.53)	5.18 (1.54)	4.86 (1.64)	4.74 (1.63)	4.63 (1.65)
Word recall delayed	4.40 (1.84)	4.23 (1.89)	4.12 (1.88)	3.75 (1.95)	3.61 (1.97)	3.49 (1.96)
Psychosocial Variables	n = 1061	n = 2787	n = 2737	n = 2646	n = 2235	n = 2031
Loneliness	1.35 (0.47)	1.43 (0.51)	1.44 (0.51)	1.43 (0.51)	1.46 (0.5)	1.43 (0.51)
Social contact	30.56 (8.37)	29.6 (8.14)	29.61 (8.6)	29.41 (8.49)	28.99 (8.78)	28.65 (8.75)
Social support	9.81 (1.53)	9.58 (1.52)	9.56 (1.6)	9.58 (1.56)	9.61 (1.59)	9.58 (1.61)
Social network diversity	3.44 (0.76)	3.41 (0.72)	3.31 (0.77)	3.25 (0.79)	3.12 (0.84)	3.04 (0.86)

Table 2. *Model Fit Indices for Immediate Word Recall and Loneliness*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	181.07	64	-	-	-	0.989	0.989	0.018	0.091
2 - Autoregressive model, bivariate	3403.41	40	-	-	-	0.687	0.484	0.119	0.178
3 - ALT, nested LGM	214.6	60	-	-	-	0.986	0.984	0.021	0.101
4 - ALT, no IWR slope	246.94	40	-	-	-	0.981	0.968	0.029	0.078
5 - ALT, fixed loneliness slope variance	136.12	38	4	103.64*	2	0.991	0.984	0.021	0.111
6 - ALT, no loneliness slope	133.73	40	5	1.21	2	0.991	0.986	0.020	0.108
7 - ALT, no loneliness slope, no time-correlations	140.54	45	6	7.14	5	0.991	0.987	0.019	0.108
8 – ALT-7 + fixed IWR autoregressions	143.53	49	7	3.64	4	0.991	0.988	0.018	0.108
9 – ALT-7 + fixed loneliness autoregressions	142.31	49	8	0	0	0.991	0.988	0.018	0.108
10 – ALT-7 + fixed IWR and loneliness autoregressions	**145.47**	**52**	**9**	**3.31**	**3**	**0.991**	**0.989**	**0.017**	**0.109**
11 – ALT-10 + fixed IWR->Lone and Lone ->IWR regressions	189.5	61	10	44.46*	9	0.988	0.987	0.019	0.109
Final Conditional Multivariate ALT	**182.69**	**86**	**-**	**-**	**-**	**0.993**	**0.990**	**0.014**	**0.081**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.01$ level; Retained models bolded; ALT = Autoregressive latent trajectory; IWR = Immediate word recall; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 3. *Model Fit Indices for Delayed Word Recall and Loneliness*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	203.45	64	-	-	-	0.988	0.988	0.019	0.088
2 - Autoregressive model, bivariate	3400.98	40	-	-	-	0.711	0.523	0.119	0.175
3 - ALT, nested LGM	246.57	60	-	-	-	0.984	0.982	0.023	0.100
4 - ALT, no cognitive slope	294.11	40	-	-	4	0.978	0.964	0.033	0.077
5 - ALT, fixed loneliness slope	157.11	36	4	112.33*	4	0.990	0.981	0.024	0.078
6 - ALT, no loneliness slope	158.00	40	5	5.32	4	0.990	0.983	0.022	0.106
7 - ALT, no time-specific uniquesses correlations	173.30	40	5	15.84*	4	0.989	0.981	0.024	0.089
8 – ALT, no loneliness slope, no time-specific uniquesses	164.90	45	6	7.67	5	0.990	0.985	0.021	0.106
9 – ALT-8 + fixed DWR autoregressions	170.04	49	8	5.50	4	0.990	0.986	0.020	0.106
10– ALT-8 + fixed loneliness autoregressions	164.88	49	9	0	0	0.990	0.987	0.020	0.106
11 – ALT -10 + fixed DWR autoregressions	**165.59**	**52**	**10**	**0.69**	**3**	**0.990**	**0.988**	**0.019**	**0.106**
12 – ALT-11 + fixed DWR->lone & lone->DWR regressions	228.00	61	11	63.46*	12	0.986	0.984	0.021	0.108
Final Conditional Multivariate ALT	219.31	82	-	-	-	0.991	0.986	0.017	0.079

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.01$ level; Retained model bolded; ALT = Autoregressive latent trajectory; DWR = Delayed word recall; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 4. *Model Fit Indices for Mental Status and Loneliness*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	681.48	64	-	-	-	0.938	0.936	0.04	0.084
2 - Autoregressive model, bivariate	1829.50	40	-	-	-	0.82	0.703	0.087	0.155
3 - ALT full model	187.25	34	-	-	-	0.985	0.97	0.028	0.076
4 - ALT nested LGM	376.98	60	3	170.52*	26	0.968	0.965	0.03	0.092
5 - ALT no mental status slope variance	102.70	35	3	0.02	1	0.993	0.987	0.018	0.072
6 - ALT no mental status slope	693.31	40	3	155.73*	6	0.934	0.891	0.052	0.093
7 - ALT no loneliness slope variance	95.40	36	3	0.1	2	0.994	0.989	0.017	0.084
8 - ALT no loneliness slope	126.54	40	3	9.13	6	0.991	0.986	0.019	0.06
9 – ALT no loneliness slope, no time-specific correlations	132.64	44	3	15.40	10	0.991	0.987	0.018	0.066
10 – ALT-9 plus fixed MS autoregressions	164.71	48	9	29.04*	4	0.988	0.984	0.02	0.063
11 – ALT-9 plus fixed autoregressions loneliness	**101.38**	**48**	**9**	**18.1***	**4**	**0.995**	**0.993**	**0.014**	**0.098**
Conditional Multivariate ALT-no loneliness slope	**140.948**	**82**	**-**	**-**	**38**	**0.995**	**0.993**	**0.011**	**0.075**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.01$ level; Retained model bolded; ALT = Autoregressive latent trajectory; MS = Mental status; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 5. *Model Fit Indices for Social Contact and Immediate Word Recall*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	153.46	64	-	-	-	0.991	0.991	0.015	0.04
2 - Autoregressive model, bivariate	2348.89	40	-	-	-	0.763	0.61	0.098	0.141
3 - ALT, nested LGM	321.39	60	-	-	-	0.973	0.971	0.027	0.086
4 - ALT, no SC slope	523.61	39	-	-	-	0.95	0.916	0.046	0.08
5 - ALT, no SC slope, no time-specific uniquenesses correlations	210.39	45	4	10.80	4	0.983	0.975	0.025	0.073
6 - ALT-5 + fixed autoregressions for IWR	**212.84**	**48**	**5**	**0.94**	**3**	**0.983**	**0.977**	**0.024**	**0.074**
7- ALT-4 + fixed autoregressions for IWR	195.43	44	4	11.50*	5	0.984	0.977	0.024	0.073
8 - ALT-5 + fixed autoregressions for SC	231	48	5	20.21*	3	0.981	0.974	0.025	0.073
9 - ALT-5 + fixed autoregressions for IWR & SC	234.79	52	6	21.83*	4	0.981	0.976	0.024	0.073
10 - ALT-9, fixed SC->IWR regressions & fixed IWR -> SC regressions	298.2	60	5	90.08*	8	0.976	0.973	0.026	0.072
Final Conditional Multivariate ALT	**292.82**	**82**	**4**	**-**	**-**	**0.986**	**0.978**	**0.021**	**0.054**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.01$ level; Retained model bolded; ALT = Autoregressive latent trajectory; SC = Social contact; IWR = Immediate word recall; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 6. *Model Fit Indices for Social Contact and Delayed Word Recall*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	212.76	64	-	-	-	0.988	0.988	0.02	0.035
2 - autoregressive model, bivariate	3286.13	40	-	-	-	0.745	0.579	0.117	0.139
3 - ALT, nested LGM	397.54	60	-	-	-	0.973	0.971	0.031	0.084
4 - ALT, no social contact slope	350.31	40	-	-	-	0.976	0.96	0.036	0.083
5 - ALT, no social contact slope, no time-specific uniquenesses correlations	368.33	44	4	21.11*	4	0.974	0.962	0.035	0.101
6 - ALT-5 + fixed autoregressions for DWR	**304.25**	**48**	**5**	**46.37***	**4**	**0.98**	**0.972**	**0.03**	**0.071**
7 - ALT-5 + fixed autoregressions for SC	322.86	48	5	33.08*	4	0.978	0.97	0.031	0.071
8 - ALT-5 + fixed autoregressions for DWR & SC	322.70	52	6	18.94*	4	0.979	0.973	0.03	0.071
9 - ALT-8 + fixed DWR->SC & fixed SC->DWR	398.94	60	6	94.24*	12	0.973	0.971	0.031	0.069
Final Conditional Multivariate ALT	**304.502**	**86**	**-**	**-**	**-**	**0.986**	**0.979**	**0.021**	**0.065**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.01$ level; Retained model bolded; ALT = Autoregressive latent trajectory; SC = Social contact; DWR = Delayed Word Recall; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 7. *Model Fit Indices for Social Contact and Mental Status*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	707.77	64	-	-	-	0.94	0.938	0.041	0.045
2 - Autoregressive model, bivariate	1790.48	40	-	-	-	0.837	0.732	0.086	0.125
3 - ALT, nested LGM	429.20	60	-	-	-	0.966	0.962	0.032	0.065
4 - ALT, no social contact slope	137.92	39	-	-	-	0.991	0.984	0.021	0.092
5 - ALT, no social contact slope, no time-specific uniquenesses correlations	174.82	44	4	38.75*	5	0.988	0.982	0.022	0.106
6 - ALT-5 + fixed autoregressions for MS	212.78	48	4	73.31*	4	0.985	0.979	0.024	0.098
7 - ALT-5 + fixed autoregressions for SC	**149.85**	**48**	**4**	**11.57**	**4**	**0.991**	**0.987**	**0.019**	**0.057**
8 - ALT-5 + fixed autoregressions for MS & SC	181.10	52	7	28.84*	4	0.988	0.985	0.02	0.058
9 - ALT-8 + fixed MS->SC & fixed SC->MS	459.38	60	7	316.2*	21	0.963	0.959	0.033	0.06
Final Conditional Multivariate ALT	**171.872**	**82**	**-**	**-**	**-**	**0.993**	**0.99**	**0.014**	**0.061**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.01$ level; Retained model bolded; ALT = Autoregressive latent trajectory; SC = Social contact; MS = Mental Status; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 8. *Model Fit Indices for Social Support and Immediate word Recall*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	224.642	64	-	-	-	0.986	0.986	0.021	0.11
2 - Autoregressive model, bivariate	3559.657	40	-	-	-	0.697	0.5	0.122	0.183
3 - ALT, nested LGM	168.958	60	-	-	-	0.991	0.99	0.017	0.109
4 - ALT, no SS slope	123.24	40	-	-	-	0.993	0.988	0.019	0.122
5 - ALT, no SS slope, no time-specific uniquenesses correlations	133.92	44	4	10.82*	4	0.992	0.988	0.019	0.122
6 - ALT, SS slope estimated, constrained time-specific uniquenesses correlations	132.16	40	4	0	4	0.992	0.987	0.02	0.081
7 - ALT, SS slope estimated, no time-specific uniquenesses correlations	117.53	40	4	0	0	0.993	0.989	0.018	0.094
7 - ALT-5 + fixed autoregressions for IWR	125.13	44	4	2.86	4	0.993	0.99	0.018	0.122
8 - ALT-5 + fixed autoregressions for SS	132.77	48	7	8.00	4	0.993	0.99	0.017	0.121
9 - ALT-5 + fixed autoregressions for IWR & SS	**135.08**	**52**	**7**	**11.01**	**8**	**0.993**	**0.991**	**0.016**	**0.121**
10 – ALT-9 + fixed IWR ->SS & fixed SS->IWR	175.24	60	7	49.95*	16	0.99	0.989	0.018	0.12
Final Conditional Multivariate ALT	**175.98**	**82**				**0.993**	**0.99**	**0.014**	**0.084**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.01$ level; Retained model bolded; ALT = Autoregressive latent trajectory; SS = Social support; IWR = Immediate word recall; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 9. *Model Fit Indices for Social Support and Delayed Word Recall*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	236.98	64	-			0.986	0.986	0.021	0.11
2 - Autoregressive model, bivariate	3518.51	40	-			0.722	0.541	0.121	0.183
3 - ALT, nested LGM	186.22	60	-			0.99	0.989	0.019	0.11
4 - ALT, no SS slope	126.78	40				0.993	0.989	0.019	0.122
5 - ALT, no SS slope, no time-specific uniquenesses correlations	141.97	44	4	15.13*	4	0.992	0.988	0.019	0.122
6 - ALT, SS slope estimated, no time-specific uniquenesses correlations	124.24	39	4	2.84	5	0.993	0.988	0.019	0.052
7 - ALT-5 + fixed autoregressions for DWR	143.93	48	4	17.60*	4	0.992	0.989	0.018	0.122
8 - ALT-5 + fixed autoregressions for SS	141.22	48	4	15.22	8	0.993	0.99	0.018	0.122
9 - ALT-5 + fixed autoregressions for DWR & SS	**143.56**	**52**	**4**	**18.21**	**12**	**0.993**	**0.991**	**0.017**	**0.122**
10 – ALT-9 + fixed DWR ->SS & fixed SS->DWR	198.38	60	9	54.82*	8	0.989	0.988	0.02	0.12
Final Conditional Multivariate ALT	**202.8**	**82**				**0.992**	**0.988**	**0.016**	**0.084**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.05$ level; Retained model bolded; ALT = Autoregressive latent trajectory; SS = Social support; DWR = Immediate word recall; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 10. *Model Fit Indices for Social Support and Mental Status*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	737.37	64	-			0.937	0.935	0.042	0.11
2 - Autoregressive model, bivariate	1914.89	40	-			0.824	0.709	0.089	0.166
3 - ALT, nested LGM	358.71	60	-	-		0.972	0.969	0.029	0.108
4 - ALT, no SS slope	128.51	39	-	-	-	0.992	0.986	0.02	0.058
5 - ALT, SS slope estimated, constrained uniquenesses correlations	78.05	40	-	-	-	0.995	0.992	0.015	0.09
6 - ALT, SS slope estimated, no time-specific uniquenesses correlations	78.05	40	5	12.32	0	0.996	0.994	0.013	0.091
7 - ALT, no SS slope, no time-specific uniquenesses correlations	123.95	44	6	45.90	4	0.992	0.989	0.017	0.056
8 – ALT-6 + fixed autoregressions for MS	108.60	45	6	30.55	5	0.994	0.991	0.015	0.104
9 - ALT-7 + fixed autoregressions for MS	163.40	48	7	39.44	8	0.989	0.985	0.02	0.062
10 – ALT-6 + fixed autoregressions for SS	91.39	45	6	13.33	5	0.996	0.994	0.013	0.114
11 - ALT-7 + fixed autoregressions for SS	**93.66**	**48**	**10**	**2.28**	**3**	**0.996**	**0.994**	**0.013**	**0.12**
12 – ALT-6 +fixed autoregressions for MS & SS	110.56	49	11	16.90	1	0.994	0.992	0.015	0.115
13 – ALT-7 + fixed autoregressions for MS & SS	112.24	52	11	18.58	4	0.994	0.993	0.014	0.12
14 – ALT-13 + fixed MS ->SS & fixed SS->MS	356.67	60	11	263.01	11	0.972	0.969	0.029	0.119
Final Conditional Multivariate ALT	**131.52**	**82**	**12**	**18.26**	**33**	**0.996**	**0.994**	**0.01**	**0.083**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.05$ level; Retained model bolded; ALT = Autoregressive latent trajectory; SS = Social support; MS = Mental status; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 11. *Model Fit Indices for Social Network Composition and Immediate Word Recall*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	228.78	64				0.985	0.984	0.021	0.051
2 - Autoregressive model, bivariate	3334.59	40				0.699	0.504	0.118	0.146
3 - ALT, nested LGM	246.46	60				0.983	0.981	0.023	0.074
4 - ALT, no SN slope	172.32	40				0.988	0.98	0.024	0.076
5 - ALT, SN slope estimated, no time-specific uniquenesses correlations	165.02	40	4			0.989	0.981	0.023	0.07
6 - ALT, no SN slope time-specific uniquenesses correlations	216.74	44	5	46.65*	4	0.984	0.976	0.026	0.104
7 - ALT-5 + fixed autoregressions for IWR	**177.83**	**48**	**6**	**16.09**	**8**	**0.988**	**0.984**	**0.021**	**0.076**
8 - ALT-5 + fixed autoregressions for SN	232.38	48	6	54.55*	0	0.983	0.977	0.025	0.076
8 - ALT-5 + fixed autoregressions for IWR & SN	230.68	52	8	52.73*	4	0.984	0.979	0.024	0.076
9 - ALT-8 + fixed IWR->SN & fixed SN->IWR	489.73	60	9	365*	12	0.961	0.957	0.035	0.084
Final Conditional Multivariate ALT	**1503.81**	**76**	**-**	**-**	**36**	**0.9**	**0.834**	**0.056**	**0.064**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.01$ level; Retained model bolded; ALT = Autoregressive latent trajectory; SN = Social Network; IWR = Immediate word recall; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 12. *Model Fit Indices for Social Network and Delayed Word Recall*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	247.40	64				0.984	0.984	0.022	0.052
2 - Autoregressive model, bivariate	3291.07	40				0.723	0.543	0.117	0.146
3 - ALT, nested LGM	253.97	60				0.983	0.982	0.023	0.075
4 - ALT, no SN slope	239.94	40				0.983	0.972	0.029	0.083
5 - ALT, no SN slope, no time-specific uniquenesses correlations	235.62	44	4	9.75	4	0.984	0.976	0.027	0.094
6 - ALT-5 + fixed autoregressions for DWR	**196.88**	**48**	**6**	**10.16**	**4**	**0.987**	**0.983**	**0.023**	**0.078**
7 - ALT-5 + fixed autoregressions for SN	288.93	48	6	71.80*	4	0.979	0.972	0.029	0.08
8 - ALT-5 + fixed autoregressions for DWR & SN	289.51	52	7	95.59*	4	0.98	0.974	0.028	0.08
Final Conditional Multivariate ALT	**226.877**	**82**				**0.99**	**0.985**	**0.017**	**0.05**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.01$ level; Retained model bolded; ALT = Autoregressive latent trajectory; SN = Social Network DWR = Delayed word recall; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

Table 13. *Model Fit Indices for Social Network and Mental Status.*

Model	χ^2	df	CM	$\Delta\chi^2$	$\Delta\chi^2$	CFI	TLI	RMSEA	SRMR
1 - LGM, bivariate unconditional	704.15	64	-	-	-	0.936	0.934	0.041	0.067
2 - Autoregressive model, bivariate	1681.37	40	-	-	-	0.836	0.729	0.083	0.134
3 - ALT, nested LGM	412.20	60	-	-	-	0.965	0.961	0.031	0.086
4 - ALT, no SN slope	138.78	40	-	-	-	0.99	0.984	0.02	0.107
5 - ALT, no SN slope, no time-specific uniquenesses correlations	155.85	44	4	17.23*	4	0.989	0.983	0.021	0.114
6 - ALT, no SN slope, fixed time-specific uniquenesses correlations	165.11	44	4	28.41*	4	0.988	0.982	0.022	0.103
7 - ALT-5 + fixed autoregressions for MS	185.92	48	5	27.18*	4	0.986	0.981	0.022	0.108
8 - ALT-5 + fixed autoregressions for SN	**133.81**	**48**	**5**	**16.26***	**4**	**0.991**	**0.988**	**0.017**	**0.084**
9 - ALT-5 + fixed autoregressions for MS & SN	158.23	52	8	22.56*	4	0.989	0.986	0.019	0.085
Final Conditional Multivariate ALT	**155.33**	**82**	**-**	**-**	**-**	**0.994**	**0.991**	**0.012**	**0.055**

Notes. * on $\Delta\chi^2$ means the difference in fit from the comparison model was significant at $p \leq 0.01$ level; Retained model bolded; ALT = Autoregressive latent trajectory; SN = Social Network; MS = Mental status; X^2 = chi-square test of model fit; df = degrees of freedom; CM = comparison model in the $\Delta\chi^2$; $\Delta\chi^2$ = chi square difference test; dfΔ = change in degrees of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

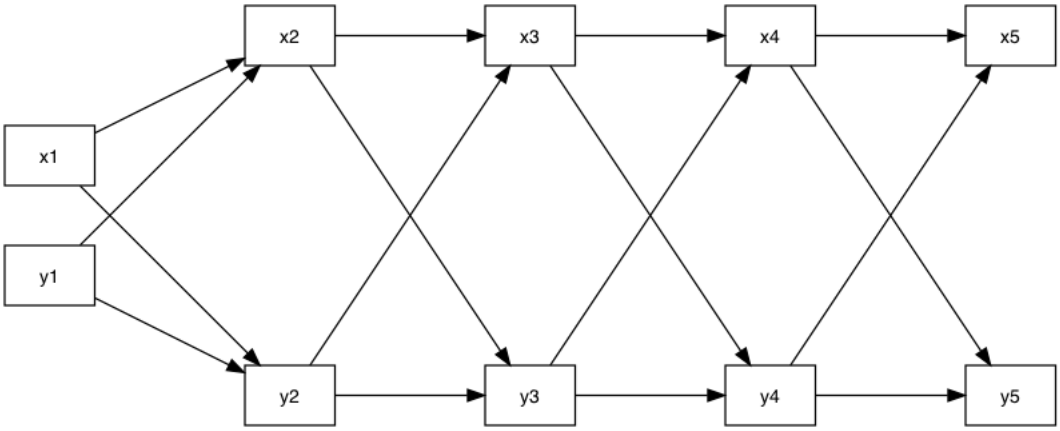

Figure 4. An autoregressive model.

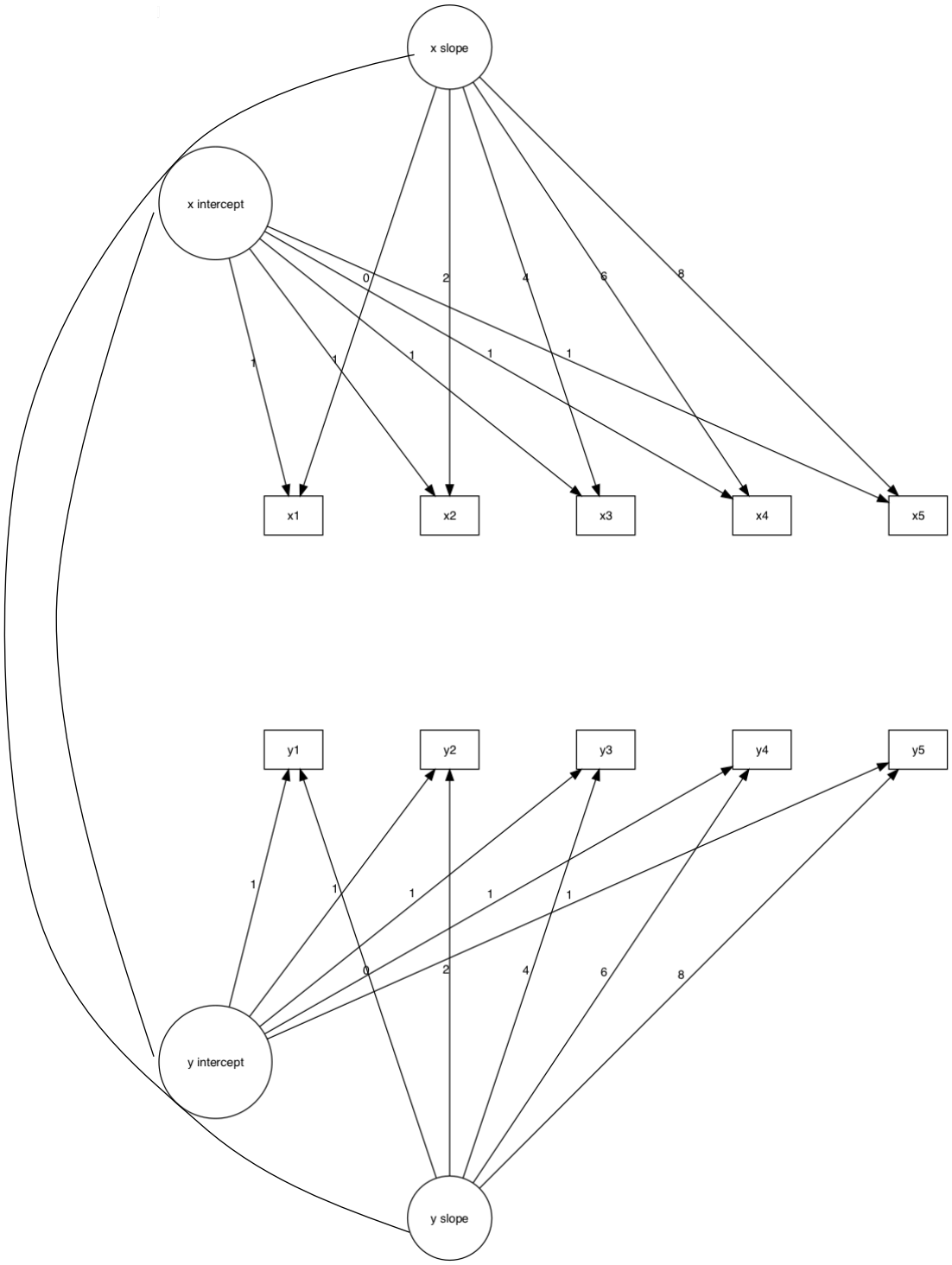

Figure 5. An example bivariate latent growth model.

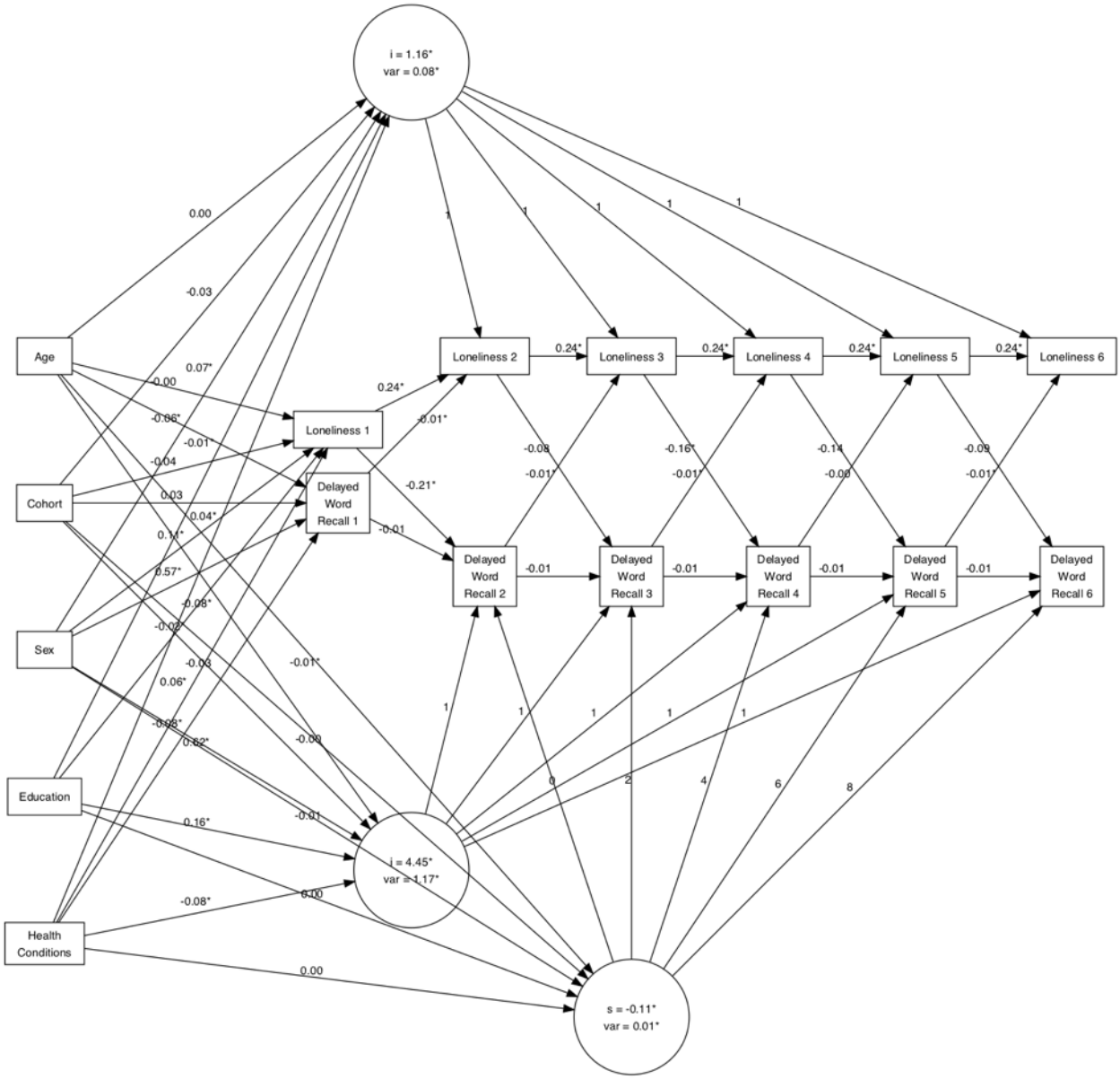

Figure 6. The final conditional autoregressive latent trajectory model for loneliness and immediate word recall.

* indicates $p < .05$

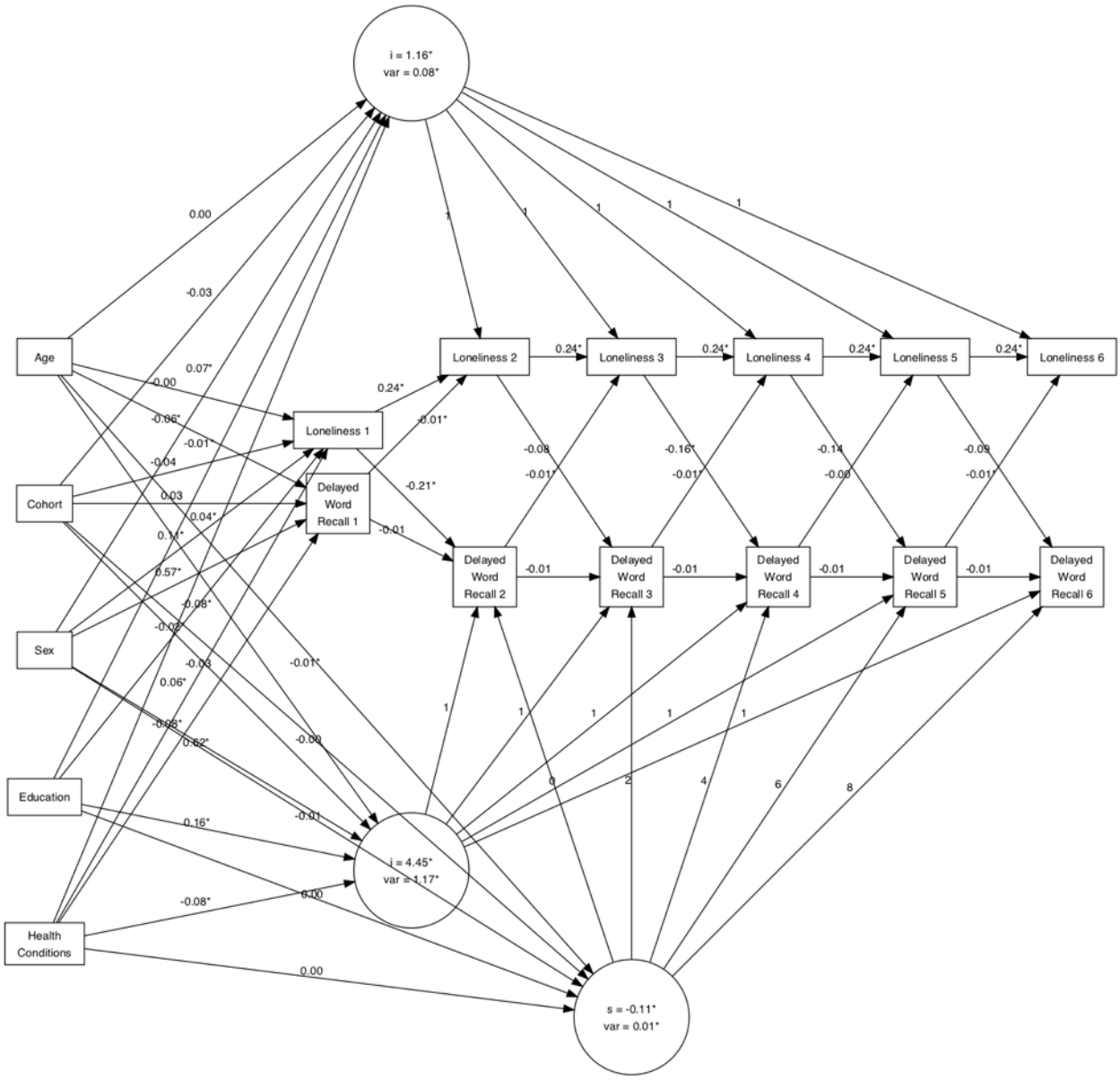

Figure 7. The final conditional autoregressive latent trajectory model for loneliness and delayed word recall.

* indicates $p < .05$

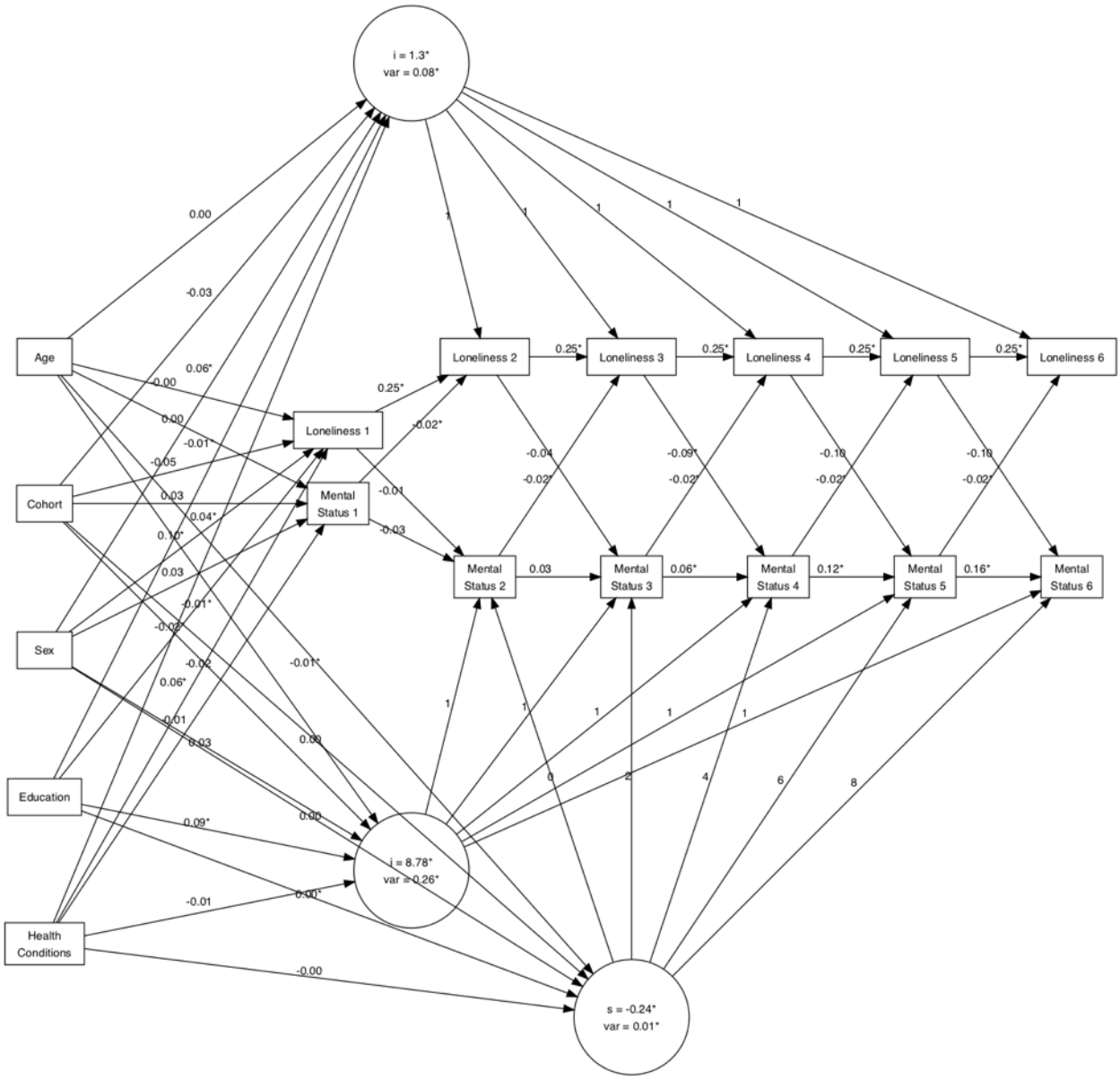

Figure 8. The final conditional autoregressive latent trajectory model for loneliness and mental status.

* indicates $p < .05$

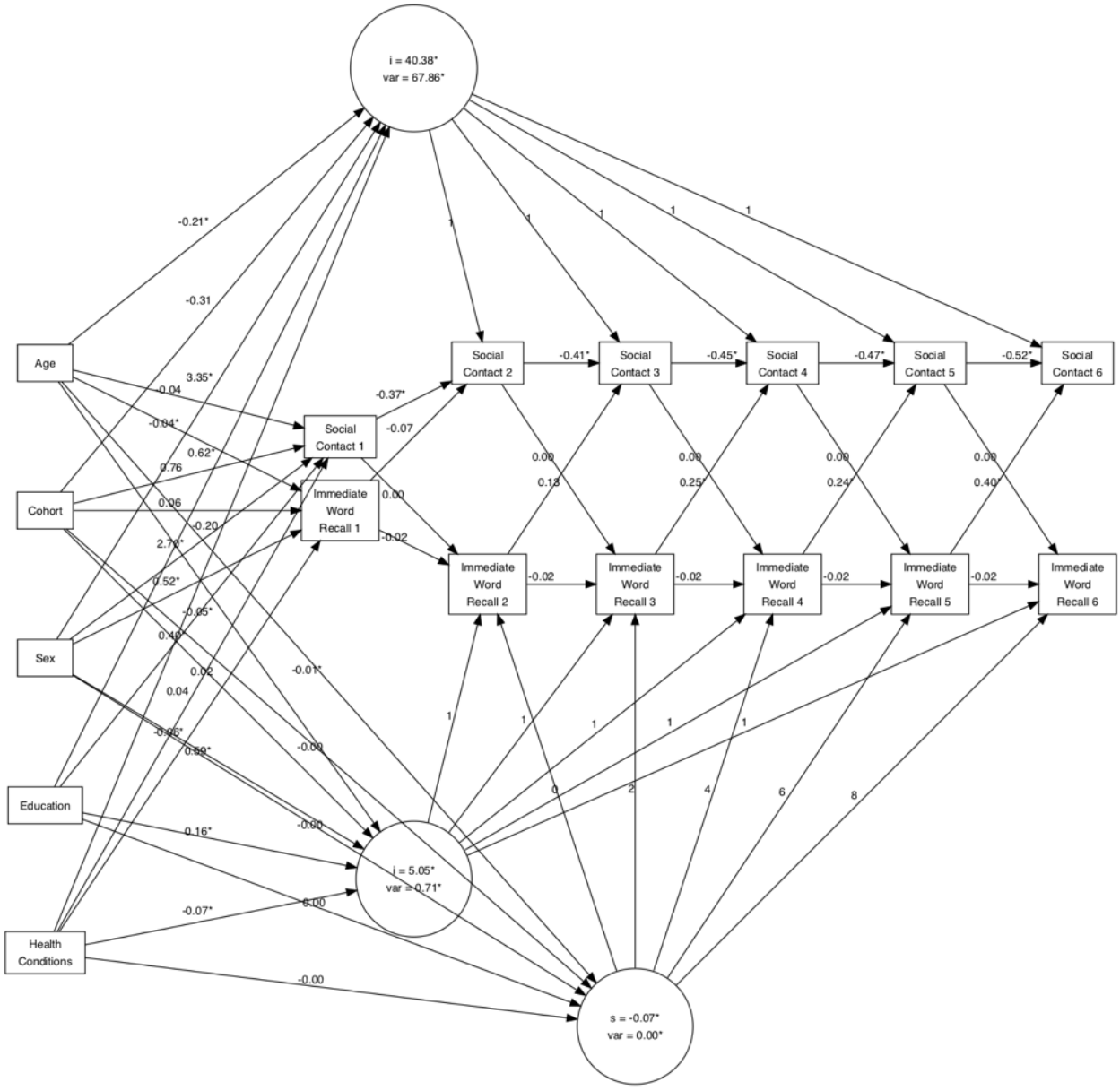

Figure 9. The final conditional autoregressive latent trajectory model for social contact and immediate word recall.

* indicates $p < .05$

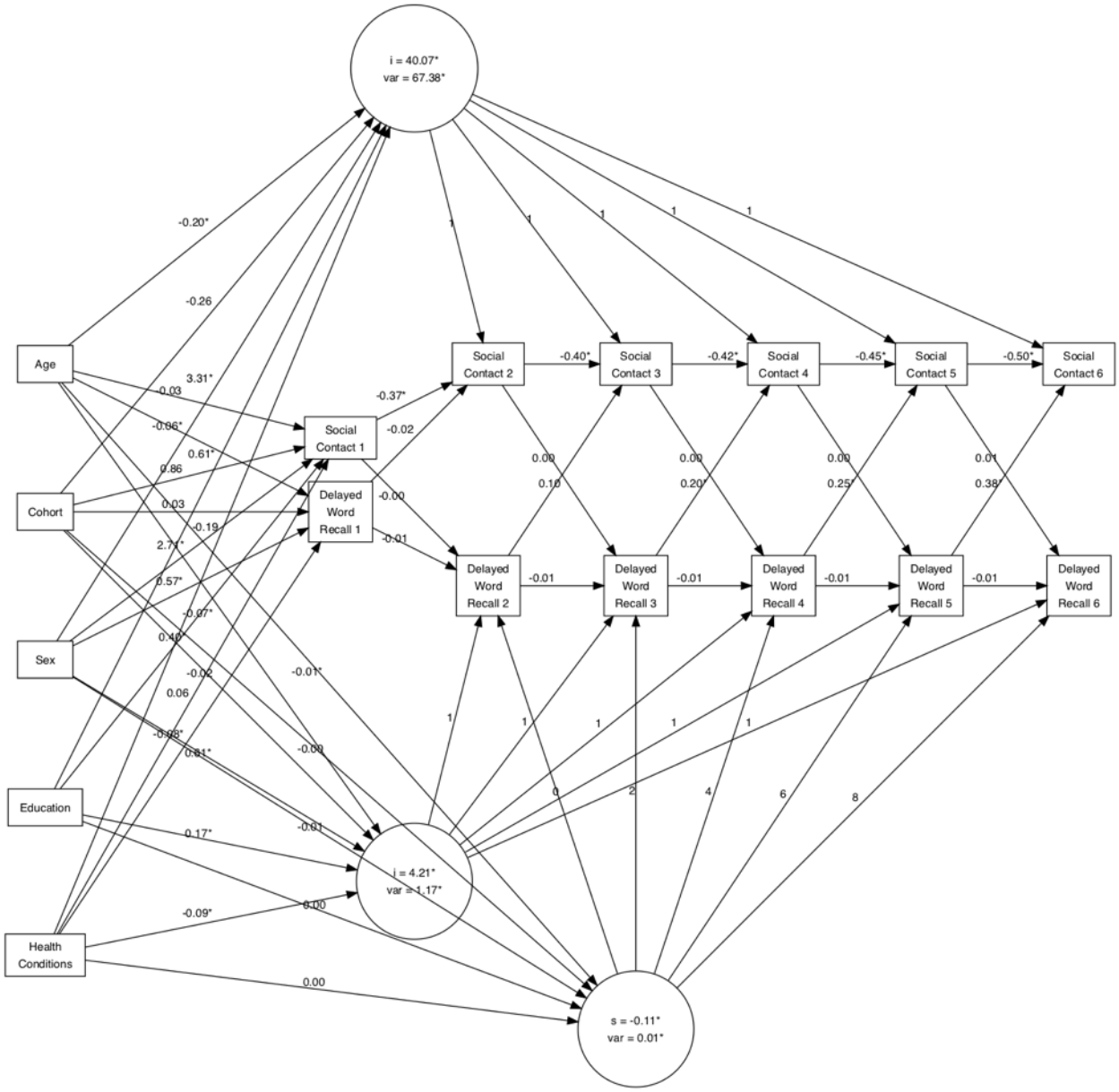

Figure 10. The final conditional autoregressive latent trajectory model for social contact and delayed word recall.

* indicates $p < .05$

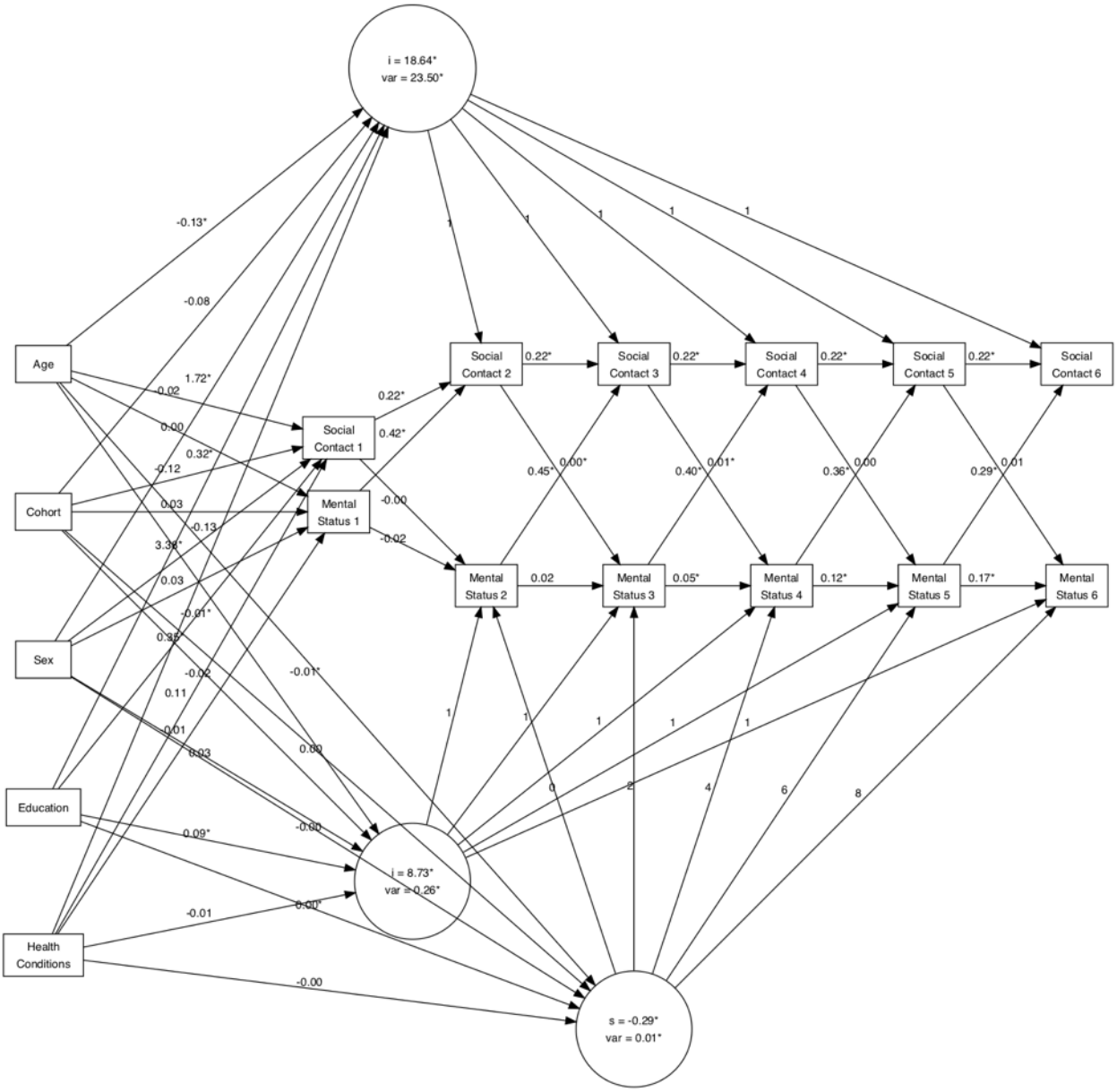

Figure 11. The final conditional autoregressive latent trajectory model for social contact and mental status.

* indicates $p < .05$

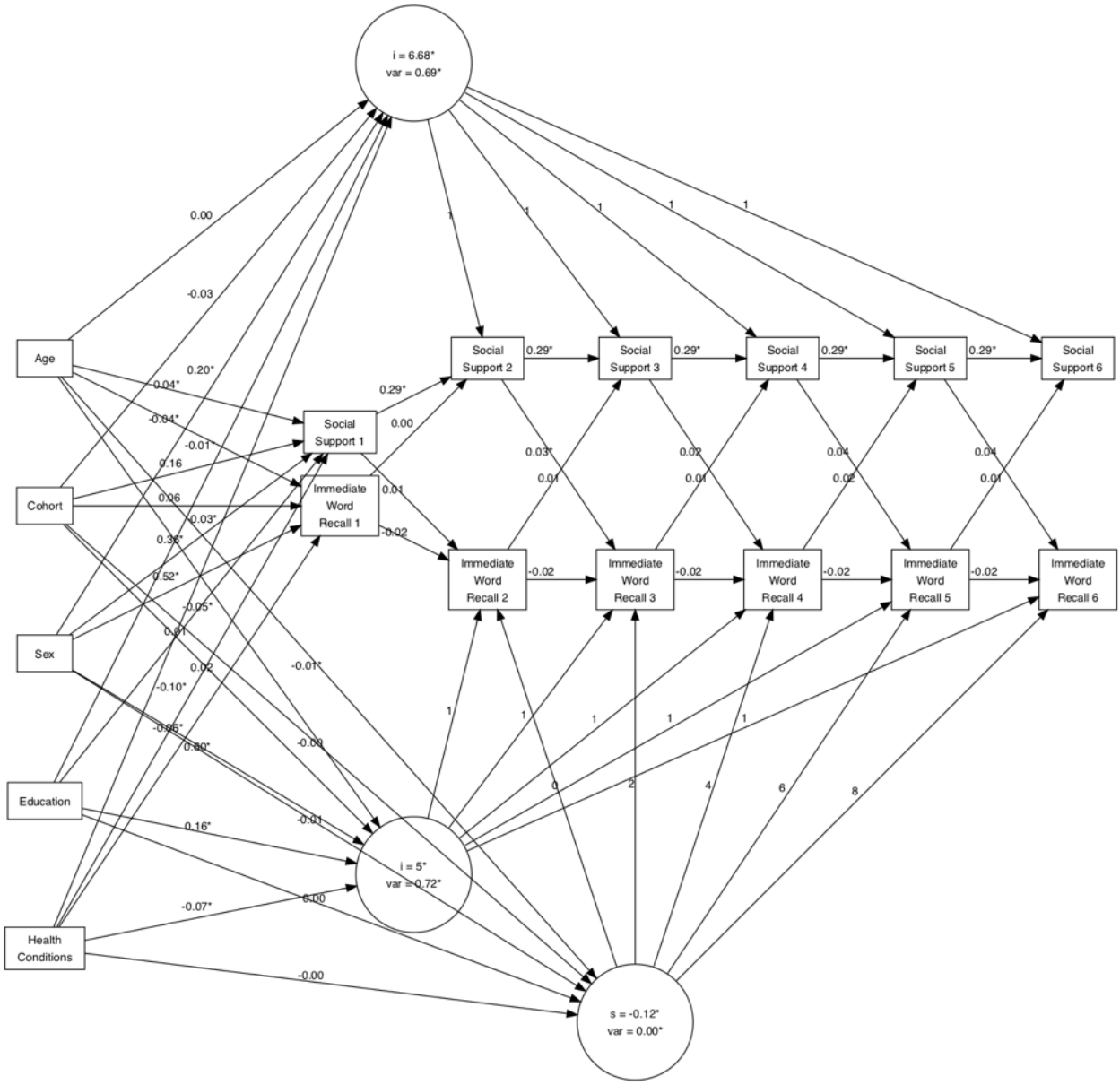

Figure 12. The final conditional autoregressive latent trajectory model for social support and immediate recall.

* indicates $p < .05$

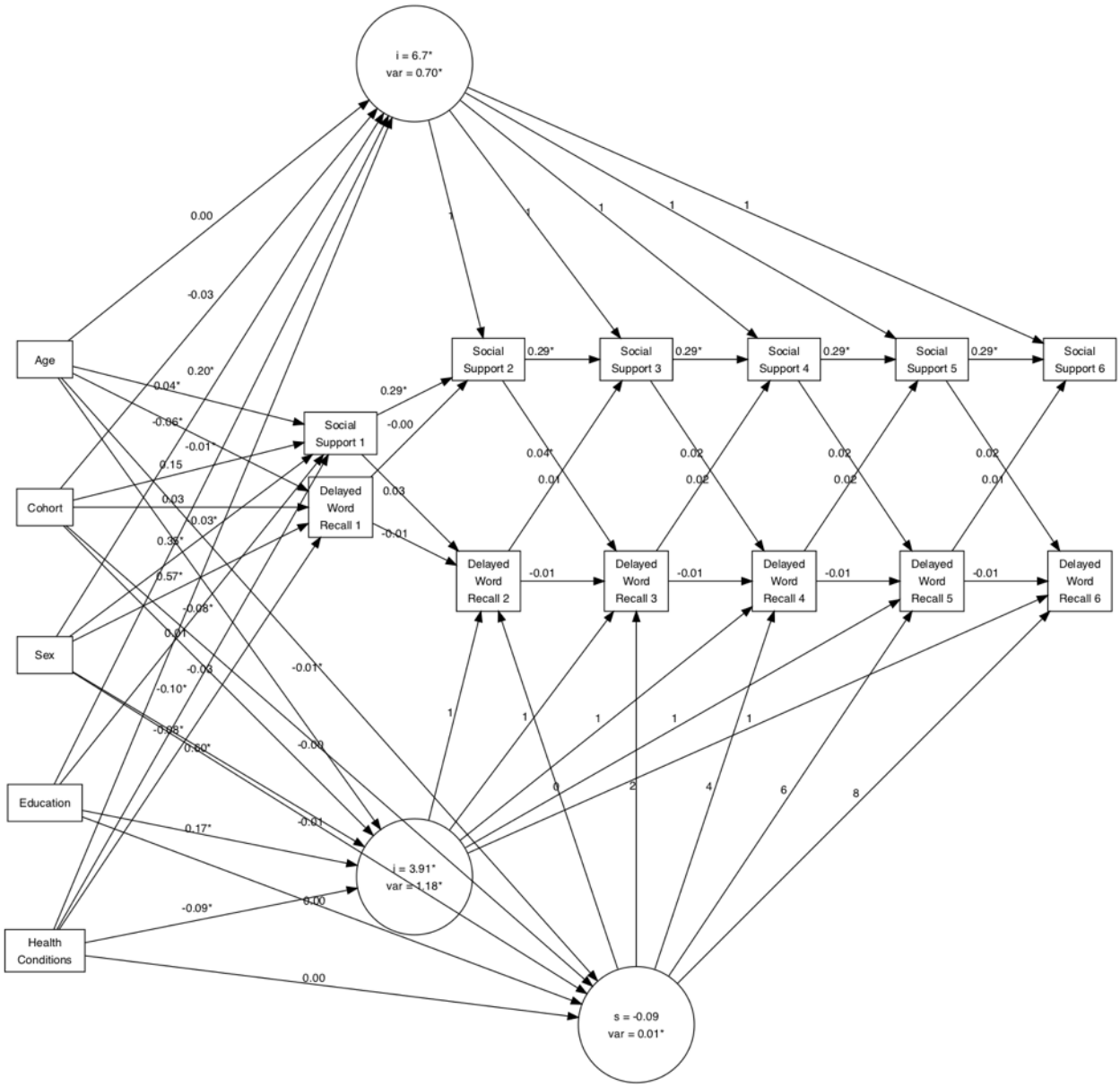

Figure 13. The final conditional autoregressive latent trajectory model for social support and delayed word recall.

* indicates $p < .05$

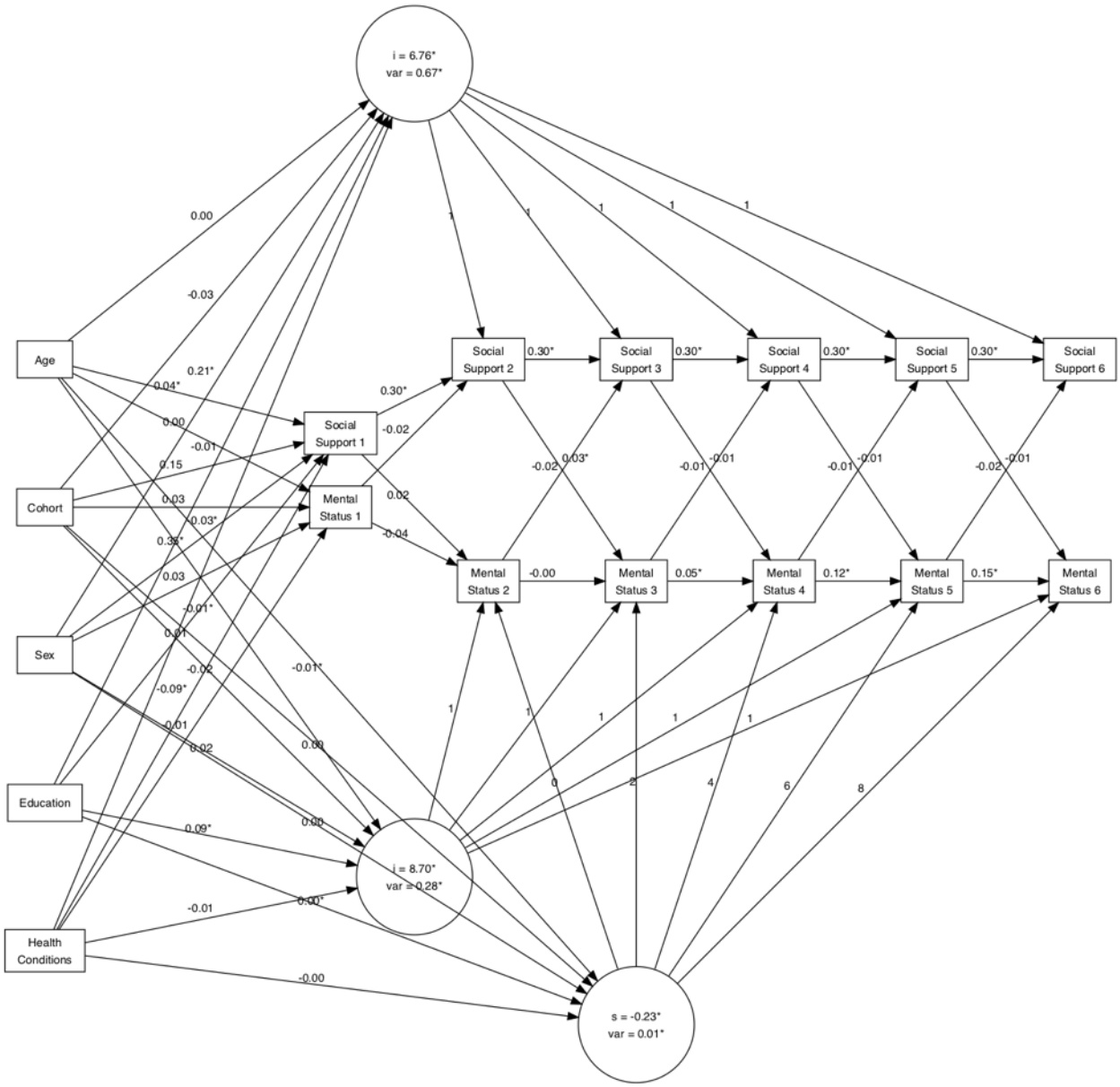

Figure 14. The final conditional autoregressive latent trajectory model for social support and mental status.

* indicates $p < .05$

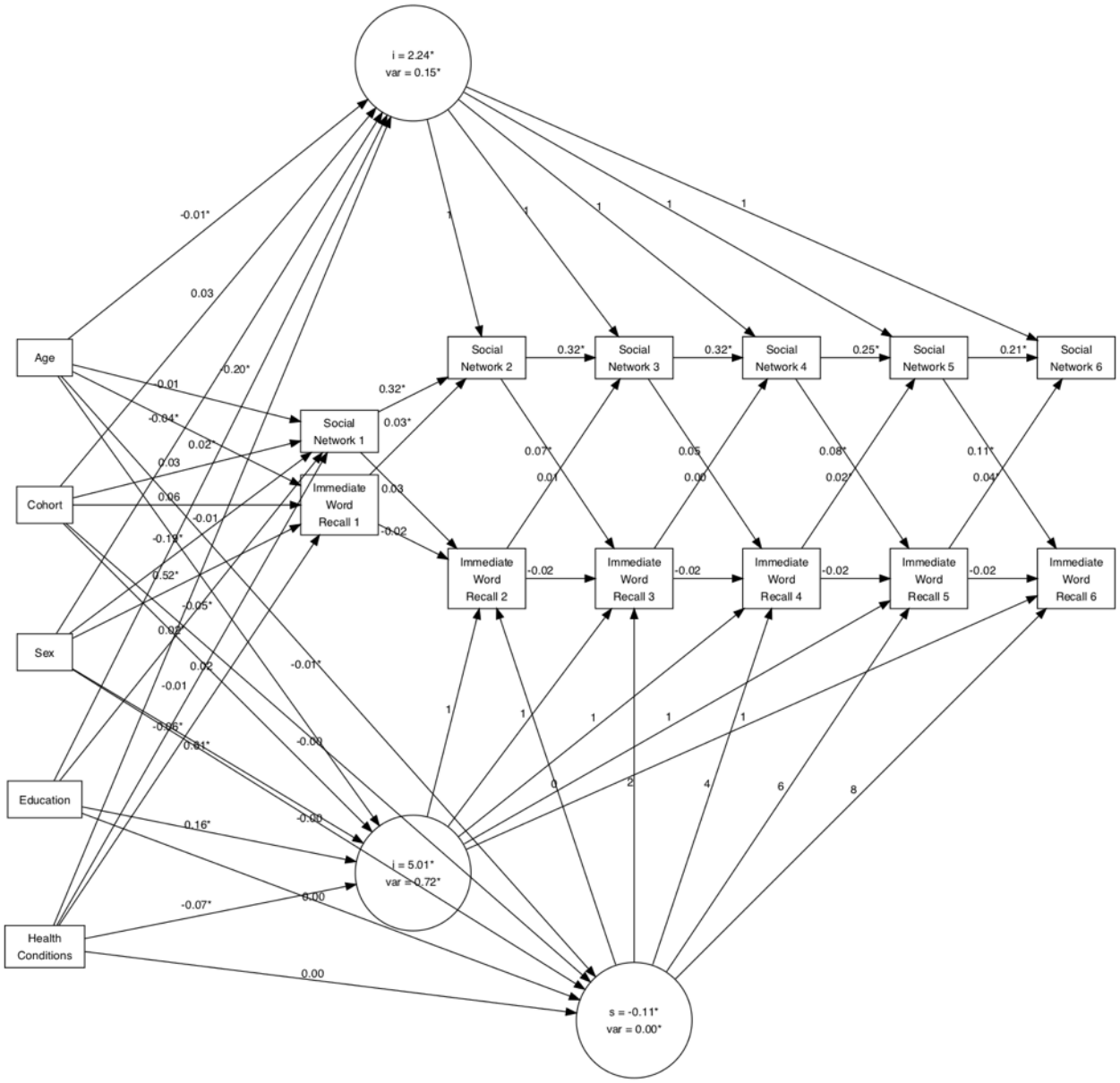

Figure 15. The final conditional autoregressive latent trajectory model for social network composition and immediate word recall.

* indicates $p < .05$

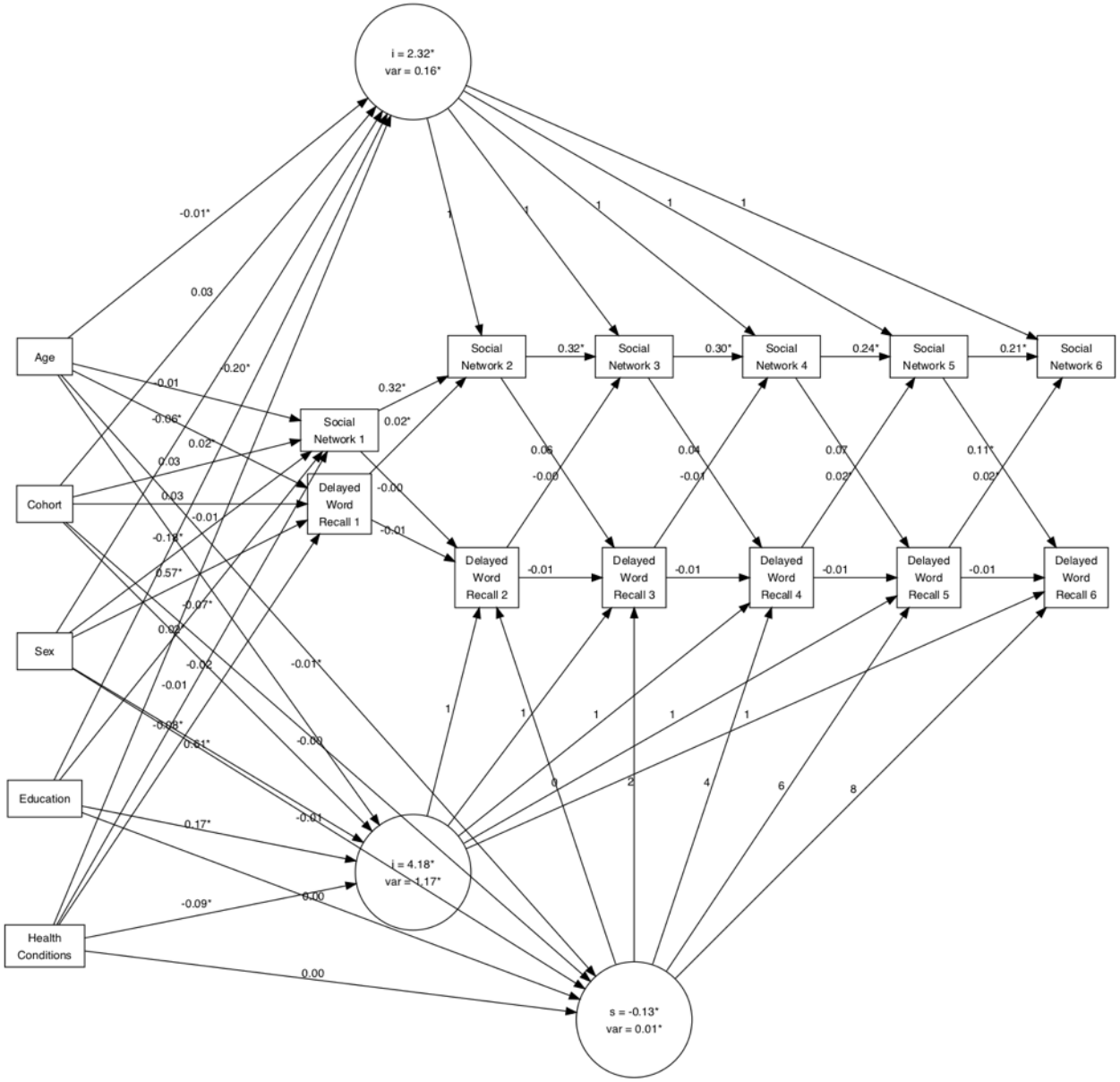

Figure 16. The final conditional autoregressive latent trajectory model for social network composition and delayed word recall.

* indicates $p < .05$

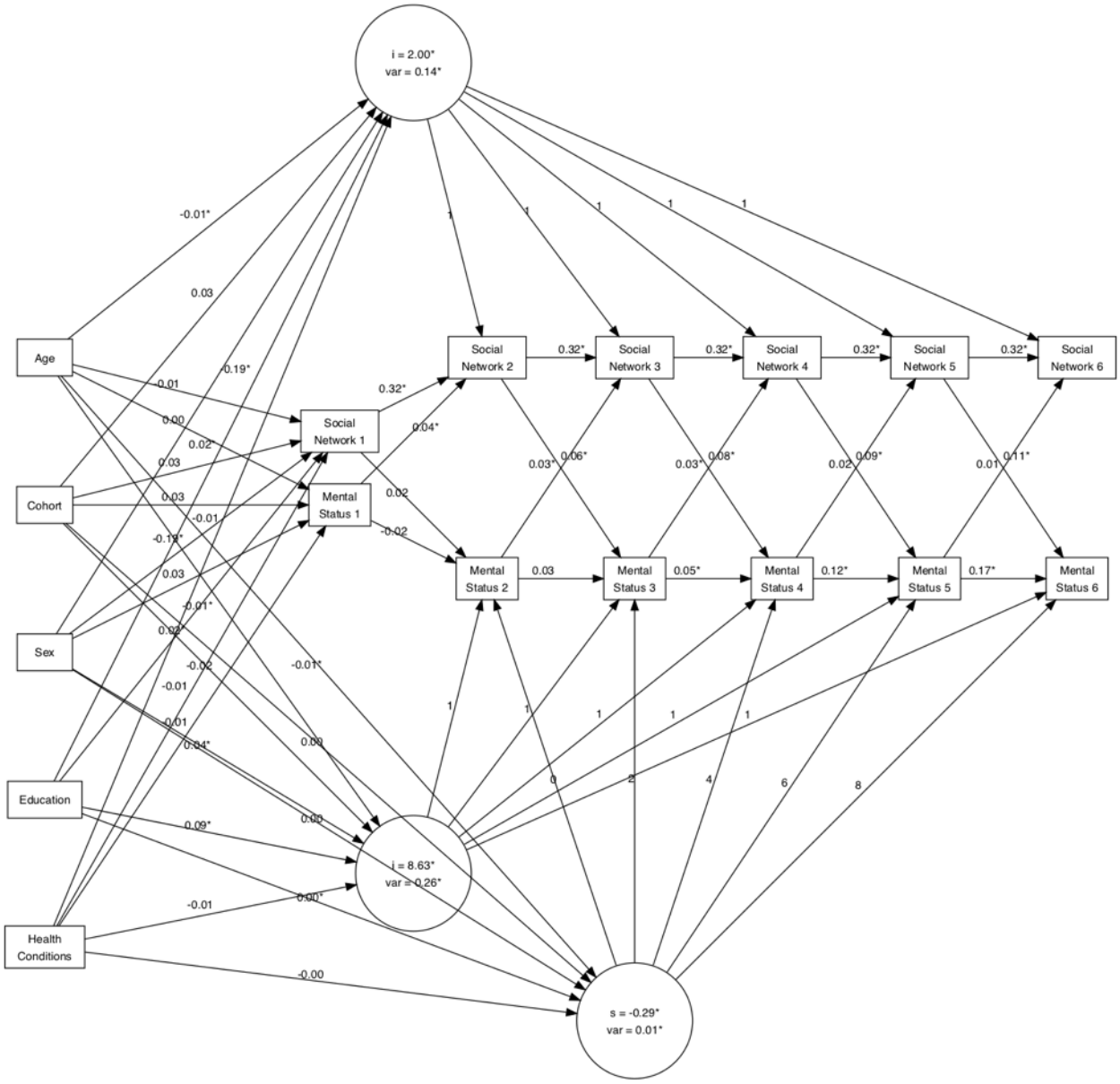

Figure 17. The final conditional autoregressive latent trajectory model for social network composition and mental status.

* indicates $p < .05$

Chapter 3: Changes in Social, Psychological, Lifestyle, and Cognitive Functioning Following a Spouses Diagnosis of Dementia

Abstract

Spouses who are partners in care of individuals living with dementia are at risk of increased psychological distress and cognitive decline. Spouses may also face particular challenges in maintaining social involvement and be at increased risk for social isolation and loneliness which may further increase risk of negative psychological outcomes and cognitive decline. However, most studies compare caregivers with non-caregivers, leaving open the possibility that some of the differences observed are attributable to pre-existing factors such as assortative mating and cumulative effects of lifestyle. Participants drawn from population-based Health and Retirement Study, which includes linked information on both members of a couple as well as information on individual's diagnosis of dementia, were identified through the partners' linked identification number. Of 8672 included individuals with a partner, 8608 had a spouse never diagnosed with a memory disease, and 547 have a spouse with dementia. Linear growth models were estimated for cognitive, social, and psychological variables, with spouse's dementia diagnostic status dummy coded as a time-varying covariate to investigate its impact on within person change. The impacts on cognitive outcomes of interactions between social variables and spouse's dementia status were examined. Limited evidence was found for within person change in cognitive abilities following a spouse's diagnosis of dementia, with exception of immediate recall. This suggests that risk factors that accumulate over time, such as shared lifestyle, may better account for increased risk of cognitive decline in spouses of individuals with dementia. A diagnosis of dementia was related to within person decreases in psychological wellbeing and reduced social contact consistent with previous studies. There was no interaction of social variables with spouse's dementia status that would support the hypothesis that social support may buffer the stress of a spouse's diagnosis. Thus, interventions targeting psychological

wellbeing of caregivers may be most helpful but are unlikely to significantly impact risk of cognitive decline.

Introduction

Some older adults face particular challenges to their ability to participate in social activities and retain meaningful social relationships. In particular, one at-risk group of older adults are those who have a spouse or partner who has been diagnosed with dementia. Spouses often take on the primary caregiving role. Spousal caregivers in particular may become isolated from friends and other family members because they do not want to leave their spouse alone or socialize without them (Drentea, Clay, Roth, & Mittelman, 2006). Caregivers are more likely than non-caregivers to experience social isolation (Ory, Hoffman, Yee, Tennstedt, & Schulz, 1999) and loneliness (Beeson, 2003). Further, caregivers frequently suffer from higher levels of psychological distress, including depression and anxiety (Pinquart & Sörensen, 2003; Sherwood, Given, Given, & Von Eye, 2005). Consistent with the conceptualization of caregivers as experiencing chronic stress, caregivers have also shown increased levels of cortisol and reduced antibodies (Vitaliano, Zhang, & Scanlan, 2003). Further, caregivers are more likely than non-caregivers to exhibit cognitive problems and show greater cognitive decline (de Vugt et al., 2006; Vitaliano, Murphy, Young, Echeverria, & Borson, 2011). In a study of 1,221 married couples, those who had a spouse diagnosed with dementia were found to have a risk of incident dementia that was six times higher than those whose spouses did not have dementia (Norton et al., 2010). A decline in cognitive function among spouses of individuals with dementia has important implications in that it compromises their ability to assist their partner, which may necessitate a greater level of formal care, and in the absence of other supports may put both members at risk for negative outcomes (Norton et al., 2010).

Three possible explanations for findings of decreased cognitive functioning, and increased risk of dementia in spouses of individuals living with dementia have been proposed:

assortative mating, shared lifestyle, and the stresses of caregiving (Norton et al., 2010; Vitaliano et al., 2011). The assortative mating explanation is centred around the strong association between risk of dementia and demographic variables, most strongly, education (Evans et al., 1997). This has been partially addressed in many studies by controlling for demographic factors or by comparing caregivers to matched non-caregiver samples (de Vugt et al., 2006). It is more difficult to control for shared lifestyle or other more nuanced factors such as personality.

There is little question that having a spouse diagnosed with dementia and caregiving are significant stressors. Caregivers are more likely to have limitations on time and energy to engage in social and other lifestyle activities. A spouse's declining cognitive function alters the relationship that may have been an individual's primary source of social support and many people cite the loss of their partner as one of the most difficult aspects (Pozzebon, Douglas, & Ames, 2016). Further, the grief associated with a partner's illness puts them at risk for psychological distress, decreased well-being and lower life satisfaction. Thus, the stresses of caregiving may confer additional risks for cognitive decline (Vitaliano et al., 2011).

The impact of shared lifestyle develops over many years, and thus could account for differences between caregivers and non-caregivers, but would not account for within person changes. However, if a spouse's diagnosis of dementia is impactful on cognitive function because of psychosocial stressors, a within person change would be expected. Thus, the current study looks to examining the temporal sequence of the relations between a spouse's diagnosis of dementia, loneliness, social support, and social contact. Basic sociodemographic factors with known associations to dementia risk was controlled for.

The stress-buffering hypothesis, is a theory positing that social factors are important because social support buffers the impact of stress and the resulting physiological cascade that

causes wear and tear on bodily systems over time (Cohen, 2004). This suggests that caregivers may be particularly in need of social support to buffer the stress of having a spouse or partner diagnosed with dementia, and the presence or absence of such support may be predictive of negative outcomes such as cognitive decline. However, the relations between the transition to caregiving, loneliness, social support, and social participation are not clear. It makes intuitive sense that caregivers may report increased levels of loneliness because the demands of caregiving might make regular contact with social network members more challenging, but, to my knowledge, no study to date has examined change in social contact following a spouse's diagnosis of dementia. Most studies are cross-sectional, comparing caregivers to groups of non-caregiver older adults or, less commonly, comparisons between caregivers for spouses with different types of diseases. Thus, the present study addresses whether a spouse's diagnosis of dementia is associated with a within person change in social support, social contact frequency, loneliness and depressive symptoms. Although dementia is a disease of insidious onset, and cognitive decline and difficult behaviors appear increasingly over time, time of diagnosis is used for two reasons. The first is that it is an identifiable point that typically occurs once symptoms have become concerning enough that medical attention is sought. Thus, the level of stress prior to this point may be minimal. The second reason is that learning the spouse's diagnosis, and the implications, is likely an important component.

The stress buffering hypothesis would predict that, following a spouse's diagnosis of dementia, inadequate social support would put individuals at risk of negative outcomes due to stress. However, it is also unclear whether perceptions of social support are altered by a spouse's diagnosis of dementia and/or if there is an actual decrease in objective social variables (i.e., social network members, social contact with network members). A decrease in actual social

contact frequency might then result in feelings of loneliness, and lower perceived social support. However, it is also possible that a spouse's diagnosis of dementia alters individual's perceptions of the adequacy of their social situation even if social contact frequency has not objectively changed. Loneliness is distinct from the frequency of actual social contact with the more important factor being whether one views their social needs as being met (Hawkley & Cacioppo, 2010). The importance of differentiating between the two is important for caregivers as well, as the relationship to outcomes has been shown to differ. For example, the effect of perceived social support was shown to be larger, and more consistent, than that of received social support on subjective caregiver burden in a recent metanalysis (del-Pino-Casado et al., 2018). Addressing loneliness is not as simple as providing more opportunities for social interactions and the formation of new relationships (Masi, Chen, Hawkley, & Cacioppo, 2011). This has implications for the spouses of individuals living with Alzheimer's disease or dementia because conventional wisdom suggests that since perceived social support is important for wellbeing, one should simply increase possibilities for social support to increase caregiver wellbeing. However, this assumption may be false if the reasons for low perceived social support and loneliness are not due to actual social contact frequency and a lack of activity participation. Thus, these social factors are examined separately in the present study.

This investigation examines whether a spouse's diagnosis of dementia is related to a change in social factors, psychological experience, and cognitive function. First, trajectories of change in each variable is examined to evaluate whether change over measurement occasions has occurred, as linear change over time is expected in cognitive performance, but not necessarily in social factors or depressive symptoms. Further, it is possible that a spouse's diagnosis of dementia will be associated with a decline in perceived social support from the spouse, friends,

and children, and other family friends, but not with an actual decrease in social contact frequency from these network members. This might indicate that social support is perceived as lower because need is higher rather than due to an actual decrease in social contact. Second, for social factors, depressive symptoms, the impact of a spouse's diagnosis of dementia will be examined by including the diagnostic status of the spouse as a time varying predictor. Third, the interaction between a spouse's diagnosis of dementia and social and psychological factors in predicting change in cognitive functioning will also be examined to evaluate the possibility that theory that social factors may buffer the stress of having a spouse diagnosed with dementia and therefore reduce the impact on cognitive decline.

Method

Participants

Participants were drawn from the 2004, 2006, 2008, 2010, 2012, and 2014 waves of the Health and Retirement Study (HRS). Because HRS includes both members of a spouse/partner couple, the spouses of HRS participants who report that they have received a diagnosis of "memory-related disease", "dementia", or "Alzheimer's disease" were identified through the partners' linked identification number. Those who reported themselves having a "memory-related disease", "dementia", or "Alzheimer's disease" were excluded. The pattern of a spouse's diagnosis was examined and those with missing data that left the wave of diagnosis uncertain, and those with improbable patterns where a consistent diagnosis was not clear, were excluded. The spouse's diagnosis of memory related disease was imputed when missing if both the previous and subsequent waves had the same value or if there was a pattern of no diagnosis of dementia followed by missing data. Individuals whose interviews were completed by proxy were also excluded. These restrictions resulted in a sample size of 8672 individuals, including 8608

who were married with a spouse never diagnosed with a memory disease, 64 individuals with a spouse who was diagnosed prior to 2004 data collection, and 483 participants whose spouse was diagnosed at any of the six included waves.

Measures

Demographics. Age at each occasion, gender, and years of education were gathered based on self-report.

Social contact. Respondents were also asked the extent to which they are in contact with members of their social network (excluding spouses) (Smith et al., 2013). Participants responded to three questions regarding how often they 'Meet up', 'Speak on the phone', and 'Write or email' each subgroup: children, other family, and friends. Responses were given on a 1 = Three or more times a week to 6 = Less than once a year or never, scale. Responses were reverse coded and summed for a total score of overall contact with social network with a possible range of 3 (if only one social network category was endorsed) to 54, with higher values indicating greater social network contact.

Social support/Relationship quality. Social support was measured by three items of a social support scale developed by Walen & Lachman (2000). Similar measurements were used in previous studies and found to be reliable (e.g.,(Bertera, 2005). Three items assessing social support include: ''How much do they really understand the way you feel about things?'' ''How much can you rely on them if you have a serious problem?'' and ''How much can you open up to them if you need to talk about your worries?'' Items were asked in four loops in reference to participants' spouse/partner, children, family members, and friends. The response options ranged from 1 (a lot), 2 (some), 3 (a little), to 4 (not at all). Negatively worded items were re-coded so that a higher value indicates a higher level of social support. Social support for each category

was calculated as the average of responses to the above three items and a total social support score was created by summing the means for each category. The total social support score had a possible range of 3 to 12.

Loneliness. The Revised University of California Los Angeles Loneliness Scale is a self-report measure of loneliness (Hughes et al., 2004; Russel et al., 1980). The Revised version of the UCLA Loneliness scale is a short form of the widely used original scale. Respondents were asked to rate, on a 3-point scale, how often they felt as if they (a) lacked companionship, (b) were left out, or (c) were isolated from others. To obtain an overall loneliness score, the mean of the 3 items will calculated, with a higher score representing greater loneliness (range 1–3).

Depressive Symptoms. Depressive symptoms were measured by seven items taken from the Center for Epidemiologic Studies Depression Scale (CES-D). The Center for Epidemiological Studies Depression Scale (CES-D) is a self-report measure originally developed for use in the general population (Radloff, 1977). Respondents were asked to respond 'yes' or 'no' to whether 'Much of the time during the past week' they felt 8 depressive symptoms (e.g., "You could not get going."). Positively worded items are recoded such that higher scores indicate more depressive symptoms in the past week (range 0-8).

Episodic Memory. Memory functioning was assessed either in a face-to-face interview or over the phone. The two modes are expected to result in comparable performance (Ofstedal et al., 2005). Memory functioning in HRS was assessed with two memory tasks. An immediate word recall task where respondents were aurally given a list of 10 nouns and asked to recall as many words as possible from the list in any order (range 0-10) and a delayed verbal memory task where after 5 min of engaging in other survey questions, respondents are asked to repeat the list of nouns previously presented to as part of the immediate recall task. In order to minimize the

impact of prior experience (at previous waves of assessment) with the material, four different lists of 10 words were constructed that contained different but equivalent nouns. One and two syllable nouns of high frequency (Thorndike & Lorge, 1944), high imagery, and concreteness (6.0 or more according to the norms by (Paivio et al., 1968) were considered for inclusion in the four word lists. Nouns meeting these conditions were ordered by recall-ability according to norms developed by Rubin (Rubin & Friendly, 1986) and distributed to six lists. The four lists used in HRS were selected for maximum equivalence in a pretest with 30 HRS respondents. The lists were randomly assigned to participants so that they were originally equal in frequency. Participants receive the lists in order so that each form will be given only once to each participant over four study waves.

Mental Status. Mental status was assessed in all HRS participants aged 65 and older with a series of questions (Ofstedal et al., 2005). Respondents were asked to count backwards, as quickly as possible, for 10 continuous numbers starting at the number 20. Respondents were asked to give "today's date" including the month, day, year, and day of the week. Two object naming questions were asked "What do you usually use to cut paper?" and "What do you call the kind of prickly plant that grows in the desert?". Respondents were asked to give the name of the current President and Vice President of the United States. Responses to mental status questions were summed for a mental status total score (range 0-9).

Analysis

To examine whether a spouse's diagnosis of Alzheimer's disease or dementia is associated with change in social, psychological, and cognitive functioning, a series of multilevel models was estimated using Mplus version 6. Initially, social contact frequency, social support, loneliness, depressive symptoms, episodic memory, and mental status were examined as

dependent variables in a linear growth model to investigate whether each process was well described by a linear trajectory of change. Each unconditional level-1 growth was modeled with time coded as the length of time since 2004 assessment (0, 2, 4, 6, 8, 10). Then, using the approach outlined in McCoach & Kaniskan (2010), spouse's dementia status was included in each model as a time-varying predictor (coded as 0 'no diagnosis' or 1 'diagnosis') with a persisting effect of diagnosis (i.e., once diagnosed the covariate remained coded as 1). Widowhood was included as a second time-varying covariate also coded as 0 'not widowed' and 1 'widowed' as it is possible that the transition to widowhood would also impact social and cognitive factors. Between person covariates age, education, and sex were also examined as time-invariant covariates. Age and education were grand mean centered to aid interpretation of model results. Male was coded as the reference group for sex.

Lastly**,** to investigate whether social and psychological factors interact with spousal dementia status to predict change in cognitive functioning, social variables that showed significant relations with a spouse's diagnosis of dementia were added as predictors of each cognitive variable. Social and psychological variables were added as time varying covariates, as well as in an interaction term with spousal dementia status, separately for each cognitive outcome (episodic memory and mental status).

Results

Descriptive statistics for the included sample are presented in Table 14. The number of participants in each wave is the number of participants for which there was any data at that wave. This number is lower at some waves because of the inclusion criteria used, specifically that proxy interviews were not included and some waves had a higher number of proxy interviews. The n is lower for psychosocial variables because these items were completed in a questionnaire

given every four years. However, in the analysis the total sample (top n in Table 14) was included with the psychosocial variables treated as missing data on waves in which this data was not collected. Sixty-five percent of the spouses of individuals diagnosed with dementia were women, while 52% of the spouses of individuals not diagnosed with dementia during the study period were women. Model results are presented in three tables (Table 15 to Table 17), for each cognitive outcome and Table 18 and Table 19 for psychological and social factors, respectively.

The unconditional linear growth model of immediate recall performance showed that the average score at Time = 0 in 2004 was 5.85 (out of 10), and the mean immediate recall score decreased at a rate of -0.12 ($p < .001$) words per wave (see Table 15). There was statistically significant between person variation in initial immediate word recall performance ($Var_{intercept} = 1.00$, $p < .001$), and in the rate of decrease ($Var_{slope} = 0.006$, $p = .001$). In the second model, including time-invariant predictors and spouse's diagnosis of memory disease and widowhood, age at first included occasion, sex, and number of years of education all significantly predicted immediate recall performance with being older associated with poorer performance and being female, and having more years of education associated with better initial performance. Of the time invariant covariates, only baseline age was significantly related to rate of change in immediate recall performance, such that older individuals showed greater decline. The coefficient for the TVC indicated that after a spouse's diagnosis of dementia, participants show a significant within person loss of 0.13 words on average, after accounting for the age at baseline, education, and gender. The transition to widowhood did not independently predict within person change in immediate recall performance.

The unconditional model of delayed word recall showed that the average score at Time 0 was 4.87 (out of 10), with significant variation ($Var_{intercept =} 1.52$, $p < .001$; see Table 16).

Delayed recall scores decreased by 0.13 words per wave on average, with significant variation in the rate of decrease ($Var_{slope} = 0.012$, $p < .001$). Age at first included occasion, sex, and number of years of education all significantly predicted immediate recall performance with being older associated with poorer performance, while being female, and having more years of education were associated with better initial performance. Of the time invariant covariates, only baseline age was significantly related to rate of change in delayed recall performance, such that older individuals showed greater decline. Neither a spouse's diagnosis of dementia nor widowhood was significantly related to within person change in delayed recall performance.

The unconditional model of mental status showed that the average mental status score at Time 0 was 8.63 (out of 9) with significant variation around this average ($Var_{intercept} = 0.19$, $p < .001$; see Table 17). On average, mental status decreased by 0.10 points a year with significant variation around this as well ($Var_{slope} = 0.02$, $p < .001$). Time-invariant covariates were added, age, sex, and years of education, with a spouse's diagnosis of memory disease as a TVC. Age was significantly and negatively related to rate of change in mental status; years of education was significantly and positively related to rate of change in mental status; sex was not. A spouse's diagnosis of memory problems was not significantly related to within person change in mental status. However, the transition to widowhood predicted a within person decrease of 0.11 in mental status.

The unconditional model of depressive symptoms showed that the average level of depressive symptoms at Time 0 was 1.09 (out of 8) with significant variation around this average ($Var_{intercept} = 1.66$, $p < .001$; see Table 18). On average, individuals endorsed 0.03 more depressive symptoms each year, although this varied significantly (0.04, p <.001). Age at baseline, sex, and years of education were all related to intercept of depression, such that older

adults and those with more education reported fewer depressive symptoms while women endorsed more. A spouse's diagnosis of dementia was added as a TVC and significantly predicted depression at the within person level, such that a spouse's diagnosis of dementia was associated with a 0.31 increase in depressive symptoms ($p < .001$). Widowhood was associated with a 0.70 ($p < .001$) increase in depressive symptoms at a within person level.

The unconditional model of loneliness showed that the average level of loneliness at Time 0 was 1.4 (out of 3), with significant variation around this average ($Var_{intercept} = 0.03$, $p < .001$; see Table 19). Participant loneliness increased on average by 0.09 points a year and there was significant variance around this rate of change ($Var_{slope} = 0.002$, $p < .001$). In the covariate model, younger individuals endorsed greater loneliness, but greater age was related to greater increases in loneliness over time. Gender was not significantly related to initial level of loneliness but being female was related to an increased rate of change in loneliness over time. At the within person level, a spouse's diagnosis of dementia was associated with a 0.11 increase in loneliness ($p <.001$) and widowhood was associated with a 0.24 increase in loneliness ($p < .001$).

The unconditional model of social contact showed that average social contact at Time 0 was 30.68, with significant variation about this average ($Var_{intercept} = 45.4$; see Table 19). Social contact decreased by an average of -0.1 points each year with significant variation around this rate of change (0.81, $p < .001$). When covariates were added, age at baseline was significantly related to social contact such that older individuals had higher initial social contact but older age was associated with an additional -0.02 ($p < .001$) decline. Women had significantly more initial social contact than men (2.98, $p < .001$), however the average rate of change in social contact did not differ between men and women (-0.00, $p = .96$). A spouse's diagnosis of dementia was

associated with a -0.78 (p = .038) while widowhood was associated with an 0.77 (p = .002) increase in social contact.

The unconditional model of social support showed that average level of social support at Time 0 was 9.50 (Out of 12), with significant variation about this average ($Var_{intercept}$ = 1.40; see Table 19). On average, there was also significant decline over time in social support (-0.01, p = .019), and the variation about this trajectory was significant (0.02, p < .001). When covariates were added, age at baseline was significantly related to initial social support such that older individuals had greater initial social support (0.01, p <.0001) but no difference in rate of change in social support. Women endorsed significantly greater initial social support than men but gender was also not related to rate of change. Education was not related to initial social support or rate of change in social status. A spouse's diagnosis of dementia was associated with a -0.17 (p = .013) decrease in social support while the transition to widowhood was associated with a within-person increase in social support of 0.18 (p < .001).

Next, models were estimated to investigate whether there was a significant interaction between social variables and spouse's memory disease in predicting cognitive change (see Tables 15 to 17). Models with spouse's memory disease, widowhood, and social variables would not converge and so widowhood was not included in the analysis as this was not the primary variable of interest. Social variables, and social variable by spouse's diagnosis of dementia interaction were added as time-varying covariates. Loneliness, depressive symptoms, social support, and social contact were all significant predictors of immediate word recall in each respective model however interaction terms were not. Increases in loneliness, depressive symptoms, and social support were associated with additional within person decline, while increases in social contact were associated with less decline in immediate word recall

performance (see Table 15). However, there was no additional impact of loneliness, depressive symptoms, or social support for individuals whose spouses were diagnosed with dementia. For delayed recall, when social variables were examined as time-varying covariates, only loneliness and depressive symptoms were significant, indicating that an increase in loneliness and depression was associated with a greater decrease in delayed word recall performance, over and above the predicted slope (see Table 16). However, there was no significant interaction between a spouse's diagnosis of dementia and depressive symptoms or loneliness indicating that having a spouse diagnosed with dementia does not alter the relationship of these factors to delayed recall performance.

For mental status, when social variables and depressive symptoms were examined as time-varying covariates, increased loneliness and increased social contact were associated with less decline, while more depressive symptoms were associated with more decline (see Table 17). There was a significant interaction such that having a spouse diagnosed with dementia and more symptoms of depression was associated with smaller decline in mental status.

Discussion

There were two main aims to the present study. The first, was to investigate whether a spouse's diagnosis of a memory related disease was related to within person change in cognitive performance, and social and psychological factors. The second aim was to investigate whether an interaction occurs between a spouse's diagnosis of dementia and social and psychological factors in their impact on cognition. With regards to cognitive function, a spouse's diagnosis of dementia predicted a within person decrease in immediate recall performance, but no additional change, above that accounted for by linear trajectory over time, in delayed recall performance or mental status. Thus, there is some evidence that having a spouse diagnosed with a memory

related disease may be associated with small changes in cognitive performance on specific tasks (immediate recall), but little evidence of global decline in mental status. The discrepancy in findings between domains of cognitive function may be indicative of a non-neurobiological basis for poorer performance. Immediate recall is sensitive to attention, which particularly under conditions of psychological distress can be transiently variable but not indicative of an enduring change. Whereas mental status, and delayed recall, which is more a measure of the adequacy of memory storage and retrieval, are less likely to be impacted by temporary variation in attention and concentration and may be better indicators of lasting effects. Previous studies have also found that spousal caregivers' evidence greater decline in performing measures of attention and processing speed (Vitaliano et al., 2009) but there is little evidence of longitudinal changes in other cognitive domains. Cross sectional studies have reported decreased immediate and delayed recall in spousal caregivers, however, it is difficult to disentangle the relative impact of assortative mating, years of shared life style, and psychosocial stresses and physiological dysregulation due to caregiving (Vitaliano et al., 2011). The present study addressed this issue by examining rates of within person change, prior to and following a spouse's diagnosis of dementia. That no additional change in delayed recall or mental status was predicted by a spouse's diagnosis of dementia can be viewed as support for the first two explanations: assortative mating and shared lifestyle. However, an important limitation of this study is that it is not known whether spouses were actually caregivers and to what extent they were providing care. It is possible that including those who identified as caregivers and were confirmed to be providing significant amounts of care would yield different results. Further, although the follow up period included in the present study was up to 10 years, this includes years before the spouse's diagnosis as well, and the amount of time the spouse has been living with dementia

could range from 10 years to just one year. It may be that the follow up period was not sufficiently long to capture greater rates of decline in delayed recall and mental status. Widowhood was also included as a time-varying covariate to control for potential effects, although models with and without widowhood included showed no difference in terms of the significance of a spouse's diagnosis of dementia on cognitive function. However, widowhood was itself an independent predictor of increased decline in delayed recall and mental status, consistent with previous research (Aartsen, Van Tilburg, Smits, Comijs, & Knipscheer, 2005).

A spouse's diagnosis of dementia was associated with a within person increase in depressive symptoms, loneliness, and social support, but a decrease in social contact. These findings are consistent with previous research which has found that spousal caregivers of persons with dementia are more likely to have depressed mood (Pinquart & Sörensen, 2003), social isolation (Ory et al., 1999) and loneliness (Beeson, 2003). Qualitative research has similarly identified the loss of one's partner as a central theme to the challenge of having a spouse diagnosed with dementia (Pozzebon et al., 2016). The decrease in social support associated with a spouse's diagnosis of dementia is consistent with predictions, although, for widowhood there was an increase. It may reflect an activation of social support for those who have lost a spouse in response to increased need that does not occur for those with a spouse diagnosed with dementia. Subsequent models investigated whether an interaction between symptoms of depression or loneliness and having a spouse diagnosed with a memory disease predicted within person change in cognitive outcomes. These models revealed no such effects.

The Health and Retirement study dataset is somewhat unique in that information is available for a subset of participants both before and after spouse's diagnosis of dementia. Previous literature has suggested that caregiving is associated with increased risk of cognitive

decline and psychological distress, but most studies compare caregivers to non-caregivers. This investigation looked at within-person change in outcomes with a spouse's diagnosis of a memory related disease (dementia or Alzheimer's disease) as a time varying predictor.

There are several limitations to the present study. First, the methodology used to identify participants whose spouses had received a diagnosis of dementia relied on linking spousal records within the Health and Retirement Study dataset but did not take into consideration whether the spouses actually identified as caregivers, whether they were providing significant care, or the current functioning of the partner living with dementia. Further, subtypes of dementia were not considered independently, and earlier waves asked about memory-related disease, rather than Alzheimer's disease or dementia specifically. These may be important factors in determining whether having a spouse diagnosed with dementia is associated with increased risk of cognitive decline. However, the present study did find that a spouse's diagnosis of dementia was associated with increased depressive symptoms and loneliness, which does suggest that the impact on psychological wellbeing was significant among the identified group.

Information on whether a spouse had a diagnosis of dementia, and when the diagnosis occurred was not always clear due to missing data. In cases when it was particularly ambiguous, for example, no diagnosis prior to the missing data and then a diagnosis after, it was not clear how to code the missing wave so those cases were removed. However, to preserve as much information as possible in cases where there was no diagnosis of dementia followed by missing data, these were coded as non-cases and retained in the sample. These inclusion/exclusion criteria may have impacted findings. Social and psychological variables were only collected every four years while cognitive function was available for every two years, with the alternating years for social and psychological variables treated as missing data. Although this approach

maximizes the use of available information it may reduce the ability to detect associations. Further, although the first wave at which a diagnosis of dementia or Alzheimer's disease was reported was the first occasion when a spouses diagnosis of dementia was considered present, neurodegenerative disease are insidious in their onset and significant symptoms are very often present for years prior to diagnosis. The focus on before and after diagnosis as discrete may have made any related changes in a spouse's cognitive, psychological and social wellbeing harder to detect. Similarly, having a spouse with dementia was coded as an effect that persisted over time but did not increase. It is possible that as the disease progresses there is an increase in impact on the spouse in terms of level of stress experienced, and coding the impact as increasing would have been more accurate. However, it is also possible, as was assumed here, that while the sources of stresses may change, for example from accepting the gravity of the diagnosis to coping with challenging behaviors as a spouse's functioning worsens, the level may remain constant.

Lastly, many other potential factors that could not all be included may be important to consider in examining whether a spouse's diagnosis of dementia is associated with an accelerated rate of cognitive decline and changes in psychological wellbeing and social involvement. These represent areas for future research, as continuing to identify individuals more at risk for decline themselves, following a spouse's diagnosis, and employing empirically supported interventions preventatively remain important goals.

In conclusion, the present study found limited evidence of within person change in cognitive abilities following a spouse's diagnosis of dementia. This suggests that risk factors that accumulate over time, such as shared lifestyle, may better account for previously observed associations. Further, a spouse's diagnosis of dementia was related to within person decreases in

psychological wellbeing and reduced social contact consistent with previous studies. This confirms that interventions targeting psychological wellbeing of caregivers may be most helpful.

Table 14. *Descriptive statistics by wave*

	2004	2006	2008	2010	2012	2014
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
	n = 7946	n = 8252	n = 8371	n = 8285	n = 7784	n = 7125
Women (%)	54.81	51.47	50	50	50	50
Age	62.29 (9.28)	64.32 (9.28)	66.17 (9.34)	68.39 (9.36)	69.91 (9.12)	71.28 (8.98)
Years of education	12.98 (3.01)	12.94 (3.04)	12.94 (3.05)	12.96 (3.04)	12.97 (3.06)	13.02 (3.06)
Widowhood (n (%))	61 (0.77%)	62 (0.75%)	290 (3.46%)	610 (7.36%)	845 (10.86%)	1016 (14.26%)
Spouse diagnosed with dementia (n (%))	64 (0.81%)	122 (1.48%)	201 (2.4%)	284 (3.43%)	351 (4.51%)	369 (5.18%)
Both spouse diagnosed with dementia and widowhood	0	17	45	97	131	158
Mental status	8.57 (0.76)	8.55 (0.78)	8.5 (0.81)	8.22 (1)	8.26 (1.02)	8.22 (1.09)
Word recall immediate	5.84 (1.51)	5.78 (1.57)	5.67 (1.59)	5.47 (1.66)	5.37 (1.68)	5.38 (1.7)
Word recall delayed	4.85 (1.82)	4.82 (1.86)	4.7 (1.88)	4.48 (1.97)	4.4 (1.98)	4.4 (1.99)
Psychosocial variables	n = 1553	n = 3902	n = 3602	n = 3856	n = 3071	n = 3379
Loneliness	1.35 (0.43)	1.38 (0.45)	1.51 (0.53)	1.46 (0.55)	1.53 (0.52)	1.51 (0.54)
Social contact	30.8 (8.75)	30.3 (8.12)	30.55 (8.64)	30.94 (8.64)	30.63 (9)	30.18 (8.81)
Social support	9.68 (1.46)	9.44 (1.47)	9.46 (1.48)	9.48 (1.51)	9.5 (1.53)	9.46 (1.53)
Social network composition	3.71 (0.61)	3.75 (0.51)	3.67 (0.61)	3.62 (0.63)	3.45 (0.77)	3.37 (0.82)
Depressive symptoms	1.07 (1.71)	1.14 (1.73)	1.14 (1.73)	1.15 (1.75)	1.18 (1.8)	1.2 (1.8)

Table 15. *Immediate word recall*

		Model 1 - Unconditional	**Model 2 - Spouse dementia and widowhood**	**Model 3 - Loneliness**	**Model 4 – Depression**	**Model 5 – Social support**	**Model 6 – Social contact**
	Parameter	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Initial status	Intercept	5.85 (0.02)**	5.43 (0.02)**	4.49 (0.03)	5.48 (0.02)**	4.69 (0.06)**	5.23 (0.05)**
	Age intercept		-0.03 (0.00)**	-0.04 (0.00)**	-0.03 (0.00)**	-0.04 (0.00)**	-0.03 (0.00)**
	Female		0.53 (0.03)**	0.51 (0.04)**	0.54 (0.03)**	0.50 (0.05)**	0.46 (0.04)**
	Yrs Ed		0.17 (0.00)**	0.17 (0.17)**	0.16 (0.00)**	0.17 (0.01)**	0.16 (0.01)**
Rate of change	Slope	-0.12(0.00)**	-0.12 (0.01)**	-0.14 (0.01)	-0.12 (0.01)**	-0.15 (0.01)**	-0.13 (0.01)**
	Age		-0.01 (0.01)	-0.01 (0.00)**	-0.01 (0.00)*	-0.01 (0.00)**	-0.01 (0.00)**
	Female		0.00 (0.03)	0.03 (0.01)*	0.00 (0.01)	0.03 (0.01)	0.00 (0.01)
	Yrs ed		-0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TVC - Spouse dementia			-0.13 (0.05)*	-0.46 (0.23)*	-0.15 (0.06)*	-0.11 (0.10)	-0.27 (0.19)
TVC - Widowhood			-0.04 (0.03)				
TVC - Social/psych				-0.03 (0.01) *	-0.05 (0.00)**	-0.04 (0.01)**	0.01 (0.00)**
TVC - Interaction				0.01 (0.01)	0.01 (0.02)	-0.01 (0.03)	0.01 (0.01)
Variance	Intercept	1.00 (0.03)**	0.59 (0.02)**	0.95 (0.07)**	0.57 (0.02)**	0.99 (0.11)**	0.57 (0.05)**
	Slope	0.01 (0.00)**	0.00 (0.00)	0.00 (0.01)	0.00 (0.00)	0.01 (0.01)	0.01 (0.00)
	Within Person Residual	1.39 (0.02)**	1.39 (0.02)**	1.57 (0.03)**	1.39 (0.02)**	1.55 (0.04)**	1.16 (0.03)**
Goodness-of-fit	AIC	166138.044	161647.069	71205.093	160470.802	65450.274	64683.273
	BIC	166190.656	161769.801	71323.034	160602.208	65566.884	64801.219
	Parameters	6	14	15	15	15	15

Note: * $p < .05$, ** $p < .001$; TVC = Time varying covariate; Model 1 is the unconditional model; Model 2 includes time invariant covariates and spouse diagnosis of dementia and widowhood as time-varying covariates; Model 3 includes time invariant covariates, and spouse diagnosis of dementia, loneliness, and the loneliness x spouse diagnosis of dementia interaction; Model 4 includes time invariant covariate, and spouse diagnosis of dementia, depressive symptoms, and the depressive symptoms x spouse diagnosis of dementia interaction; Model 5 includes time invariant covariate, and spouse diagnosis of dementia, depressive symptoms, and the depressive symptoms x spouse diagnosis of dementia interaction; Model 6 includes time invariant covariate, and spouse diagnosis of dementia, social contact, and the social contact x spouse diagnosis of dementia interaction.

Table 16. *Delayed word recall*

		Model 1 – Unconditional	**Model 2 – Spouse dementia and widowhood**	**Model 3 - Loneliness**	**Model 4 – Depression**	**Model 5 – Social support**	**Model 6 – Social contact**
	Parameter	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Initial status	Intercept	4.87 (0.02)**	4.40 (0.02)**	4.70 (0.05)**	4.47 (0.02)**	4.31 (0.09)**	4.34 (0.08)**
	Age intercept		-0.03 (0.00)**	-0.04 (0.00)**	-0.03 (0.00)**	-0.04(0.00)**	-0.04 (0.00)**
	Male		0.60 (0.03)**	0.51 (0.04)**	0.62 (0.03)**	0.51 (0.04)**	0.51 (0.04)**
	Yrs Ed		0.18 (0.01) **	0.17 (0.01)**	0.17 (0.01)**	0.17 (0.01)**	0.17 (0.01)**
Rate of change	Slope	-0.13 (0.00)**	-0.13 (0.01)**	-0.14 (0.01)**	-0.13 (0.01)**	-0.14 (0.01)**	-0.14 (0.01)**
	Age		-0.01 (0.00)**	-0.01 (0.00)**	-0.01 (0.00)**	-0.01 (0.00)**	-0.01 (0.00)**
	Female		0.01(0.01)	0.03 (0.01)*	0.00 (0.01)	0.02 (0.01)	0.02 (0.01)
	Yrs ed		0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TVC - Spouse dementia			-0.10 (0.06)	-0.23 (0.21)	-0.13 (0.07)	0.57 (0.42)	-0.53 (0.22)*
TVC - Widowhood			-0.05 (0.04)				
TVC - Social/psych				-0.17 (0.03)**	-0.06 (0.01)**	0.02 (0.01)	0.01 (0.01)
TVC - Interaction				0.07 (0.13)	0.03 (0.02)	-0.08 (0.04)	0.01 (0.01)
Variance	Intercept	1.52 (0.04)**	1.00(0.04)**	0.94 (0.07)**	0.97 (0.04)**	0.95 (0.07)**	0.95 (0.07)**
	Slope	0.01 (0.00)**	0.01 (0.00)*	0.00 (0.01)	0.01 (0.00)*	0.01 (0.01)	0.01 (0.01)
	Within Person Residual	1.86 (0.02)**	1.86 (0.02)**	1.57 (0.03)	1.86 (0.02)**	1.56 (0.03)**	1.57 (0.03)**
Goodness-of-fit	AIC	180587.280	176643.098	70790.383	175446.164	71253.361	71064.940
	BIC	180639.886	176765.818	70908.242	175577.557	71371.314	71182.853
	Parameters	6	14	15	15	15	15

Note: * $p < .05$, ** $p < .001$; TVC = Time varying covariate; Model 1 is the unconditional model; Model 2 includes time invariant covariates and spouses diagnosis of dementia and widowhood as time-varying covariates; Model 3 includes time invariant covariate, and spouses diagnosis of dementia, loneliness, and the loneliness x spouses diagnosis of dementia interaction; Model 4 includes time invariant covariate, and spouses diagnosis of dementia, depressive symptoms, and the depressive symptoms x spouses diagnosis of dementia interaction; Model 5 includes time invariant covariate, and spouses diagnosis of dementia, depressive symptoms, and the depressive symptoms x spouses diagnosis of dementia interaction; Model 6 includes time invariant covariate, and spouses diagnosis of dementia, social contact, and the social contact x spouses diagnosis of dementia interaction.

Table 17. *Mental status models.*

		Model 1 – Unconditional	**Model 2 – Spouse dementia and widowhood**	**Model 3 - Loneliness**	**Model 4 – Depression**	**Model 5 – Social support**	**Model 6 – Social contact**
	Parameter	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Initial status	Intercept	8.63 (0.01)**	8.49 (0.02)**	8.65 (0.03)**	8.52 (0.02)**	8.44 (0.60)**	8.31 (0.04)**
	Age		0.01 (0.00)**	0.01 (0.00)**	0.01 (0.00)**	0.01 (0.00)**	0.01 (0.00)**
	Male		0.06 (0.02)**	0.09 (0.03)**	0.07 (0.02)**	0.09 (0.03)**	0.07 (0.03)*
	Yrs Ed		0.09 (0.00) **	0.07 (0.01)**	0.08 (0.00)**	0.08 (0.01)**	0.07 (0.01)**
Rate of change	Slope	-0.10 (0.00)**	-0.07 (0.01)**	-0.07 (0.01)**	-0.07 (0.01)**	-0.06 (0.01)**	-0.06 (0.01)**
	Age		-0.01 (0.00)**	-0.01 (0.00)	-0.01 (0.00)**	-0.01 (0.00)**	-0.01 (0.00)**
	Female		0.01 (0.01)	0.00 (0.01)	0.01 (0.01)	0.00 (0.01)	0.00 (0.01)
	Yrs ed		0.01 (0.00)**	0.01 (0.00)**	0.01 (0.00)**	0.01 (0.00)**	0.01 (0.00)*
TVC – Spouse dementia			-0.01 (0.04)	0.05 (0.14)	-0.09 (0.04)*	0.03 (0.26)	-0.23 (0.17)
TVC - Widowhood			-0.11 (0.03)**				
TVC - Social/psych				0.10 (0.02)**	-0.03(0.00)**	0.01 (0.01)	0.01 (0.00)**
TVC - Interaction				-0.04 (0.08)	0.05 (0.01)**	-0.01 (0.03)	0.01 (0.01)
Variance	Intercept	0.19 (0.02)**	0.13 (0.02)**	0.03 (0.03)	0.12 (0.02)**	0.04 (0.03)	0.04(0.03)
	Slope	0.02 (0.00)**	0.02 (0.00)**	0.01 (0.00)**	0.02 (0.00)**	0.01 (0.00)**	0.01 (0.00)**
	Within Person Residual	0.45 (0.01)**	0.45 (0.01)**	0.45 (0.02)**	0.44 (0.01)**	0.45 (0.02)**	0.45 (0.02)**
Goodness-of-fit	AIC	73106.218	71025.333	29735.203	69890.024	30078.325	29980.606
	BIC	73156.043	71141.580	29846.563	70014.463	30189.790	30092.055
	Parameters	6	14	15	15	15	15

Note: * $p < .05$, ** $p < .001$; TVC = Time varying covariate; Model 1 is the unconditional model; Model 2 includes time invariant covariates and spouses diagnosis of dementia and widowhood as time-varying covariates; Model 3 includes time invariant covariate, and spouses diagnosis of dementia, loneliness, and the loneliness x spouses diagnosis of dementia interaction; Model 4 includes time invariant covariate, and spouses diagnosis of dementia, depressive symptoms, and the depressive symptoms x spouses diagnosis of dementia interaction; Model 5 includes time invariant covariate, and spouses diagnosis of dementia, depressive symptoms, and the depressive symptoms x spouses diagnosis of dementia interaction; Model 6 includes time invariant covariate, and spouses diagnosis of dementia, social contact, and the social contact x spouses diagnosis of dementia interaction.

Table 18. *Psychological Variables*

		Depression		Loneliness	
		Unconditional Model	**Covariate model**	**Unconditional Model**	**Covariate model**
	Parameter	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**
Initial status	Intercept	1.09 (0.02)**	1.06 (0.02)**	1.37 (0.01)**	1.40 (0.01)**
	Age intercept		-0.02 (0.00)**		-0.01 (0.00)**
	Female		0.29 (0.03)**		0.01 (0.01)
	Yrs Ed		-0.12 (0.01)**		-0.02 (0.00)**
Rate of change	Slope	0.03 (0.00)**	0.01 (0.01)*	0.01 (0.00)**	-0.01 (0.00)*
	Age		-0.02 (0.01)*		0.00 (0.00)*
	Female		0.00 (0.00) *		0.01 (0.00)*
	Yrs ed		0.00 (0.00)**		0.00 (0.00)**
TVC - Spouse dementia			0.31 (0.07)**		0.11 (0.03)**
TVC - Widowhood			0.70 (0.05)**		0.24 (0.02)**
Variance	Intercept	1.66 (0.06)**	1.46 (0.06)**	0.14 (0.01)	0.13 (0.01)**
	Slope	0.04 (0.00)**	0.04 (0.00)**	0.00 (0.00)**	0.00 (0.00)**
	Within Person Residual	1.38 (0.02)**	1.37 (0.02)**	0.11 (0.00)**	0.11 (0.00)**
Goodness-of-fit	AIC	170237.079	168463.366	23169.744	22580.388
	BIC	170289.682	168586.077	23216.934	22690.469
	Parameters	6	14	6	14

Note: * $p < .05$, ** $p < .001$; TVC = Time varying covariate.

Table 19. *Social variables*

		Social Contact		Social Support	
		Unconditional model	**Covariate model**	**Unconditional model**	**Covariate model**
	Parameter	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**
Initial status	Intercept	30.68 (0.11)**	28.60 (0.17)**	9.50 (0.02)**	9.27 (0.03)**
	Age intercept		0.03 (0.01)*		0.01 (0.00)**
	Female		2.98 (0.22)**		0.41 (0.04)
	Yrs Ed		0.53 (0.04)* *		0.01 (0.01)
Rate of change	Slope	-0.10 (0.03)**	0.01 (0.01)*	-0.01(0.00)**	-0.01 (0.01)
	Age		-0.02 (0.00)**		0.00 (0.00)
	Female		-0.00 (0.06)		-0.01 (0.01)
	Yrs ed		0.01 (0.01)		0.00 (0.00)
TVC - Spouse dementia			-0.78 (0.38)*		-0.17 (0.07)*
TVC - Widowhood			0.77 (0.25)*		0.18 (0.05)**
Variance	Intercept	45.41 (1.65)**	40.92 (1.59)**	1.40 (0.05)**	1.35 (0.05)**
	Slope	0.81 (0.12)**	0.77 (0.12)**	0.02 (0.00)**	0.02 (0.00)**
	Within Person Residual	27.31 (0.66)**	27.18 (0.66)**	0.83 (0.02)**	0.82 (0.02)**
Goodness-of-fit	AIC	132807.751	131740.309	64896.082	64545.327
	BIC	132854.974	131850.466	64943.309	64655.495
	Parameters	6	14	6	14

Note: * $p < .05$, ** $p < .001$; TVC = Time varying covariate

Chapter 4: Loneliness and Social Engagement Among Older Adults: Investigating the role of Rejection Sensitivity and Social Avoidance

Abstract

Current theories of loneliness suggest that, for some individual's, loneliness becomes a self-perpetuating cycle whereby they fail to participate in social activities that might ameliorate feelings of loneliness because of concerns about social rejection and fears of negative social evaluation. However, these studies have been primarily conducted with younger adults. The current study investigates the relations between activity participation, social participation, loneliness, social support, rejection sensitivity, social anxiety and distress, fear of negative evaluation by others, and depressive symptoms in a sample of 32 community dwelling older adults. Linear regression analysis was used to investigate whether loneliness, depressive symptoms, rejection sensitivity, social avoidance and distress, and fear of negative evaluation predict social activity participation. Rejection sensitivity was investigated as moderator of the relationship between loneliness and social participation. Social activity participation was related to rejection sensitivity and loneliness but not with social avoidance and distress or fear of negative evaluation. Consistent with studies of younger adults, rejection sensitivity and loneliness were significantly correlated. Both loneliness and rejection sensitivity significantly predicted social activity participation but there was no evidence of an interaction and when both were included in the model neither remained significant predictors. Overall, a possible role for rejection sensitivity in loneliness, depressive symptoms, and lack of social activity participation among older adults was found. These findings should be substantiated with further investigation as rejection sensitivity may be a possible target for intervention.

Introduction

Social engagement is often cited as an important component of successful aging (Rowe & Kahn, 1997). Loneliness and lack of social engagement among older adults has been linked to lower self-rated health (Nummela, Seppänen, & Uutela, 2011), poorer sleep quality (Hawkley, Preacher, & Cacioppo, 2010), depressive symptoms (Cacioppo, Hughes, Waite, Hawkley, & Thisted, 2006), and all-cause mortality (Holt-Lunstad, Smith, & Layton, 2010). Given this, the question of why some individuals have fewer social contacts and less satisfying social relationships is significant. One perspective is that the developmental stage of older adulthood includes transitions that limit opportunities for social integration such as retirement and no longer having children at home (Burn, Dennerstein, Browning, & Szoeke, 2016). The socioemotional selectivity theory postulates that older adults selectively focus their efforts on the closest and most meaningful relationships, which has the benefit of maximizing positive interactions but puts older adults with small social networks at particular risk for social isolation should network members be lost, something that becomes increasingly common as spouses and friends pass away (Carstensen, Isaacowitz, & Charles, 1999). The literature on loneliness, primarily based on research conducted with younger adults, proposes that temporary normative loneliness provides those experiencing it with motivation to engage with others with the goal of ameliorating the negative feelings of loneliness (Hawkley & Capitanio, 2015). However, feelings of loneliness are problematic for some people who become trapped in a self-perpetuating cycle of loneliness where fears of negative reactions from others prevent them from seeking the social engagement that may ameliorate feelings of loneliness (Hawkley et al., 2010). Fears of negative reactions may take the form of social anxieties or rejection sensitivity. Rejection sensitivity is “a disposition to anxiously expect, readily perceive, and over-react to rejection” (Watson &

Nesdale, 2012). Rejection sensitivity is a significant predictor of loneliness among younger adults (Watson & Nesdale, 2012). Further, the association between rejection sensitivity and loneliness was mediated by social avoidance suggesting that for some individuals, a way to cope with the possibility of social rejection is to avoid social situations which in turn exacerbates loneliness (Watson & Nesdale, 2012). It is widely recognized that the relations are likely reciprocal where loneliness can lead to social withdrawal and possibly increase rejection sensitivity (Hawkley et al., 2010; Watson & Nesdale, 2012). However, to my knowledge, the contribution of rejection sensitivity, social avoidance and fears of negative evaluation to loneliness and actual social participation have not been investigated in older adults. This has important implications for intervention studies, as providing opportunities for increased social activity may not be sufficient to address the psychological factors contributing to social isolation and feelings of loneliness. Thus, the current study will investigate the relations between activity participation, social participation, loneliness, social support, rejection sensitivity, social anxiety and distress, fear of negative evaluation by others, and depressive symptoms in a sample of community dwelling older adults. If older adults experience loneliness primarily due to lack of social opportunities one would expect to see an association between loneliness and social activity participation regardless of levels of rejection sensitivity. However, if individuals are not participating in activities due to rejection sensitivity and experiencing loneliness, one would expect greater levels of both rejection sensitivity and loneliness among those not socially active.

Hypothesis 1: Consistent with findings among younger adults, social activity participation, rejection sensitivity, social avoidance and distress, and fear of negative evaluation, and loneliness will all be associated within in the sample of older adults.

Hypothesis 2: Loneliness, depressive symptoms, rejection sensitivity, social avoidance and distress, and fear of negative evaluation will predict lower social activity participation.

Hypothesis 3: Lonely individuals will show lower social activity participation than non-lonely individuals regardless of level of rejection sensitivity.

Method

Participants

Participants were a convenience sample of 32 older adults living in the Southern Vancouver Island area who responded to advertisements seeking participants over age 65 for a study on social experiences. Posters were placed in community centres and distributed at events focused on older adults. The mean age was 75 (range 65-88). The only exclusion criterion was not having a spouse or partner diagnosed with dementia, Alzheimer's disease or another condition requiring significant amounts of care. Ethical approval for this study was obtained from the University of Victoria Research Ethics Board and signed informed consent was obtained from all participants.

Measures

Activity questionnaire. Activity participation was assessed using the well validated VLS Activity Lifestyle Questionnaire (VSL-ALQ; Hultsch et al., 1999). Individuals responded to 57 questions about the frequency of participation in common activities over the past 2 years on a 9-point scale from 0 'never' to 8 'daily'. Activities included everyday types of cognitive (e.g., using the computer, $n = 39$), social (e.g., visiting friends, $n = 7$), and physical activities (e.g., jogging, $n = 4$). Social activities were summed for a social activity total with a possible range of 0 to 56. Cronbach's alpha for the activity questionnaire was 0.66.

Depressive symptoms. Depressive symptoms were assessed using a short form of Geriatric Depression Scale (GDS; (Yesavage et al., 1983). The GDS contains 15 items (e.g.,

"Do you feel happy most of the time?") inquiring about various aspects of depression. Respondents are instructed to answer for how they felt over the past week and respond "yes" or "no" to each item. Some are reverse coded (e.g., "do you feel that your life is empty?") for a possible total score range from 0-15 with greater numbers indicating greater symptoms of depression. A score above 5 is considered to suggest depression. Cronbach's alpha was 0.83.

Loneliness. Loneliness was measured with the 11-item De Jong Gierveld loneliness scale (De Jong Gierveld & Van Tilburg, 1999). The scale can be considered a unidimensional loneliness scale but items were developed based on Weiss (1973)'s distinction between social (e.g., "There are enough people I feel close to") and emotional (e.g., "I experience a general sense of emptiness") loneliness and separate scales can be calculated for each. Responses are given on a 5 point scale from 'no!' to 'yes!' with some negatively worded and some positively items which are recoded so that negative or neutral items are 0 and positive items are 1 to create a summary measure of loneliness where a higher score indicates greater loneliness (possible range of 0 to 11). Cronbach's alpha was 0.83.

Social Avoidance and Distress Scale. The Social Avoidance and Distress Scale (SADS; (Watson & Friend, 1969) includes 28 items measuring participants' experience of anxiety in social situations (e.g., "I am seldom at ease in a large group of people"). Questions also measure the tendency to avoid social situations (e.g., "I try to avoid situations that force me to be sociable"). Responses are given as 'True' or 'False' responses to 28 statements for total score ranging from 0-28. A Cronbach's alpha of .94, and a test-retest reliability over one month of .68 were reported in the development samples (Watson & Friend, 1969).

Fear of Negative Evaluation Scale. The fear of Negative Evaluation Scale (FNE; Watson & Friend, 1965) was used to assess the degree to which individuals experience

apprehension about the possibility of being negatively evaluated by others. The FNE scale includes 30 statements to which 'True' or 'False' responses are given for a total score ranging from 0-30. Some items are positively worded (e.g., I rarely worry about seeming foolish to others) and others are negatively worded. Negatively worded items are recoded so that greater scores indicate greater fears of negative evaluation. Cronbach's alpha was .95 in the present study.

Rejection sensitivity. Rejection sensitivity was evaluated using a modified version of the Adult Rejection Sensitivity Questionnaire (ARSQ; Berenson et al., 2009). The modified version included seven hypothetical social situations involving interactions with partners, family, friends, and strangers, that contain the potential for rejection. For example, "you approach a close friend to talk after doing or saying something seriously upsetting to him/her". Participants are then asked to rate the degree to which they are concerned or anxious about the person's reaction (ranging from 1 "very unconcerned" to 6 "very concerned). For each situation they also rate the likelihood of being rejected ranging from 1 "very unlikely" to 6 "very likely". Two items from the original scale were not included due to limited relevance for the older adult population. A rejection sensitivity total score was calculated according to the formula rejection sensitivity = (rejection concern)*(7-acceptance expectancy). Cronbach's alpha was 0.78 in the present study.

Social Support Measure. Social support was assessed using a social support measure (Krause & Markides, 1990) designed to assess four dimensions of social support; informational support (7 items), practical support (9 items), emotional support (11 items), and integration (13 items) designed specifically to be relevant for older adults. Respondents are asked to rate their frequency of receiving, and for the integration scale providing, support within each category on a

4-point scale from 0 ‘never’ to 4 ‘very often’. All items were summed to create a social support total score with a possible range of 0 to 108. Cronbach’s alpha for the total scale was 0.95.

Procedure

Participants were seen either in their homes or at the University of Victoria for the informed consent process and the structured interview component. Participants completed the interview with one of two interviewers based on availability only. Following completion of the interview, participants were given a pre-addressed mail back package containing all paper and pencil questionnaires and the instructions for each were explained, highlighting the instruction section at the top of each individual questionnaire. Rate of return of mail-back packages was 100%, all participants who came for the interview also returned their questionnaires.

Analysis

The majority of questionnaires were returned with missing item responses. Only six participants fully completed all questionnaires with no missing items. Thus, excluding all questionnaires with missing items would have resulted in a significant loss of information. Further, listwise deletion and simple methods of missing data management such as mean imputation have been shown to introduce bias. The proportion of missing data was not higher than 25% for any individual and was only greater than 10% for three participants. Missing items tended to be distributed across questionnaires with no clear pattern of particular items being missed. For three participants, age and number of years of education was missed. There was no missing data for gender or marital status. Multiple Imputation by Chained Equations (MICE; van Buuren, 2018), was used to impute missing values at the level of the individual questionnaire item. In short, MICE uses other variables in the dataset to predict and impute missing values. As is typical, five datasets were created. Regression analysis was conducted separately for each of

the imputed datasets and then estimates from each fitted model were pooled according to Rubin's rules using a pool function in the MICE package (van Buuren, 2018). To initially explore relations among variables, a simple correlation matrix of pooled multiple imputation values and scatterplots for individual variable combinations were examined.

To investigate whether loneliness, depressive symptoms, rejection sensitivity, social avoidance and distress, and fear of negative evaluation predict social activity participation a linear regression analysis was conducted. Age, gender, and marital status are controlled for as covariates. To examine whether rejection sensitivity moderates the relationship between loneliness and social participation a linear regression analysis was conducted with loneliness and rejection sensitivity, and a loneliness-rejection sensitivity interaction term as predictor variables and social participation as the dependent variable. To assess whether including both rejection sensitivity and loneliness, and the interaction, improved the model predicting social participation, the Wald method for comparison of pooled models was used. This tests the null hypothesis that, the added parameters (rejection sensitivity, loneliness x rejection sensitivity interaction term) are all equal to zero (Meng and Rubin, 1992).

Results

Basic demographics, means, and ranges of the raw, unimputed data, for each questionnaire are presented in Table 20. The majority of participants were married and female. 15 participants were considered not lonely (a score of 2 or less on the scale) and 15 were moderately lonely (a score of 3 to 8). No participant's level of loneliness fell in the severe loneliness (9-10) or very severe loneliness (11) range. Eight participants endorsed a number of symptoms of the GDS that is considered suggestive of depression (more than 5). Pooled pairwise correlations of variables showed several significant correlations (see Table 21). Women had

more social activity participation. Total activity participation was significantly correlated with social activity participation, loneliness, and rejection sensitivity. Social activity participation was significantly correlated with loneliness and rejection sensitivity. Symptoms of depression were significantly correlated with loneliness, social anxiety and distress, and rejection sensitivity. Loneliness and rejection sensitivity were also significantly correlated. All other correlations were not significant (see Table 21).

A linear regression analysis was used to investigate whether loneliness, depressive symptoms, rejection sensitivity, social avoidance and distress, and fear of negative evaluation predict social activity participation. Age, gender, and marital status were included as covariates. Initially, each predictor that showed a significant correlation with social activity, loneliness and rejection sensitivity, was evaluated individually. With the effects of covariates held constant in individual regression models, loneliness and rejection sensitivity significantly predicted social activity (see Table 22) such that a one unit increase in rejection sensitivity was, after accounting for age, gender, and marital status, associated with a 1.27 decrease in social activity participation, which, considering the scale of social activity participation would mean a decrease in frequency category of one social activity for example, from about once a month to 2 or 3 times a year. In the loneliness and covariates only model, a one unit increase in loneliness, meaning endorsement of one more loneliness item, was associated with an average decrease in nearly one and half frequency categories for one (or two) social activities. To investigate whether rejection sensitivity moderates the relationship between loneliness and social activity, a linear regression model with a loneliness x rejection sensitivity interaction term was estimated. However, once both loneliness and rejection sensitivity were added to the model as predictors, neither were significant (see Table 22) and this remained true once the interaction term was included. The

Wald method, comparing the simpler model with just loneliness and covariates (see Table 22) or with just rejection sensitivity and covariates (see Table 22), confirmed that the effect of the additional predictor (loneliness or rejection sensitivity) was not significantly different from zero. Further, the interaction term was not significantly different from zero (see Table 22). However, examining the estimates for rejection sensitivity and loneliness in the model with both and the interaction term, it is apparent that they are similar to the estimates obtained when each were included independently. However the confidence intervals for each estimate are wider indicating a lack of precision in the estimates which may be due to the small sample size, and dispersion of loneliness and rejection sensitivity (Trafimow, 2018).

Discussion

The first hypothesis, that social variables; social activity participation, rejection sensitivity, social avoidance and distress, and fear of negative evaluation, and loneliness would all be associated was partially supported. Specifically, in this sample, social activity participation was related to rejection sensitivity and loneliness but not with social avoidance and distress or fear of negative evaluation. Further, consistent with studies of younger adults, rejection sensitivity and loneliness were significantly correlated. Rejection sensitivity was also significantly correlated with symptoms of depression such that those who reported more sensitivity to social rejection were also more likely to report symptoms of depression. Participants who reported greater levels of loneliness also reported more rejection sensitivity, more symptoms of depression, and lower social activity participation. These findings are consistent with the theory that loneliness can become a self-perpetuating cycle (Hawkley et al., 2010). To investigate whether loneliness and rejection sensitivity predicted social activity participation independently and after accounting for relevant covariates, a linear regression

analysis with, age, gender, and marital status controlled for, was conducted. Loneliness and rejection sensitivity both significantly predicted social activity participation once gender, age, and marital status were controlled for, although when included in the same model were neither remained significant predictors. Rejection sensitivity and loneliness were highly correlated and may be overlapping constructs explaining the same variation in social activity participation but contributing little independent of one another. Another possible explanation, supported by the fact that the estimates of rejection sensitivity and loneliness remained of similar size while the confidence intervals surrounding the estimates increases, is that power was limited by the small sample size. However, excluding age and marital status as covariates, as they were not significant predictors, did not change the results.

Rejection sensitivity is the expectation of, and the tendency to perceive, social rejection (Watson & Nesdale, 2012). That sensitivity to social rejection showed a strong correlation with loneliness and was related to social participation among older adults has implications for programs aimed at decreasing social isolation and loneliness. Increasing attention to the problem of social isolation and lack of social participation among older adults often results in the creation of community programs designed to increase social opportunities. Although this makes intuitive sense, the present findings suggest that such programs may not be attended by those most in need, i.e., socially inactive older adults, due to concerns about social rejection. This is consistent with meta-analysis findings that the most effective randomized controlled trial interventions to reduce loneliness were those that addressed maladaptive social cognitions, in comparison to those that attempted to improve social skills, increase social support, or increase opportunities for social interactions (Masi et al., 2011). Thus, interventions may need to target older adults'

sensitivity to social rejection so that they are able to begin taking advantage of social opportunities.

Such interventions may include a form of cognitive behavioral therapy, often offered in a group setting, that involves teaching strategies for psychological reframing that have previously been used to address loneliness (Masi et al., 2011). Similar programs such as Living Life to the Full have been designed to address mild mood and stress-related difficulties (Williams, Morrison, McConnachie, McClay, Matthews, & Haig, n.d) and this model could be adapted to include a focus on reducing rejection sensitivity.

This study confirmed previous research suggesting that although 50% of participants self-reported no loneliness, a substantial portion, the other 50% reported moderate loneliness. That no participants in the study reported severe or very severe levels of loneliness is likely reflective of participant characteristics and the communities from which participants were drawn. The majority of participants (71%) were married and living with their spouses. Further, southern Vancouver Island is a well-known Canadian retirement destination and many participants mentioned, anecdotally, the wealth of social opportunities available for older adults. Previous research has suggested that loss of partners and friends to death is the most significant predictor of loneliness among older adults (Dykstra, 2009; Dykstra, van Tillburg, & de Jong Gierveld, 2005).

There are several important limitations to this study. First, as described, participants were drawn from a convenience sample of older adults who responded to posted advertisements. The location of some of the posters and the tendency of some participants, to discuss their participation in the study resulted in a sample where some of the participants knew each other. Further, many spouses both participated. This lack of independence of participants may have

influenced the findings but the small sample size precluded attempting to account for this lack of independence.

Second, and relatedly, further investigation is needed to clarify independent relations between social variables which may be helpful in informing potential social interventions for older adults. This study was limited by small sample size and relatively low rates of difficulties on social variables. Specifically, on the social avoidance and distress scale the unimputed mean was five out of 23, indicating very low endorsement of difficulties with social avoidance. Similarly, little fear of negative social evaluation was endorsed by participants (7/29 on average). This may be reflective of the high social functioning of this sample. Larger scale studies that purposefully target more socially isolated older adults, in communities with fewer established programs for older adults, will be needed to investigate this issue.

The present study was limited by missing data. This is a common difficulty and when questionnaires are mailed back there is no opportunity to check for reasons questions are not answered and encourage participants to carefully attend to each item. The level of missing data for each participant and on any given variable was low and analysis conducted using multiple imputation by chained equations (MICE; van Buuren, 2018). However, it is possible that results obtained do not reflect those that would have been obtained with complete data.

Lastly, this was a purely observational study examining associations. Thus, statements about causation cannot be made. Although social activity participation was examined as the dependent variable in this study based on the theory that loneliness and social rejection would decrease willingness to participate in social activities, it is also possible that lower social activity participation contributes to loneliness and fears of rejection.

In conclusion, the present study indicates a possible role for rejection sensitivity in loneliness, depressive symptoms, and lack of social activity participation among older adults. Larger, more representative studies are needed to further investigate whether sensitivity to social rejection may be a barrier for older adults in accessing social participation opportunities. Should these findings be substantiated with further investigation, interventions aimed at decreasing rejection sensitivity may be helpful in reducing loneliness among older adults.

Table 20. *Participant characteristics*

Measure	Mean / % of sample	Standard Deviation	Range
Age (yrs)	74.92	6.48	65-88
Female (%)	64%		-
Years of Education	14.88	2.15	10-18
Marital Status (%)			
Married	71%	-	-
Widowed	18%	-	-
Single	11%	-	-
Activity Participation	184.42	25.27	135-235
Social Activity Participation	46.48	9.85	27-70
Loneliness Score	3.31	2.99	0-10
Geriatric Depression Scale	1.17	2.27	0-9
Social Anxiety and Distress	4.89	5.31	1-24
Fear of Negative Evaluation	5.75	7.11	0-30
Rejection Sensitivity	6.21	2.77	3.29-13.14
Social Support Total	40.60	18.08	13-84

Table 21. *Correlations*

Measures	Gend	Act	SoAct	GDS	Lone	SAD	FNE	RS	SoSup
Age	-0.15	-0.03	0.00	-0.24	-0.05	-0.08	-0.01	0.01	0.01
Gender (Gend)	1.0	0.08	0.42*	0.34	0.03	0.26	0.13	0.00	0.42
Activity Participation (Act)		1.00	0.55**	-0.27	-0.43*	-0.13	-0.11	-0.39*	0.55**
Social Activity (SoAct)			1.00	-0.26	-0.49*	-0.24	0.11	-0.50*	0.31
Geriatric Depression Scale (GDS)				1.00	0.74**	0.46*	0.27	0.67**	-0.26
Loneliness (Lone)					1.00	0.16	0.32	0.72**	-0.49*
Social Anxiety and Distress (SAD)						1.00	0.24	0.06	-0.24
Fear of Negative Evaluation (FNE)							1.00	0.09	0.12
Rejection Sensitivity (RS)								1.00	0.11
Social Support (SoSup)									1.00

Table 22. *Predictors of Social Activity Participation*

	Rejection Sensitivity		Loneliness		Social Activity Participation			
					Rejection Sensitivity and Loneliness		Rejection Sensitivity, Loneliness and Interaction Term	
Variable	*B*	95% CI	*B*	95% CI	B	95% CI	B	95% CI
Constant	48.21*	9.70, 86.66	47.86*	9.93, 85.78	48.78**	10.31, 87.25	50.34**	11.11, 89.58
Gender	8.72*	2.46, 15.30	8.98**	2.52, 15.44	8.88**	2.43, 15.32	8.23*	1.39, 15.8
Age	-0.06	-0.59, 0.47	-0.10	-0.61, 0.42	-0.07	-0.60, 0.47	-0.04	-0.59, 0.51
Marital status	5.44	-1.27, 12.07	5.43	-1.20, 12.05	4.89	-1.88, 11.67	5.78	-1.64, 13.20
Loneliness			-1.42*	-2.56, -0.29	-0.91	-2.56, 0.74	-1.78	-4.84, 1.29
Rejection Sensitivity	-1.27*	-2.36, -0.27			-0.70	-2.24, 0.84	-1.46	-4.37, 1.45
Loneliness x Rejection Sensitivity							0.13	-0.26, 0.53
R^2	0.49	0.21, 0.74	0.50	0.20, 0.74	0.53		0.54	
F					4.93		4.08	
					Compare to Rejection Sensitivity	Compare to Loneliness	Compare to Rejection Sensitivity and Loneliness	
ΔR^2	-		-		0.04	0.03	0.05	
Wald test	-		-		0.92	1.37	0.48	

Note. * p <.05. **p <.0

Chapter 5: Conclusions

The focus of this dissertation was testing hypothesized pathways for the relations between social factors and cognitive change in aging and then, examining psychological factors and barriers to social participation. There is a large body of literature investigating the importance of social factors in aging, for older adults generally and for specific populations such as caregivers. There is also a substantial literature examining various aspects of social relationships and their associations with cognitive functioning. However, there was room for specifically identifying and testing proposed pathways of relations, and basing this in neuropsychological and psychological knowledge. Specific questions related to these aims were investigated in three distinct studies. Of note, direct comparisons between studies are limited by differences in study designs. The first two studies included large sample sizes where even very small effects could be detected as statistically significant. However, the third study, being a small pilot study with much fewer participants, was limited in power resulting in even medium effect sizes being not statistically significant. For example, to have 80% power to detect the 0.31 correlation between social activity participation and social support as statistically significant 79 participants would have been needed.

Study one used a large population-based American longitudinal study to investigate associations between specific social factors and cognitive function, and an advanced modeling strategy to differentiate between associations of longstanding trait-like or between person differences, and associations within person, of relatively short-term, or "state-like" changes. There was little support for a link between "trait-like" level of social variables and "trait-like" levels of cognitive performance. However, there was evidence of a reciprocal link between fluctuations in cognitive performance and social factors. These results are novel in applying ALT models to examine the relations between state- and trait-like components of both structural and

functional aspects of social relationships over time. They also suggest that shifting the focus of intervention efforts from encouraging social participation to prevent cognitive decline to identifying older adults experiencing mild cognitive decline as at risk for social isolation and loneliness which may in turn put them at risk for other negative health outcomes.

One of the most prevalent theories as to how social factors may relate to cognitive function is through physiological dysregulation in response to stress, with the stress being either social isolation itself (Hawkley & Cacioppo, 2010) or other life stresses that may be buffered by strong social ties (Cohen, 2004). Caring for an individual with dementia has been shown to be particularly stressful and related to a number of deleterious outcomes. Spouses of those who have received a diagnosis of dementia are likely to also experience significant stress which may in turn impact cognitive function. Previous research has also suggested those who have a spouse with dementia are at greater risk themselves for cognitive decline. Study two used the fact that spouses in the Health and Retirement study were automatically included and many were followed over a period of many years to identify individuals who had a spouse diagnosed over the study period. This allowed for the testing whether a spouse's diagnosis of dementia was associated with a within person change in social and cognitive outcomes compared to prior to the diagnosis. Study two found limited evidence of within person change in cognitive abilities following a spouse's diagnosis of dementia. This suggests that risk factors that accumulate over time, such as shared lifestyle, may better account for previously observed associations. Further, a spouse's diagnosis of dementia was related to within person decreases in psychological wellbeing (i.e., increased loneliness and depressive symptoms) and reduced social contact consistent with previous studies. This confirms that interventions targeting psychological wellbeing of caregivers may be very helpful but they may not impact the cognitive functioning

of caregivers. However, it is also possible that the cognitive effects of caregiving are less immediate than the psychological consequences. Further research, with a longer time frame, would be helpful in investigating a possible later manifestation of cognitive changes.

Study three was a small pilot study in the Southern Vancouver Island area that investigated possible barriers to social activity participation and was novel in investigating rejection sensitivity among older adults. Findings from study three indicate a possible role for rejection sensitivity in loneliness, depressive symptoms, and lack of social activity participation among older adults. This suggests that interventions aimed at decreasing rejection sensitivity may be helpful in reducing loneliness among older adults and may be a more effective target for some older adults than simply increasing social opportunities.

Overall, the findings from this dissertation research revealed little support for direct pathways by which social factors are related to cognitive function, although there was evidence for reciprocal associations with cognitive changes possibly driving changes in social variables. When examining within person changes among those whose spouses were diagnosed with dementia, there was little evidence that social factors increase in importance for buffering the impact of the stress of having a partner diagnosed with dementia on cognitive function. However, as expected, there were within person increases in loneliness and depressive symptoms, and decreases in social contact and social support associated with a spouse's diagnosis of dementia. There was also evidence that a spouse's diagnosis of dementia is associated with a change in immediate recall performance, but not in other measures of cognitive function. This may reflect the role of attention and disrupted ability to engage attention that often occurs under times of stress. It is not clear that this reflects neurobiological changes, but it is possible that this represents the beginning of cognitive changes that may be more long lasting in

nature. This study was unique in examining within person change following a spouse's diagnosis, whereas previous studies on caregivers and spouses of individuals with dementia have relied on comparisons between groups or examining change but only after becoming caregivers. Future research is needed to further clarify the source of increased risk for adverse outcomes among caregivers in order to properly target interventions. Further, given the preliminary evidence for a relationship between rejection sensitivity and lack of social activity participation among older adults, interventions may need to target such aspects of social cognition rather than focusing purely on increasing opportunities. The possibility of adapting existing cognitive behavioral therapy based programs designed for community based groups to target social cognition barriers such as rejection sensitivity should also be explored in future research.

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Appendix

Supplementary Materials

Results from unconditional univariate models

The univariate model results for each social and cognitive variable are presented in the supplemental Tables 1 through 7. The plots of the mean predicted trajectory for each process are presented as supplementary Figures 1 through 7.

Immediate Word Recall

For immediate word recall, the full ALT model (model 3) evidenced the best model fit (see supplementary Table 1). The intercept of immediate word recall score was (μ_{t1} = 5.43). Overall, immediate word recall performance decreased over time (β = -0.12 , p = 0) the variance in slope was not significant (ψ = 0.00, p = 0.05). The ability of immediate word recall preformance to predict immediate word recall performance two years later, once overall trajectories were taken into account, was consistently small and not significant (ρ_{21} = -0.02, p = 0.33; ρ_{32} = -0.01, p = 0.71; ρ_{43} = -0.02, p = 0.06; ρ_{54} = -0.01, p = 0.53; ρ_{65} = -0.00, p = 0.88). Supplementary Figure 1 shows the predicted mean trajectory for immediate word recall.

Delayed Word Recall

For delayed word recall, univariate model results indicate that the full ALT model (model 4) is the best model by fit indices (see supplementary Table 2). The intercept indicated that on average across all occasions participants recalled just under half of the ten words (μ_{α} = 4.21, p = 0). Overall, delayed word recall performance decreased over time (β = -0.10 , p = 0) with significant variance in the slope (ψ = 0.00, p = 0.01). The ability of

delayed word recall performance to predict later delayed word recall performance was not significant for the first to second wave (ρ_{21} = 0.00, p = 0.89). Previous delayed word recall performance significantly predicted future performance for the next three waves ρ_{32} = 0.02, p = 0.23; ρ_{43} = -0.02, p = 0.25; ρ_{54} = -0.02, p = 0.26) but delayed word recall performance at time 5 (2012) did not significantly predict performance at time 6 (2014) ρ_{65} = -0.02, p = 0.41 over and above the overall trajectory of change. A plot of the predicted mean trajectory is shown in supplementary Figure 2.

Mental Status

For the univariate mental status models, the full ALT model (model 4) shows the best model fit according to fit indicies (see supplementary Table 3). The estimate mental status intercept is high (μ_α = 8.70, p = 0). With significant variability. Overall, mental status decreased over time (β = -0.28, p = 0) with significant variance in the slope (ψ = 0.01, p = 0). The ability of earlier mental status to predict later mental status, over and above the overall trajectory of change was consistently significant (ρ_{21} = -0.02, p = 0.49; ρ_{32} = 0.03, p = 0.14; ρ_{43} = 0.05, p = 0.01; ρ_{54} = 0.12, p = 0; ρ_{65} = 0.17, p = 0). A plot of the predicted mean trajectory of mental status performance is shown in supplementary Figure 3.

Loneliness

For the univariate loneliness models, the ALT model with only the level of loneliness estimated (no slope) and autoregressive parameters constrained to equality over time was the best fitting most parsimonious model according to fit indices (see supplementary Table 4). The intercept was μ_α = 1.41, p = 0, with significant variability. Previous

loneliness scores significantly predicted later loneliness $\rho_{t,t-1}$ = 0.02, p = 0.91. Supplementary Figure 4 shows the predicted mean trend of loneliness over time. Although, the ALT model with no slope for loneliness was indicated in the model comparison, when estimated in the full ALT model the slope term of loneliness was significant (β = 0.00 , p = 0.00) with non-significant variance (ψ = 0.00, p = 0.57).

Social Contact

For social contact, the full ALT model was the best fitting model according to model fit indices (see supplementary Table 5). The estimated intercept was (μ_α = 30.30, p = 0) with significant variability. Social contact increased over time (β = 1.28 , p = 0) and the variance in the slope was not significant (ψ = 0.18, p = 0.05). The ability of earlier social contact to predict later social contact, over and above the overall trajectory of change was consistently significant but negative (ρ_{21} = -0.11, p = 0; ρ_{32} = -0.20, p = 0; ρ_{43} = -0.30, p = 0; ρ_{54} = -0.41, p = 0; ρ_{65} = -0.53, p = 0). When the autoregressive parameters are fixed over time, the slope becomes significant and negative. This suggests that when the autoregressive parameters are allowed to vary over time the decline in social contact over time is accounted for by the autoregressive parameters rather than in in the linear slope term, however, examing trajectory plots reveals that in both cases the mean predicted trajectory of social contact shows a decrease over time in social contact (see supplementary Figure 5).

Social Support

For univariate social support models, comparing model results showed that autoregressive parameters to equality over time did not result in significantly poorer

model fit compared to the full ALT model and so is retained as the more parsimonious model (see supplementary Table 6. The intercept is (μ_α = 10.36, p = 0) with significant variability. Social support did not show a significant mean trend over time (β = 0.54, p = 0.00) but there was significant variance in the slope (ψ = -0.00, p = 0.84). Previous social support scores significantly predicted later social support, over and above the overall trajectory of social support (ρ_{21} = -0.08, p = 0.60). See supplementary Figure 6 for a plot of the mean predicted trajectory.

Social Network Composition

Among the univariate social network models, the full ALT model showed significantly better fit than all models except the model with autoregressive parameters constrained across time which is superior as the more parsimonious model (see supplementary Table 7. The intercept was (μ_α = 2.90, p = 0) with significant variability. Social network size significantly declined over time (β = -0.04 , p = 0) and there was significant variance in these trajectories (ψ = 0.00, p = 0.01). Previous social network scores significantly predicted later social network size, over and above the overall trajectory of social network ($\rho_{t,t-1}$ = 0.15, p = 0.25). A plot of the predicted mean trajectory of social network is shown in supplementary Figure 7.

Table 1 *Model Fit Indices for Immediate Word Recall*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
Autoregressive, univariate	2803.192	10	-	-	-	0.631	0.446	0.217	0.231
LGM	2111.987	15	-	-	-	0.723	0.723	0.153	0.219
ALT, full model	62.780	8	-	-	-	0.993	0.986	0.034	0.014
LGM, nested in ALT	89.504	13	3	27.49	5	0.990	0.988	0.031	0.014
ALT, no slope variance	96.973	11	3	32.92	3	0.989	0.985	0.036	0.018
ALT, no slope	323.871	12	3	239.13	4	0.959	0.948	0.066	0.040
ALT, fixed regressions	88.117	12	3	25.69	4	0.990	0.987	0.033	0.013

Table 2 *Model Fit Indices for Mental Status*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
Autoregressive, univariate	1189.141	10	-	-	-	0.811	0.717	0.141	0.181
LGM	1731.138	15	-	-	-	0.725	0.725	0.139	0.215
ALT, full model	33.008	8	-	-	-	0.996	0.992	0.023	0.016
LGM, nested in ALT	218.420	13	3	208.82	5	0.967	0.962	0.052	0.020
ALT, no slope variance	136.077	11	3	108.60	3	0.980	0.973	0.044	0.032
ALT, no slope	544.434	12	3	498.34	4	0.915	0.893	0.086	0.084
ALT, fixed regressions	212.368	12	3	213.11	4	0.968	0.960	0.053	0.019

Table 3 *Model Fit Indices for Loneliness*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
Autoregressive, univariate	267.307	10	-	-	-	0.880	0.819	0.066	0.254
LGM	366.452	15	-	-	-	0.836	0.836	0.063	0.299
ALT, full model	4.250	8	-	-	-	1.000	1.003	0.000	0.113
LGM, nested in ALT	16.812	13	3	10.30	5	0.998	0.998	0.007	0.173
ALT, no slope variance	16.497	11	3	9.91	3	0.997	0.996	0.009	0.197
ALT, no slope	15.823	12	3	9.34	4	0.998	0.998	0.007	0.198
ALT, fixed regressions	19.197	12	3	13.41	4	0.997	0.996	0.010	0.176
ALT, no slope, fixed autoregressions	22.676	16	3	15.94	8	0.997	0.997	0.008	0.198

Table 4 *Model Fit Indices for Social Contact*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
Autoregressive, univariate	248.593	10	-	-	-	0.916	0.874	0.063	0.170
LGM	399.476	15	-	-	-	0.864	0.864	0.066	0.258
ALT, full model	6.119	8	-	-	-	1.000	1.001	0.000	0.072
LGM, nested in ALT	18.866	13	3	10.29	5	0.998	0.998	0.009	0.080
ALT, no slope variance	19.173	11	3	9.62	3	0.997	0.996	0.011	0.092
ALT, no slope	38.244	12	3	24.02	4	0.991	0.988	0.019	0.085
ALT, fixed regressions	21.890	12	3	13.57	4	0.997	0.996	0.012	0.074
ALT, no slope, fixed autoregression	121.961	16	3	96.40	8	0.963	0.965	0.033	0.095

Table 5 *Model Fit Indices for Social Support*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
Autoregressive, univariate	326.229	10	-	-	-	0.897	0.845	0.073	0.270
LGM	648.796	15	-	-	-	0.793	0.793	0.084	0.350
ALT, full model	37.717	8	-	-	-	0.990	0.982	0.025	0.130
LGM, nested in ALT	41.652	13	3	7.44	5	0.991	0.989	0.019	0.211
ALT, no slope variance	43.816	11	3	8.16	3	0.989	0.985	0.022	0.236
ALT, no slope	41.899	12	3	7.86	4	0.990	0.988	0.020	0.235
ALT, fixed regressions	45.932	12	3	8.99	4	0.989	0.986	0.022	0.218
ALT, no slope, fixed autoregression	51.111	16	3	17.38	8	0.989	0.989	0.019	0.232

Table 6 *Model Fit Indices for Social Network Composition*

Model	χ^2	df	CM	$\Delta\chi^2$	dfΔ	CFI	TLI	RMSEA	SRMR
Autoregressive, univariate	140.513	10	-	-	-	0.940	0.909	0.047	0.179
LGM	429.240	15	-	-	-	0.808	0.808	0.068	0.289
ALT, full model	6.264	8	-	-	-	1.000	1.002	0.000	0.121
LGM, nested in ALT	12.636	13	4	5.87	5	1.000	1.000	0.000	0.113
ALT, no slope variance	20.023	11	4	11.24	3	0.996	0.994	0.012	0.132
ALT, no slope	28.835	12	4	18.76	4	0.992	0.990	0.015	0.136
ALT, fixed regressions	10.949	12	4	4.48	4	1.000	1.001	0.000	0.125
ALT, no slope, fixed autoregression	315.038	16	4	280.24	8	0.861	0.870	0.056	0.172

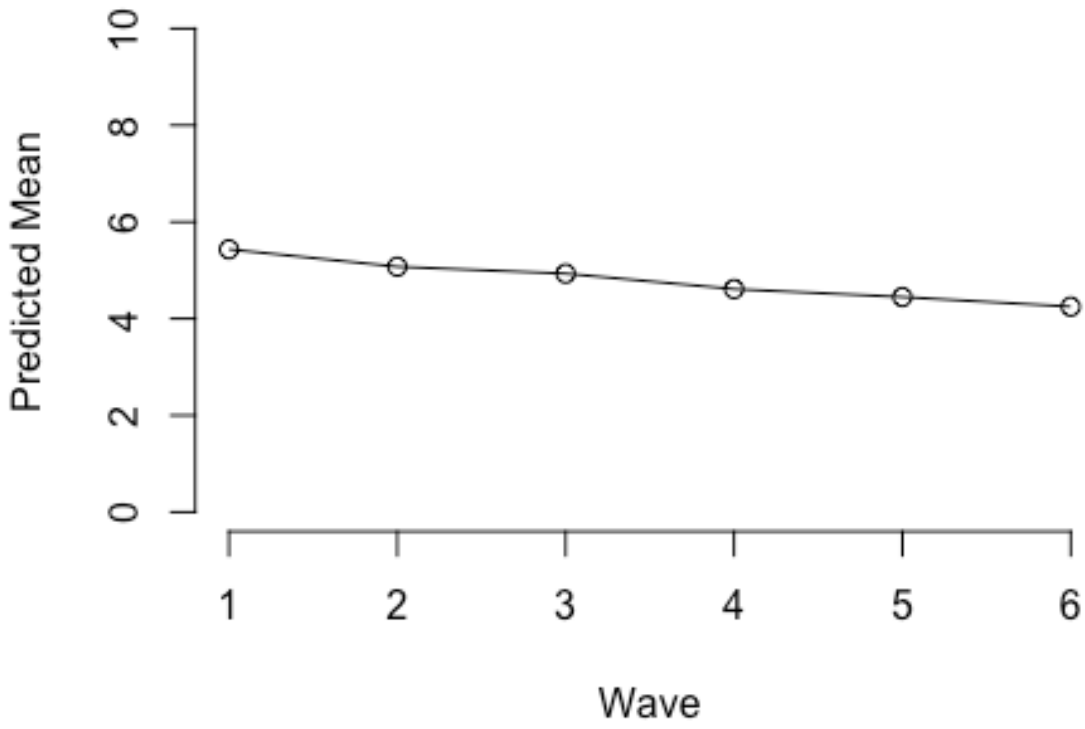

Figure 1. Predicted trajectory of immediate word recall performance.

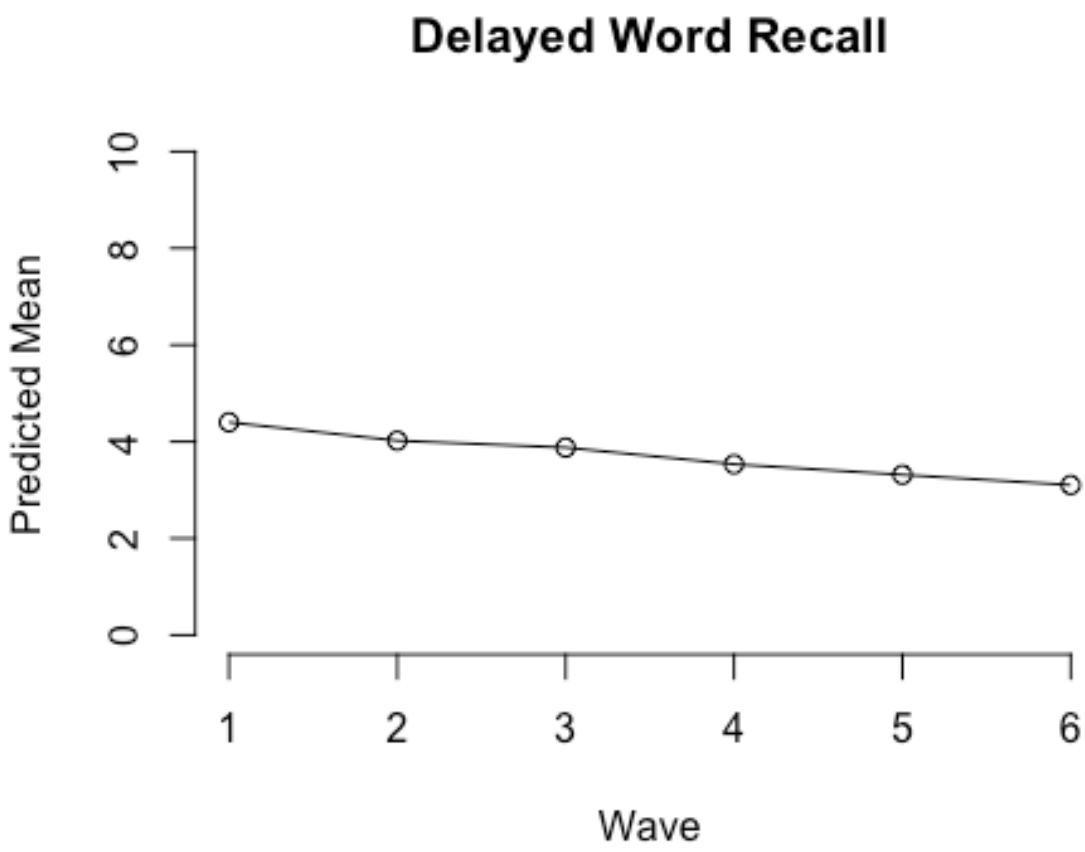

Figure 2. Predicted trajectory of delayed word recall performance.

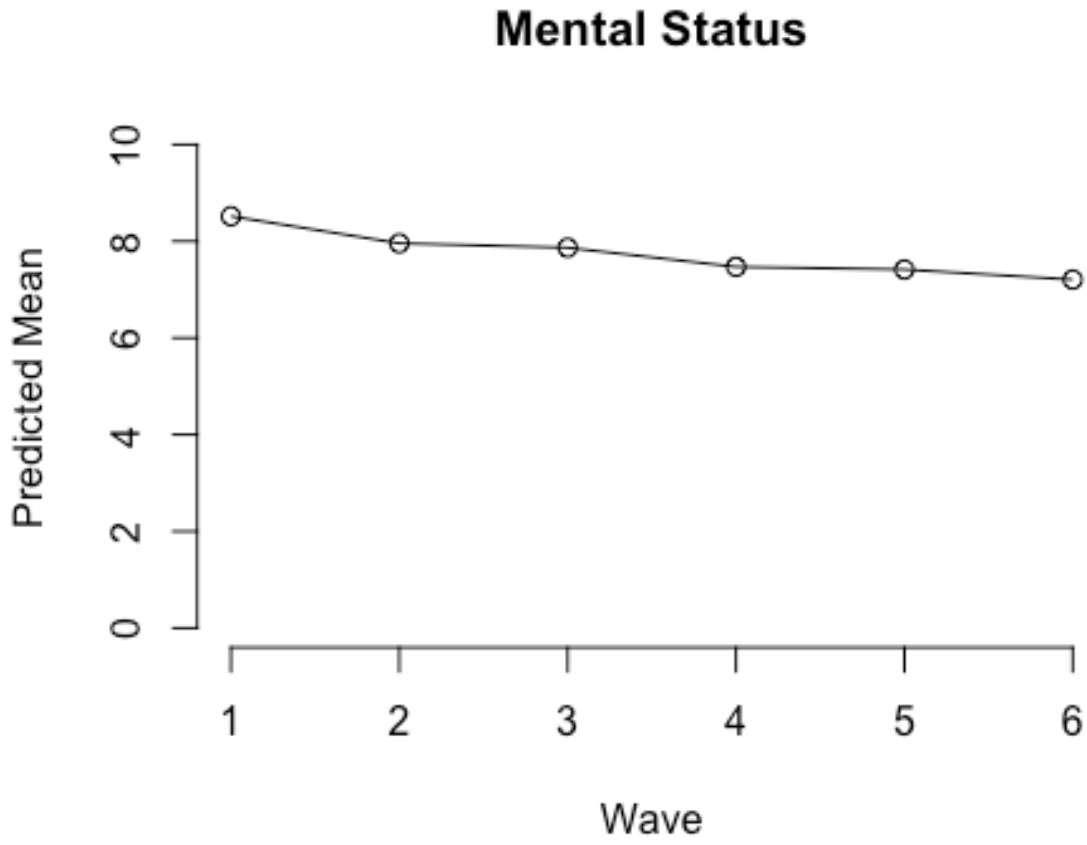

Figure 3. Predicted trajectory for mental status.

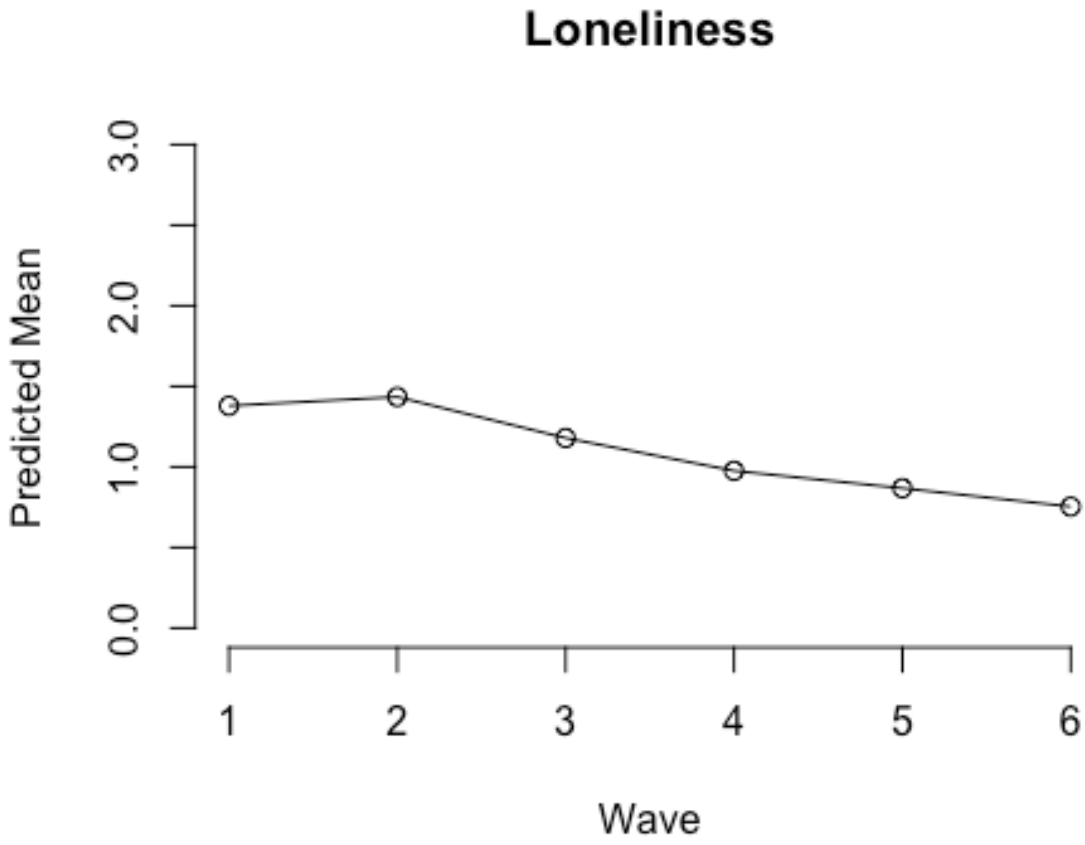

Figure 4. Predicted trajectory for loneliness.

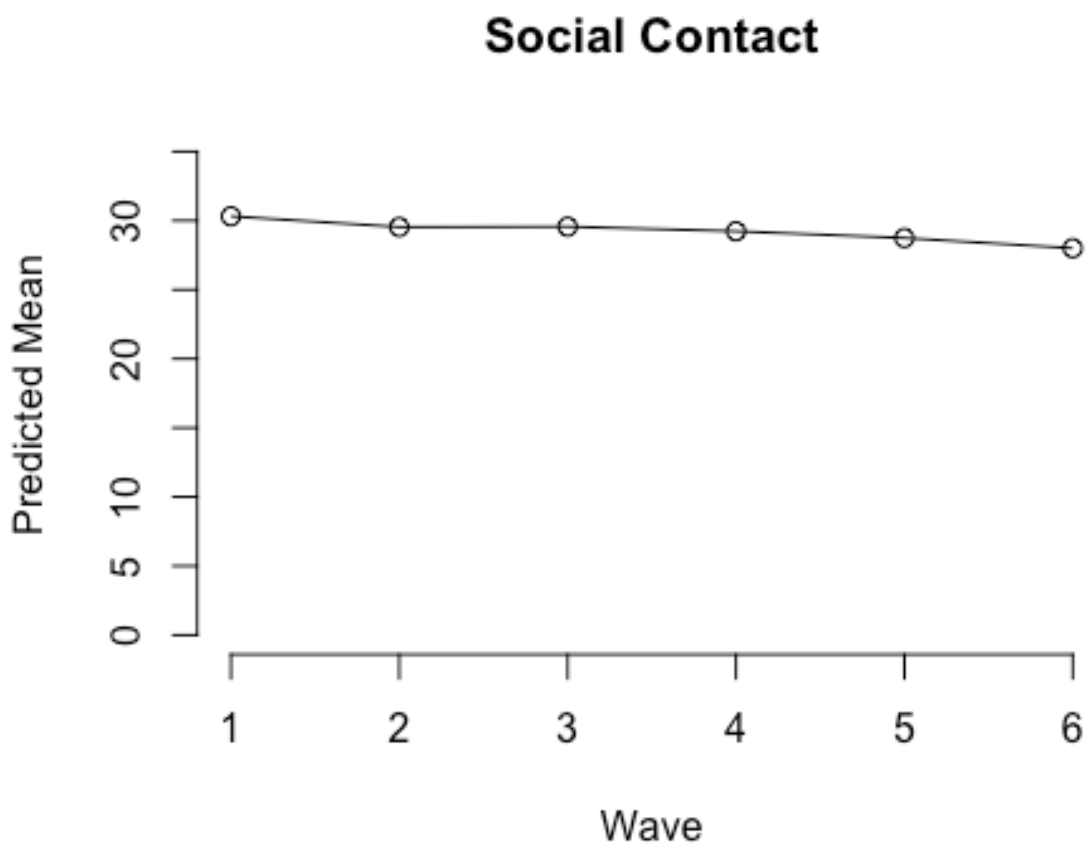

Figure 5. Predicted trajectory for social contact.

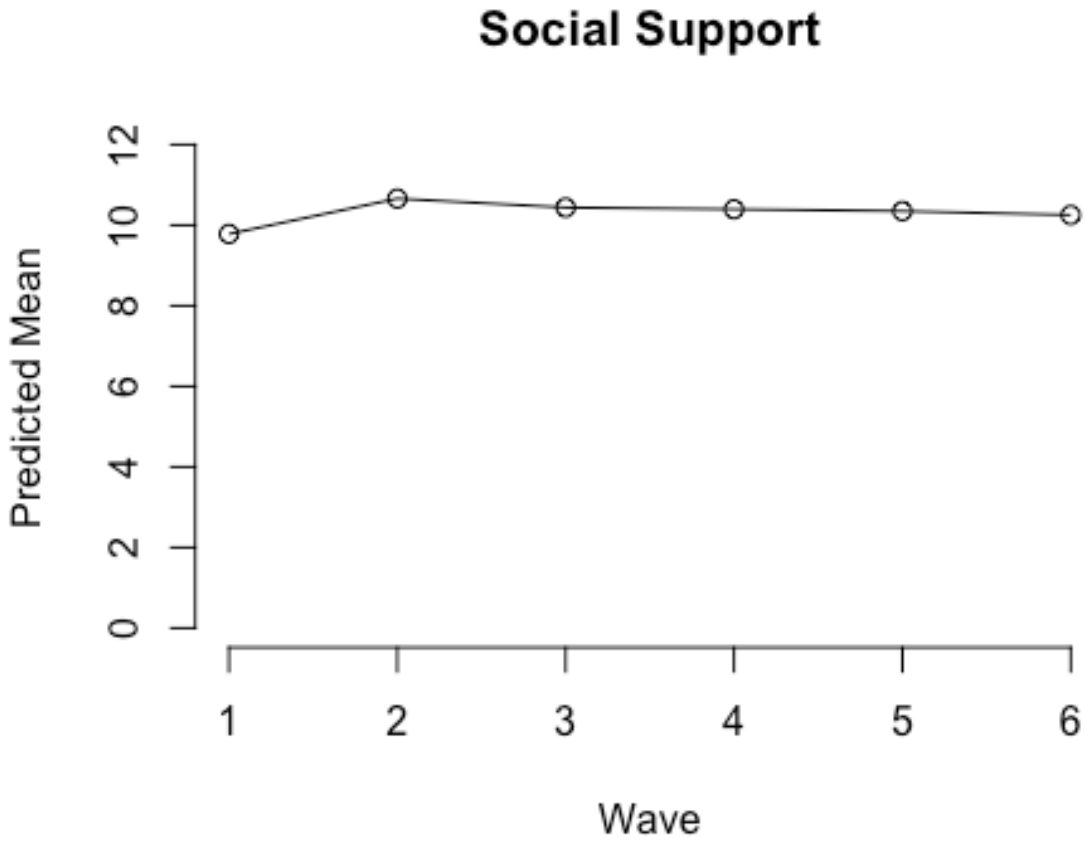

Figure 6. Predicted trajectory for social support.

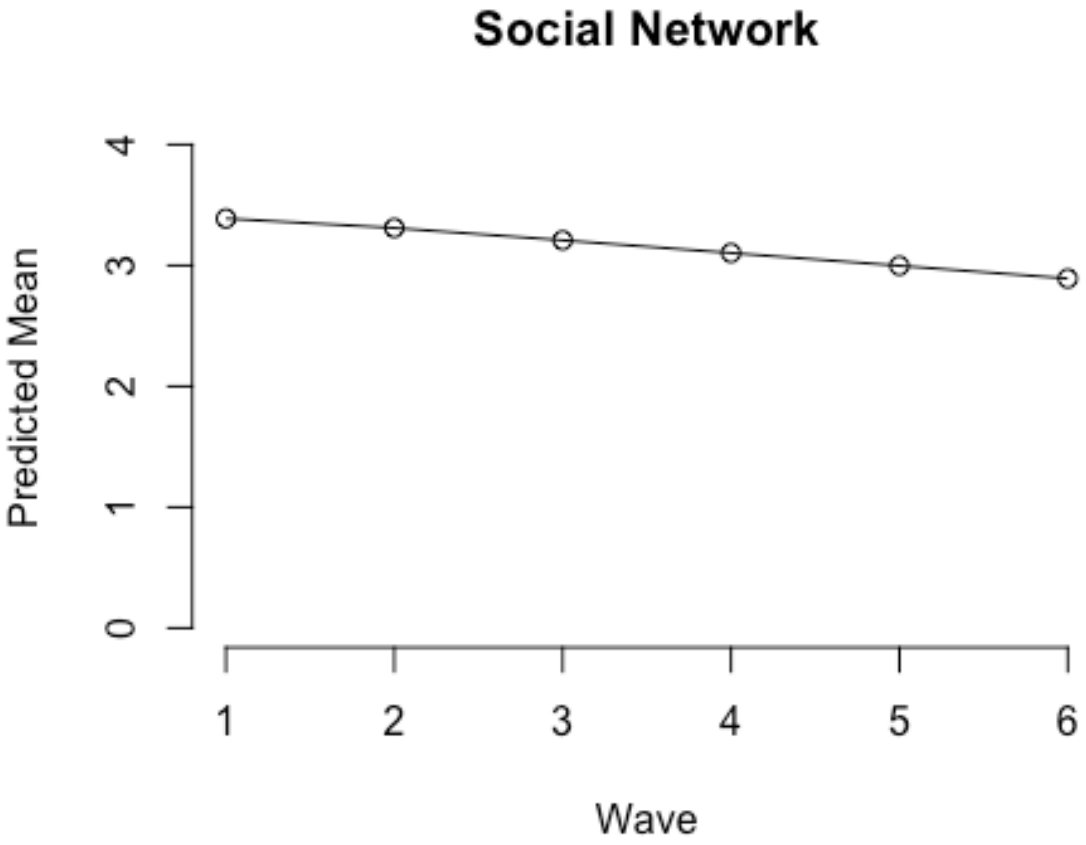

Figure 7. Predicted trajectory for social network composition.