

Understanding the Individual and Combined Impacts of Social Isolation and Loneliness on Memory: A
Sequential Explanatory Mixed Methods Study

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Social isolation (SI) and loneliness (LON) are important risk factors for cognitive health; however, their combined effects on memory, a key cognitive domain, are under-researched. This thesis is the first sequential, explanatory, mixed methods study to examine how SI and LON individually and together affect memory in middle-aged and older adults. Using three waves of data from the Canadian Longitudinal Study on Aging (CLSA), spread over six years, LON was measured by the loneliness frequency question from the 10-item Center for Epidemiologic Studies Depression Scale. SI was measured by an index based on marital/cohabiting status, retirement status, social activity participation, and number/frequency of social network contacts. Memory was evaluated with combined immediate- and delayed-recall z-scores from the Rey Auditory Verbal Learning Test. Primary analyses utilized all available data across the three waves of CLSA data and retained participants with missing covariate data ($n = 14,208$). Linear mixed models to account for all three waves of data were used to regress combined memory scores onto SI and LON, adjusting for sociodemographic, health, functional ability, and lifestyle variables. Results showed that combined SI and LON had the greatest negative impact on memory (least-squares mean: -0.80 [95% confidence-interval: $-1.22, -0.39$]), followed by LON alone (-0.73 [$-1.13, -0.34$]), then SI alone (-0.69 [$-1.09, -0.29$]), and lastly by experiencing neither (-0.65 [$-1.05, -0.25$]). Two sensitivity analyses – one excluding participants with missing covariate data from the primary analysis sample and another employing a multiple imputation approach – both confirmed these findings. The qualitative phase involved phenomenological, semi-structured interviews with ten individuals – recruited through purposive and snowball sampling – to explain the quantitative results from the perspective of middle-aged and older adults. Based on thematic analysis, qualitative participants believed that LON has a stronger negative impact on memory than SI because individuals can still engage in mental stimulation while isolated, but are less motivated to do so when feeling lonely. Participants also believed that the combination of SI and LON is most detrimental to memory, as these conditions can exacerbate each other in a feedback loop, leading those who experience both to be more prone to self-destructive behaviours. This research highlights the need for targeted interventions involving multimodal brain health programs, which simultaneously address multiple risk factors for cognitive decline – such as SI and LON – through actionable steps, including staying socially connected, finding meaning in life, engaging in cognitively stimulating physical/leisure activities, managing medical conditions, and adopting healthy lifestyle choices.

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Table of Contents

Examining Committee Membership.....	iii
Author’s Declaration	iii
Abstract.....	iv
Acknowledgements	iv
List of Figures	xi
List of Tables	xiii
List of Abbreviations	xiii
Chapter 1 Introduction.....	1
1.1 Background	1
1.2 Research questions.....	3
1.3 Hypothesis.....	3
Chapter 2 Literature Review	4
2.1 Social isolation	4
2.1.1 Measures of social isolation.....	5
2.2 Loneliness	5
2.2.1 Measures of loneliness	6
2.3 Factors contributing to social isolation and loneliness	8
2.4 Memory.....	10
2.4.1 Measures of memory.....	11
2.5 Theoretical framework.....	12
2.5.1 Cognitive enrichment/reserve theory	12
2.5.2 Social-cognition theory	13
2.5.3 Neuroendocrinology of stress	14
2.6 Impact of social isolation and loneliness on memory	14
2.7 Individual impact of social isolation on memory	18

2.8 Individual impact of loneliness on memory	19
2.9 Conclusion.....	30
Chapter 3 Methods	21
3.1 Philosophical paradigm: Pragmatism.....	22
3.2 Phase 1 (Quantitative phase)	12
3.2.1 Study setting/design	52
3.2.2 Participant sampling and eligibility criteria.....	53
3.2.3 Study measures	54
3.2.3.1 <i>Exposure (Combined social isolation and loneliness groups)</i>	54
3.2.3.2 <i>Outcome (Memory)</i>	56
3.2.3.3 <i>Covariates</i>	57
3.2.4 Data analysis	58
3.2.4.1 <i>Primary analytical sample (Modified AADA: AADA + MCA)</i>	58
3.2.4.2 <i>Descriptive analyses</i>	59
3.2.4.3 <i>Regression analyses</i>	59
3.2.4.4 <i>Missing data</i>	31
3.2.4.5 <i>Clinical significance</i>	32
3.2.5 Research Ethics.....	32
3.3 Phase 2 (qualitative phase)	33
3.3.1 Methodology: Reflexive thematic analysis based on descriptive phenomenology.....	35
3.3.2 Participant recruitment and eligibility criteria	33
3.3.3 Informed consent procedures	35
3.3.4 Data collection	35
3.3.5 Data analysis	36
3.3.6 Data management.....	37
3.3.7 Ethical considerations	37

3.4 Integration	38
3.4.1 At the completion of quantitative analysis	38
3.4.2 Merging data	38
3.4.3 Drawing conclusions	38
Chapter 4 Quantitative Results.....	39
4.1 Analytical samples.....	39
4.1.1 Primary analysis (AADA + MCA)	39
4.1.2 Sensitivity analysis 1 (AADA alone)	39
4.1.3 Sensitivity analysis 2 (Multiple imputation).....	39
4.2 Descriptive univariate analyses	41
4.2.1 Social isolation/loneliness	41
4.2.2 Memory	41
4.2.3 Transition probabilities.....	47
4.2.4 Association between social isolation/loneliness and combined memory	55
4.2.5 Association between covariates and social isolation/loneliness	54
4.2.6 Association between covariates and memory	55
4.3 Regression analyses	56
4.3.1 Research question 1: Base model.....	56
4.3.2 Attrition bias	59
4.3.3 Research question 2: Covariate models	65
4.4 Sensitivity analyses	61
4.5 Clinical significance	66
4.6 Diagnostic models	66
Chapter 5 Qualitative Results	68
5.1 Experiences of social isolation versus loneliness	73
5.1.1 Social isolation relates to structural/objective aspects of social relationships	73

5.1.2 Loneliness is a subjective negative emotion.....	75
5.1.3 Loneliness relates to the perceived unavailability of functional social support, regardless of physical proximity to others	77
5.2 Contributing factors for social isolation and loneliness	79
5.2.1 Covid-19.....	79
5.2.2 Bereavement	80
5.2.3 Health conditions and caregiver responsibilities.....	85
5.2.4 Moving to a different place.....	85
5.2.5 Old age	87
5.3 Experiences and contributing factors related to memory changes.....	89
5.3.1 Gradual onset of memory loss, hereditary risk of memory problems, and commitment to proactive cognitive health measures	90
5.3.2 Psychological and emotional stress can exacerbate memory impairment	91
5.3.3 Memory loss as a side effect of medications	93
5.4 Comparing the associations between 'social isolation and memory' versus 'loneliness and memory'	94
5.4.1 'SI and memory': Social activities stimulate memory functions by fostering opportunities to hone public speaking skills, acquire new knowledge, establish regular routines, find goals/purpose in life, and build connections outside the home	94
5.4.2 'SI and memory': SI affects memory by heightening social anxiety	97
5.4.3 'LON and memory': LON has worse impact on memory than SI because it is harder to remedy, and individuals can still engage in mental stimulation while isolated but less so while feeling lonely	99
5.5 Memory decline in the combined isolated and lonely group.....	103
5.5.1 Social isolation and loneliness can exacerbate each other in a feedback loop.....	103
5.5.2 Those who are both socially isolated and lonely are more likely to engage in a self-destructive lifestyle.....	104
5.6 Strategies for addressing challenges related to social isolation, loneliness, and memory changes	106

5.6.1 Taking proactive, intentional steps for social contact, being self-aware of one's problems, and leveraging timely help from one's social connections can combat social isolation and loneliness	106
5.6.2 Diverse social networks provide various types of functional social support	108
5.6.3 Seeking reciprocity in social relationships	113
5.6.4 Virtual social interactions, home visits, and pet therapy as a support to social connectedness for those who are both isolated and lonely	114
5.6.5 Relying on spouses or cohabitants in memory retention	117
5.6.6 Language-based/creative activities, repetition, and planning can help manage memory changes	118
Chapter 6 Discussion	121
6.1 Phenomenology of social isolation and loneliness	123
6.2 Comparing associations of social isolation, loneliness, and their combination with memory .	126
6.3 Strengths and limitations	129
6.3.1 Quantitative phase	130
6.3.2 Qualitative phase and its integration with quantitative data	131
6.4 Future implications and conclusions	132
References	136
Appendix I Literature Review of the Evidence for the Association between SI, LON, and Memory	151
Appendix II Quantitative Research Ethics Approval	158
Appendix III Qualitative Research Ethics Approval	160
Appendix IV Recruitment Poster Information	162
Appendix V Email Newsletter Post	163
Appendix VI Email Script	164
Appendix VII Telephone Script	165
Appendix VIII Letter of Information and Consent	167
Appendix IX Interview Questions	171
Appendix X Demographic Questionnaire	172

List of Figures

Figure 1 Conceptual map of social isolation and loneliness	7
Figure 2 Flow chart of the sequential explanatory mixed-methods research process	21
Figure 3 Analytical sample extraction process	40
Figure 4 Distribution of combined memory scores at baseline, follow-up 1, and follow-up 2.....	46
Figure 5 State transition probabilities for combined memory groups across six years of follow-up ...	48
Figure 6 State transition probabilities for social isolation/loneliness groups across six years of follow-up	50
Figure 7 Mean memory score by SI/LON groups at baseline, follow-up 1, and follow-up 2.....	53
Figure 8 Regression coefficients (least-squares means) from multivariable mixed effects analyses between combined memory and social isolation/loneliness groups.....	58
Figure 9 Attrition bias for combined memory	60
Figure 10 Attrition bias for social isolation/loneliness	61
Figure 11 Residual plot.....	66
Figure 12 Influence models	67
Figure 13 Code tree summarizing themes, sub-themes, and codes	70

List of Tables

Table 1 Distribution of combined memory and covariates by social isolation/loneliness groups	42
Table 2 Distribution of covariates by combined memory.....	44
Table 3 Continuous combined memory scores at baseline, follow-up 1, and follow-up 2.....	46
Table 4 Regression analysis results – comparisons of social isolation/loneliness groups for combined memory.....	57
Table 5 Sensitivity regression analyses results – comparisons of social isolation/loneliness groups for combined memory.....	64
Table 6 Variance inflation factors for explanatory variables	67
Table 7 Participants’ demographic information.....	69
Table 8 Joint display of quantitative and qualitative results	121

List of Abbreviations

- AADA** All Available Data Approach
- ADL** Activities of Daily Living
- AIC** Akaike Information Criterion
- AR1** Autoregressive of Order 1
- BA** Baseline
- BH** Benjamini-Hochberg
- BIC** Bayesian Information Criterion
- CART** Classification and Regression Trees
- CES-D** Centre for Epidemiological Studies Depression Scale
- CI** Confidence Interval
- CLSA** Canadian Longitudinal Study on Aging
- DJGLS-6** De Jong-Gierveld Loneliness Scale (6-Item Version)
- FCS** Fully Conditional Specification
- FUP 1** Follow-up 1
- FUP 2** Follow-up 2
- IADL** Instrumental Activities of Daily Living
- IAR** Interquartile Range
- LMM** Linear Mixed Effects Models
- LON** Loneliness
- LSMEANS** Least Squares Means
- MCA** Modified Covariate Approach
- MICE** Multiple Imputation by Chained Equations
- RAVLT** Rey Auditory Verbal Learning Test
- SD** Standard Deviation
- SI** Social Isolation
- SLR** Seniors Learning in Retirement
- UCLA-3** University of California, Los Angeles Loneliness Scale (3-Item Version)
- VIF** Variance Inflation Factor

Chapter 1

Introduction

1.1 Background

This thesis assessed the individual and combined impacts of social isolation (SI) and loneliness (LON) on memory function. Memory was chosen as the outcome due to its crucial role in healthy aging, which involves maintaining physical, mental, and social well-being, along with autonomy, as one ages [1]. Healthy aging allows individuals to lead fulfilling lives by enabling them to participate in their communities and engage in activities of their choice, enhancing a sense of purpose, fulfillment, and reinforcing personal values [2,3]. Participation and engagement are facilitated by strong social connections and support systems, which can foster emotional well-being, reduce feelings of loneliness, and help individuals navigate the challenges of aging. Staying physically and mentally active is crucial to maintain mobility and strength, and to prevent cognitive decline and chronic conditions [2,3]. Finally, practicing self-care (e.g., regular health check-ups, balanced nutrition, adequate sleep) and accepting aging (i.e., embracing the natural changes that come with growing older and understanding one's needs, limitations, and strengths) are important aspects of healthy aging, contributing to reduced anxiety about the future and fostering a sense of peace/satisfaction [2,3].

The study of memory in aging adults is important because memory decline is a primary symptom of major neurocognitive disorders (e.g., Alzheimer's disease, vascular dementia, Lewy body dementia, and encephalopathy), which pose substantial risks for mortality and morbidity among aging adults [4]. Memory decline also decreases one's personal autonomy by hindering their ability to carry out basic and instrumental activities of daily living (e.g., dressing, bathing, toileting, managing finances, preparing meals, community mobility, and social participation) [5,6]. Currently, over 55 million people worldwide are living with major neurocognitive disorders. This number is expected to rise to 139 million by 2050 due to an aging global population [7]. In Canada, these global trends are also evident, as the proportion of older adults aged 65 years or over is projected to rise from 18% in 2020, to 22.5% in 2030, and to 23.6% in 2040 [8]. Given this aging population, roughly 3.6 million community-dwelling Canadians live with at least one neurocognitive disorder [9,10]. Furthermore, the prevalence of Alzheimer's disease, Parkinson's disease, epilepsy, cerebral palsy, and multiple sclerosis among Canadians aged 40 years or over is expected to double by 2031 [9]. The Alzheimer Society of Canada [11] also reported that 597,300 Canadians were living with dementia in 2020 (1.6% of the population), with 124,000 new cases diagnosed that year. The annual incidence of dementia is projected to increase to 250,000 new cases per year by 2040, representing a 200% rise in new cases from 2020 [11]. Additionally, by 2050, the number

of people living with dementia is expected to nearly triple from the 2020 level, reaching 1.7 million (3.6% of Canadians) [11].

Amid these concerning projections, preventable and reversible factors such as SI and LON have been identified as risks for memory loss [12,13]. Currently, about one-third of older adults worldwide are either socially isolated or lonely [14,15]. Holt-Lunstad et al. [16] identify SI and LON as important risk factors for unsuccessful aging and poor cognitive health, with the impact of these two factors on mortality being comparable to other established risk factors like obesity, smoking, and physical inactivity. SI has been associated with increased risks of dementia and cardiovascular diseases, including coronary heart disease and stroke; LON has been linked to higher rates of suicide, sleep disorders (e.g., insomnia and sleep apnea), mood disorders (e.g., depression and anxiety), withdrawal from social interactions, lower life satisfaction, reduced ability to control/adapt to changes in one's environment, and diminished physical or cognitive abilities (e.g., problem-solving, decision-making, and memory functions) [17–20].

The recent COVID-19 pandemic and its associated public health measures (e.g., physical distancing, closure of social spaces, stay-at-home orders) underscored the challenges of SI and LON in aging adults [21,22]. Herron et al. [22] highlighted several factors contributing to older adults' feelings of SI and LON during the pandemic, including a loss of autonomy (the inability to engage in preferred activities at their chosen time), reduced participation in social activities and spaces (e.g., restrictions on meeting friends for coffee, dining out, volunteering, and attending religious services), and a lack of meaningful connections at home (due to living alone or experiencing strained relationships with household members). The importance of SI and LON as risk factors for memory function remains relevant in the post-pandemic world, given the unfolding nature of 'long COVID' and the association between COVID-19 infection, cognitive and memory impairment, and Alzheimer's disease [23–25].

Previous research indicates that SI and LON are related, though distinct, constructs that exhibit only small to moderate correlations with one another [12,17,18,26]. However, many researchers argue that SI and LON should be examined together because their combination creates unique risk profiles for adverse health outcomes, compared to when they are considered separately [17,18,27]. Several researchers have utilized a four-level, combined SI+LON variable (i.e., socially isolated but not lonely, lonely but not socially isolated, both lonely and socially isolated, and neither lonely nor socially isolated) to examine SI and LON together, and demonstrated that adults who are both socially isolated and lonely tend to be older, female, widowed, and at higher risk of cardiovascular disease, depression, lower income, reduced quality of life, higher medical costs, and more frequent emergency room visits, compared to those who are only socially isolated or only lonely [17,18,27]. These findings highlight the importance of

addressing both social isolation and loneliness in tandem to mitigate their combined effects on health and well-being.

1.2 Research questions

This thesis examined the following research questions using a sequential explanatory mixed methods study design:

1. Quantitative phase: Among middle-aged and older, community-dwelling adults in Canada, what is the association between exposure to combinations of social isolation and loneliness, and the outcomes of immediate- and delayed-recall memory, over three time periods, namely baseline (BA), three-year follow-up (FUP1), and six-year follow-up (FUP2)?
2. Quantitative phase: Do the associations found in question 1 above change after adjustment by sociodemographic factors, health comorbidities, functional ability, and lifestyle variables?
3. Qualitative phase: How do middle-aged and older adults personally perceive, experience, and explain the relationship between social isolation, loneliness, and memory, after being presented with the summarized quantitative findings from questions 1 and 2 (e.g., do they agree or disagree with these findings, and what reasons do they provide for their judgments)?

1.3 Hypothesis

I hypothesized that individuals who were both socially isolated and lonely would experience the greatest memory declines, followed by those who were only lonely, and then those who were only socially isolated, when compared to the 'neither socially isolated nor lonely' group. This hierarchy was proposed because individuals' feelings and perceptions (LON) about a situation often more profoundly affect their health than objective reality (SI) [28].

Chapter 2

Literature Review

This chapter provides a comprehensive overview of research on the impact of SI and LON on memory function in the aging population. It begins by defining SI, LON, and memory function, while also examining commonly used measurement tools and key risk factors associated with these concepts. The chapter then explores theoretical frameworks that explain the associations between SI, LON, and memory. Finally, it reviews relevant studies where SI and/or LON serve as exposure variables and memory or other cognitive domains as the outcome, highlighting gaps in the literature that warrant further investigation.

2.1 Social isolation

Consistent with existing literature [12,17,18,26], the definitions of SI and LON in this thesis are based on the discrepancy theory of loneliness [29]. This theory views SI and LON as the objective and subjective absences of social relationships, respectively [29]. SI refers to the objective state of lacking structural social support and being physically separated from social connections, which can occur at the individual, group, or community level [30]. SI is sometimes described as physical isolation in the literature [30,31].

Structural social support refers to the objective, structural aspects of social connections, such as the quantity, type, and frequency of social networks and interactions [31]. A social network encompasses the people who interact with an individual and the social ties existing between them [32]. Key characteristics used to measure social networks include network size (the number of people with whom one interacts), network composition (the variety and types of people in the social network), and network density (the proportion of network members who know each other) [32]. SI is characterized by low structural social support, including a small social network size, low network density, and limited diversity in network composition (e.g., a network that includes only family members, rather than a mix of family, friends, neighbours, and coworkers) [33–35]. Additionally, SI involves infrequent interactions with social network members and limited participation in social or group activities (e.g., traveling/outings with family or friends, volunteering, religious participation, community group membership, and attending social events) [16,36,37]. Many studies also consider living alone, being unmarried/without a partner, and being retired as indicators of SI [17,18,38,39]. In conclusion, SI is a combination of multiple factors indicating a lack of structural social support, and no single factor is sufficient to signify the presence of SI on its own.

2.1.1 Measures of social isolation

Some of the most frequently utilized measures of SI include the Lubben Social Network Scale [40], Berkman-Syme Social Network Index [41], and Steptoe Social Isolation Index [39]. However, the Lubben Social Network Scale measures SI by asking, “How many relatives/friends do you see or hear from at least once a month?” which only captures one aspect of SI—social networks. The other two instruments assess various combinations of structural components of social relationships, including marital status, participation in social activities, social network size, and interaction frequency [31,42]. While these tools cover many aspects of SI, they overlook living arrangements and retirement status, both of which have consistently been shown to contribute to SI [18,30,31,42]. Additionally, these instruments focus on participants’ contact with close social ties, such as family and friends, but do not measure interactions with peripheral social networks, such as neighbours and colleagues [30,42]. These limitations may result in underestimating the total size of social networks and the overall frequency of social interactions.

To develop a more comprehensive measure of SI, Menec, Newall, and colleagues [17,18,38] created a new SI index using data from the Canadian Longitudinal Study of Aging (CLSA). This index included questions about retirement status, living arrangements, marital or cohabiting status, participation in social activities, and social contact with close and peripheral social networks. This index was employed to measure SI in the thesis and is described in greater detail in the Methods chapter (Chapter 3, Section 3.2.3.1).

2.2 Loneliness

In contrast to SI, LON is sometimes described as ‘perceived isolation’ [43–45] because it refers to the emotional distress caused by a person’s subjective perception of unmet social needs, regardless of whether they are socially isolated [17,18,38]. A person’s unmet social needs involve a gap between the quantity or quality of the social relationships they have, versus what they want. LON results from dissatisfaction with available levels of structural (quantity) or functional (quality) social support [18,46–48]. According to the discrepancy theory, individuals can feel lonely even if they have a large social network, or they might meet objective criteria for SI, but not experience LON [18].

Functional social support is defined and categorized according to the specific roles that an individual’s social connections play in their life [31,42]. These roles are typically divided into five types: emotional, tangible, informational, appraisal, and positive social interactions [31,42]. Emotional support is rooted in offering a trusted presence characterized by empathy, understanding, and encouragement, aimed at alleviating emotional distress during challenging times. It involves having someone to confide in

who listens and validates one's feelings [31,32,42]. Affectionate social support specifically refers to expressions of love, care, and closeness. This form of support focuses on demonstrative gestures of affection, such as verbal affirmations of love, physical touch (e.g., hugs), and actions that convey warmth and closeness [31,32,42]. Tangible support involves providing concrete/materialistic goods and services, such as financial assistance, transportation, and technology [31,32,42]. Informational and appraisal support equips individuals with helpful information, advice, and suggestions to assist them in solving problems and making decisions [31,32,42]. Lastly, positive social interactions provide individuals with a sense of companionship and practically involve the availability of others with whom to engage in activities [32].

In summary, the defining feature of LON is not the number of social connections a person has, but whether a discrepancy exists between the social support they want and what they actually receive, provided the discrepancy is regarded as unfavorable or less rewarding than their expectations [31,49].

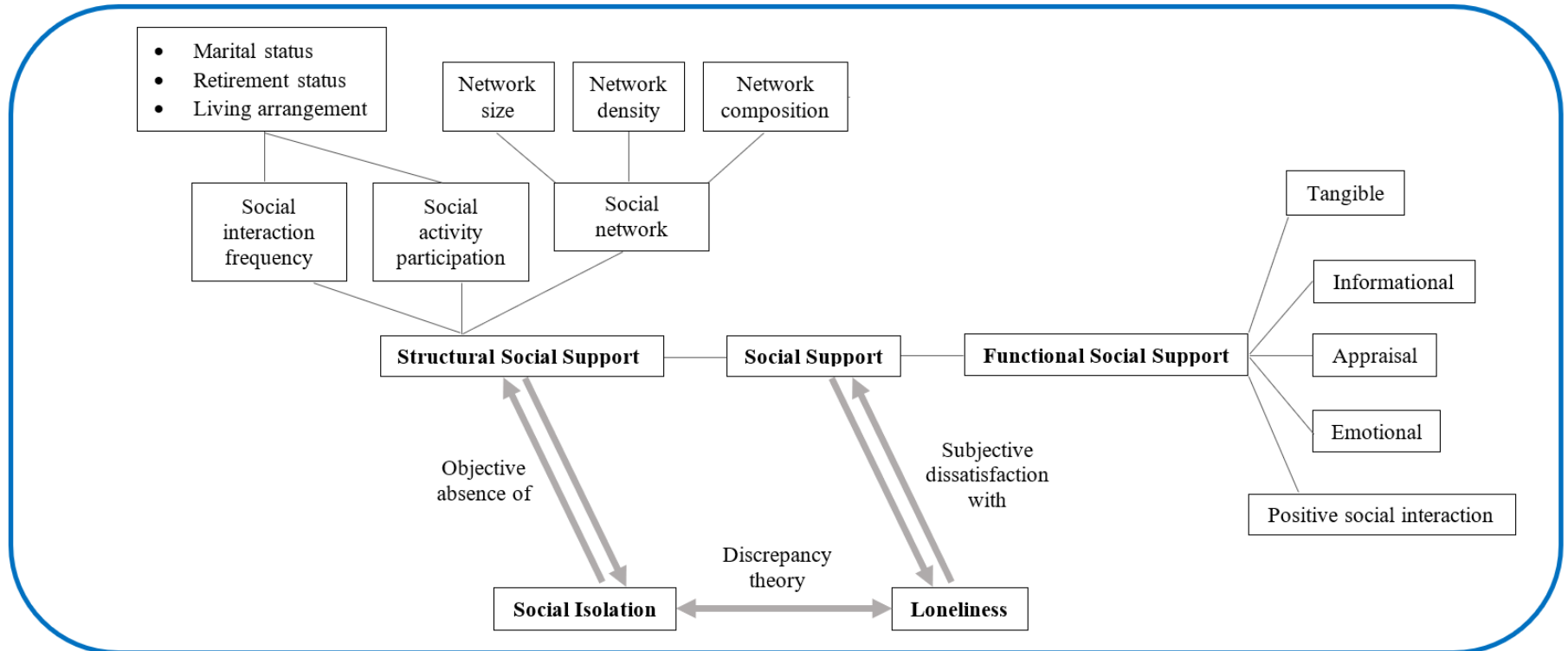
2.2.1 Measures of loneliness

The 6-item De Jong-Gierveld Loneliness Scale (DJGLS-6) [50] and the 3-item University of California, Los Angeles Loneliness Scale (UCLA-3) [51] are commonly used to assess LON. The DJGLS-6 includes questions related to a “general sense of emptiness”, “wishing to have people around”, “feeling rejected”, “feeling close to enough people”, “having people to rely on when facing problems”, and “having people to trust completely”. The UCLA-3 asks respondents how often they “feel isolated from others”, “feel left out”, or “feel that they lack companionship” [42]. These multi-item questionnaires ask respondents to indicate their satisfaction with the quality and/or quantity of their social interactions and include questions addressing both positive and negative emotions related to their social relationships [42].

Additionally, single-item measures are frequently used to assess LON, with the Centre for Epidemiological Studies Depression Scale (CES-D) [52] being a popular choice in many LON studies [17,18,49,53,54]. The CES-D includes a LON-specific item that asks, “In the last week, how often did you feel lonely?” (with response options being “lonely all the time [5 – 7 days],” “occasionally lonely [3–4 days],” “lonely some of the time [1–2 days]”, and “rarely or never lonely [less than 1 day]”). While the phrasing and response options for different single-item measures vary across studies, most assess the frequency of LON, often using four response choices similar to the CES-D [42,49]. Overall, the DJGLS-6, UCLA-3, and CES-D have been validated for use in middle-aged and older populations and have been applied across various ethnic groups [42,49]. Figure 1 below illustrates the interrelationships between SI and LON.

Figure 1.

Conceptual map of social isolation and loneliness



2.3 Factors contributing to social isolation and loneliness

Although SI and LON are distinct concepts, they share several common demographic and health-related risk factors. In terms of demographic factors, increasing age has been consistently linked to both SI and LON [31,49,55]. As individuals age, they tend to experience reductions in the size and diversity of their social networks and a decline in social participation due to the passing of close friends and family members [56,57]. Most importantly, spousal loss becomes more frequent in older adults and widowhood is a strong contributor to SI, LON, and negative health outcomes, including depression, cognitive decline, and mortality [58–60]. Additionally, older adults often encounter mobility challenges and functional limitations that can limit their ability to perform daily tasks independently (e.g., driving, preparing meals, dressing), attend social gatherings in person, and maintain regular social contact, further contributing to SI and LON [56,57].

Gender and biological sex also influence SI and LON: while both men and women experience increased levels of SI as they age [61], the structure of this isolation varies. Women typically have larger, more diverse social networks than men across all ages [62] and generally report lower levels of SI [63,64]. Men, on the other hand, prefer to maintain smaller social networks, finding the upkeep of larger networks stressful [63,64].

Marital status also plays a crucial role in SI for both genders [58–60]. Existing research suggests being unmarried or widowed may have a more profound impact on SI for men because they often rely heavily on their partners for social activities and may struggle to form new connections after the loss of a spouse [61,65,66]. In contrast, women are more likely to seek out and maintain supportive social relationships after such a loss [61,65,66].

Regarding LON, studies indicate that older females often experience higher levels of LON compared to their male counterparts. Some researchers argue that females may be more susceptible to LON due to factors such as longer life expectancy, which increases the likelihood of widowhood and living alone [67,68]. Additionally, the types of social relationships valued by men and women may differ, further influencing their experiences of LON [69]. For instance, Pinqart & Sörensen [69] posit that women tend to prioritize emotional closeness and communication in their relationships, whereas men generally place greater emphasis on shared activities and companionship. Since long-term, close relationships are more challenging to replace than casual companionship, women who rely on emotional connections may experience more intense feelings of LON when these relationships are lost or weakened, even if they remain more socially engaged than men. However, Seidler et al. [70] suggest that societal expectations and gender

norms may discourage men from expressing vulnerability, making it more difficult for them to admit feelings of LON, potentially leading to an underestimation of LON among the male population.

In addition to demographic factors, health conditions such as Alzheimer's disease, cognitive impairment, and mental illnesses have been linked to an increased risk of both SI and LON [31,47,55]. Deficits in social functioning are often observed in individuals with neuropsychiatric disorders because the brain regions responsible for processing social stimuli (e.g., the prefrontal cortex, temporal lobes, and amygdala) are densely interconnected, making them particularly vulnerable to damage and pathogenic infection. This interconnectivity facilitates the spread of dysfunction across networks, amplifying the effects of localized damage [71,72]. The relationships between social deficits and health conditions are often bidirectional; impairments in social functioning can worsen underlying health conditions, while these conditions can, in turn, hinder social interactions. For example, individuals with Alzheimer's disease may exhibit inappropriate social behavior or lack the cognitive abilities and emotional responsiveness necessary for effective social interaction [73]. Additionally, stigma against individuals with Alzheimer's disease can reduce their opportunities for social interaction, often leading to involuntary withdrawal/isolation from their communities [74]. Some individuals may also intentionally withdraw from social situations due to embarrassment or fear of others noticing their cognitive decline [73]. Psychosocial conditions such as depression, perceived stress, and neuroticism are also associated with both SI and LON [31,47,55]. Individuals with depression often have limited social interactions and functional support, which may lead them to perceive that their social support is insufficient to alleviate the distress and functional limitations caused by their depressive state [31]. As a result, depression can lead to a socially isolated and/or lonely status. Conversely, SI and LON can also contribute to the development of clinical depression, neuroticism, and perceived stress, further reinforcing the bidirectional relationship [31].

Physical conditions such as arthritis, visual impairment, hearing impairment, and a history of falling (and the associated fear of falling) can also heighten the risk for SI and LON [47,55]. Arthritis, for example, causes joint pain, stiffness, and mobility limitations, which not only increase physical discomfort but also elevate the risk of falls [75]. Nearly 50% of individuals with arthritis, particularly osteoarthritis, report having fallen within the past year, often resulting in fractures [75]. These factors can diminish one's ability or willingness to engage in social or physical activities outside of their homes, further limiting social contact [55]. Visual impairments, meanwhile, create barriers to communication by making it difficult to interpret nonverbal cues such as facial expressions or gestures, thereby hindering social engagement [32]. Similarly, hearing impairments can restrict effective verbal interactions, often leading to misunderstandings or missed information, particularly in noisy environments or group settings [32]. The psychological impact of these conditions – such as anxiety, embarrassment, or reduced self-confidence – further exacerbates

LON, as individuals may feel disconnected from their social circles or society as a whole [32]. Adults aged 50 years or over are more likely to experience greater levels of functional limitations and chronic physical and psychological conditions than younger individuals, making them particularly vulnerable to SI and LON [14].

2.4 Memory

Memory is one of the six core domains of cognitive function, alongside executive function, language, perceptual-motor skills, social cognition, and complex attention. Memory is defined as the ability to encode, store, and retrieve information, and it is generally separated into sensory, short-term, and long-term memory systems [76,77,78].

Short-term memory refers to the brief storage of limited amounts of information, primarily verbal, visual, and spatial information [78]. Notably, it is a fundamental component of the working memory system [78]. However, working memory extends beyond temporary storage; it also manipulates information to enable complex activities such as reasoning, learning, and comprehension [78]. More specifically, working memory operates through the coordination and management of the phonological loop, visuospatial sketchpad, and episodic buffer, which are overseen by central executive systems [78,79]. The phonological loop and visuospatial sketchpad are responsible for the short-term storage/processing of verbal and visuospatial information, respectively [78,79]. Meanwhile, the episodic buffer plays a crucial role in holding multiple types of information (e.g., sights, sounds, scents, textures) simultaneously. The buffer integrates this information with long-term memory to create a unified “mental snapshot” or “mini story” [79]. For instance, when watching a movie, the episodic buffer combines visual images, dialogue, and one’s memory of earlier scenes into a coherent whole, allowing individuals to follow the plot effectively. Some researchers [12,35,80,81] have also linked attention to working memory, supporting the view that attention is a crucial resource for the efficient processing and storage of information related to working memory [82].

In contrast to short-term memory, long-term memory is divided into two main types: implicit memory and explicit memory [76,83]. Implicit memory refers to automatic memory that operates without conscious awareness, such as learned skills and habits, which typically develop during early stages of life [78]. Explicit memory, on the other hand, involves the conscious retrieval of information, including specific dates, names, personal experiences, and general knowledge about the world [78]. Unlike implicit memory, explicit memory continues to develop throughout life, making it more age-dependent [78]. Explicit memory is further divided into subtypes such as episodic memory and semantic memory. Episodic memory relates to the capacity to recall and recognize information from personal past

experiences, often involving the reconstruction and reliving of sensory, perceptual, and emotional events from specific times and places [84,85]. This type of memory involves the interaction of basic brain units responsible for sensory, verbal, affective, narrative representations, and search-and-retrieval systems [84,85]. In this way, episodic memories are formed when diverse types of information are encoded into autobiographical knowledge, which includes details about life stages (e.g., childhood, university years), life themes (e.g., health, work, community), recurring life events, personal identity, and the sociocultural contexts that shape one's sense of self [84]. These memories are hierarchically organized to enable efficient retrieval [86]. Once integrated into autobiographical knowledge, they are preserved over the long term, contributing to our understanding of self (e.g., personal traits, life stories, and self-identity) by providing specific sensory details and contexts [84,86].

Unlike episodic memory, semantic memory involves concepts, facts, and ideas commonly understood as general/common knowledge (e.g., recalling the capital of a country, the meaning of words) and is not necessarily derived from personal experiences [87]. Semantic memory is composed of two subsystems that manage knowledge and fluency, organized either taxonomically or thematically [87,88]. Taxonomic memory classifies items based on their intrinsic similarities and organizes them hierarchically (e.g., grouping elephants and rabbits under the broader category of mammals) [88]. In contrast, thematic memory categorizes items based on their experiential connections rather than intrinsic similarities (e.g., fish and ocean; bird and cage; rain and umbrella) [88].

2.4.1 Measures of memory

Memory cannot be directly measured using medical imaging techniques (e.g., X-rays, CT scans, MRI, positron emission tomography) or biomarkers, as these methods are designed to visualize structural aspects of the brain rather than cognitive functions [89]. While these imaging techniques can provide insights into brain activity associated with memory tasks, they do not directly measure memory itself [89]. As a result, the assessment of memory is typically conducted through neuropsychological tests, which provide a functional measure of memory by evaluating individuals' performance in memory-utilizing tasks (e.g., recalling word lists, recognizing images, or repeating sequences of numbers) [90].

For assessing episodic memory, some of the most used tests include the Rey Auditory Verbal Learning Test (RAVLT), the Alzheimer's Disease Assessment Scale - Cognitive subscale (ADAS-Cog), and the Verbal Selective Reminding Test (VSRT) [6,91–94]. These tests typically involve a word list recall component, where participants are presented with a list of 10 to 15 unrelated words or items and asked to recall them immediately and/or after a delay of 5 to 10 minutes, sometimes with a distractor word list introduced during an 'interference' interval. While word list recall tests are traditionally used to

measure verbal learning, they are also widely employed by neuropsychologists and researchers to evaluate short-term episodic memory (not linked to autobiographical knowledge) [95,96].

For measuring working memory, the Wechsler Adult Intelligence Scale (WAIS) and the Wechsler Memory Scale (WMS) are widely used in clinical and research settings. Both scales include forward and backward digit span tests [12,35,37], where participants are required to repeat a series of digits presented by the researcher, either in the same (forward) or reverse (backward) order. The forward span is typically used to assess short-term memory, attention, encoding, and auditory processing, while the backward span is specifically used to measure working memory [97].

Finally, semantic memory is often measured using the Animal Fluency Test [12] and confrontation naming tests like the Boston Naming Test [37]. In the Animal Fluency Test, participants are asked to name as many different animals as possible within one minute, while in the Boston Naming Test, they are required to provide words or labels corresponding to 60 line-drawings of various objects and actions. These tests are frequently used to evaluate individuals' ability to retrieve semantic concepts (measured by counting the total number of correct responses) and to assess how respondents organize semantic information (by analyzing whether the responses are ordered/organized taxonomically or thematically) [98].

2.5 Theoretical frameworks

Several social and biological frameworks may explain the underlying association between SI, LON, and memory. These frameworks include the cognitive enrichment/reserve theory, social-cognition theory, and neuroendocrinology of stress.

2.5.1 Cognitive enrichment/reserve theory

Engaging in positive behaviours, such as taking care of one's health, staying socially connected, managing stress, exercising, or participating in social activities, require the use of cognitive faculties [99]. The cognitive enrichment hypothesis posits that participating in such activities enhances cognitive reserve and protects memory by reinforcing neural network structures and synaptic connections [54,100]. The cognitive enrichment hypothesis is sometimes called the 'use-it-or-lose-it' theory to reflect the idea that one's cognitive faculties must be stimulated to remain intact.

Cognitive enrichment is closely linked to concepts like resilience, brain maintenance, and cognitive reserve [101]. Resilience serves as an overarching term that captures the brain's capacity to sustain cognitive functions despite aging or disease, essentially representing the ability to adapt to adversity [101]. Resilience is supported by underlying mechanisms like brain maintenance and cognitive reserve

[101]. Brain maintenance focuses on preventing or slowing age-related neural changes and pathological damage (e.g., hippocampal atrophy and amyloid plaque accumulation associated with Alzheimer's disease) by emphasizing the preservation of brain structures and functions [101].

Unlike brain maintenance, which prevents neural changes, cognitive reserve helps compensate for existing changes [101]. Cognitive reserve enables the brain to function more effectively than anticipated given the presence of aging, injuries, or disease [101]. This reserve is shaped throughout life by factors that promote cognitive stimulation, including higher education, complex occupations, regular physical activity, and active participation in social activities [101]. Having a high reserve enables the brain to compensate for damage or aging by leveraging alternative neural networks or strategies [102,103]. Social engagement, in particular, plays a valuable role in building cognitive reserve, as it demands the use of cognitive processes such as problem-solving, memory recall, verbal learning, attention, and emotional processing [54,100]. Increased interaction within social networks exposes individuals to new social stimuli, such as diverse ideas, information, activities, and both verbal and nonverbal cues [104,105], all of which can promote cognitive stimulation and neuroprotective mechanisms. Conversely, reduced social engagement, characterized by small social networks and low participation in social activities, can lead to memory decline due to the gradual atrophy of neural and synaptic mechanisms over time [54,100].

2.5.2 Social-cognition theory

Social-cognition theory emphasizes the strong connection between social learning, social bonding, and cognitive functioning [106,107]. Social learning is a form of cognitive learning that occurs through social interactions, where individuals imitate the behaviors of others and observe the outcomes of these actions [108]. Thus, being connected to social networks is vital for facilitating social learning. This type of learning enhances neural connections through repeated exposure to social information, such as appropriate behaviors, social norms, and general world knowledge [108]. Additionally, social learning allows individuals to gain insights into others' motivations or thought processes, as well as acquire social resources to enhance their cognitive abilities, including memory [32]. For instance, if an individual regularly observes a friend using memory-enhancing techniques (e.g., mnemonic strategies) and maintaining a healthy lifestyle (e.g., getting regular check-ups and avoiding smoking/drinking), they may adopt these habits themselves, leading to improved memory [32]. In this way, social learning can influence a person's attitudes and behaviors toward memory preservation [106].

It is important to note that social bonding, or forming strong emotional/social connections, can increase opportunities for social learning because individuals are more likely to share experiences and information with close social contacts [108]. Research has shown that having a large proportion of confiding network members (those with whom one can share private feelings and intimate experiences) in

one's social network can be particularly helpful in buffering against LON, fostering a sense of belonging, and receiving emotional and positive social interaction support [32]. Additionally, having a diverse social network that includes both proximal (family and friends) and non-proximal (distant neighbors, colleagues, acquaintances) members can help bridge the gap between the quantity and quality of available social connections and the connections one ideally desires [32]. Therefore, a diverse social network has been linked to reduced LON, higher levels of subjective well-being, and lower mortality and morbidity rates [32]. In contrast, restricted networks with small network size, low diversity in network composition, and infrequent contact with members are typically associated with poorer well-being and weaker quality of functional social support [32].

2.6 Impact of social isolation and loneliness on memory

The past decade has seen a substantial increase in research investigating the impact of SI and/or LON on memory. However, a recent review by Cardona and Andrés [109] highlighted a critical gap in the literature: most published studies focused on either SI or LON independently, without considering their combined effects on memory. This review, which examined the impact of SI or LON on any of several cognitive outcomes – including short-term and episodic memory, attention, and global cognition – included longitudinal studies published between January 2017 and April 2021, with participants aged 60 years or over, who had no diagnosis of cognitive impairment or dementia. The review identified 12 articles that met these eligibility criteria, six of which assessed only LON, three focused solely on SI, and three explored both SI and LON.

The six studies investigating SI and cognition found that increased SI was associated with declines in verbal fluency, working memory [12], episodic memory [54,110,111], perceptual motor speed, orientation, visuospatial ability, processing speed [54,112], and global cognition [12,113]. Similarly, the nine studies examining LON and cognition demonstrated negative associations between LON and verbal fluency, episodic memory [12,54,114,115], working memory, global cognition [12], orientation, visuospatial ability, and numeracy [54].

Cardona and Andres [109] noted inconsistencies regarding the impact of LON on cognitive function in articles that controlled for depression. For example, Lara et al. [12], Luchetti et al. [114], and Yin et al. [115] found that LON continued to have a significant effect even after adjusting for depressive symptoms. In contrast, McHugh Power et al. [116] and Yu et al. [54] observed that LON's impact was no longer significant once depression was included as a covariate in their regression models. Notably, this pattern was not seen with SI, as all studies investigating SI's effect on cognitive function reported that its impact remained significant even after controlling for depression [12,54,112]. Cardona and Andres [109]

therefore concluded that the subjective experience of LON may be more closely tied to depression than the objective SI. They also suggested that depression might play a stronger mediating role in the relationship between LON and cognitive decline than between SI and cognitive decline, potentially diminishing the observed effects of LON on cognition.

The review also highlighted variability in the measurement of SI compared to LON. While the nine studies measuring LON predominantly used either the full or shortened versions of the UCLA Loneliness Scale or a single-item loneliness question from the CES-D (both the 10-item and 20-item versions), the six studies measuring SI employed five different approaches, each incorporating one or more of the following five indicators of SI: social network size, frequency of interaction, living arrangement, marital status, and participation in social activities. This inconsistency in measurement tools for SI, coupled with the assessment of multiple cognitive domains, complicated the ability to draw uniform conclusions about the impact of SI on memory decline, particularly in comparison to the effects of LON.

In alignment with Cardona and Andres' [109] review, I also conducted a systematic review to synthesize and critically appraise the literature on SI, LON, and cognition [78]. However, unlike prior reviews examining multiple cognitive functions, this review concentrated solely on memory as the outcome of interest and included both cross-sectional and longitudinal studies. This review also included a broader age range (45-85 years) compared to other reviews that focused on participants over 60 years old [5,109,117], recognizing the importance of middle-aged populations, as they experience higher rates of SI and LON compared to the general population and carry the effects of these issues into later life [118,119].

I searched for English-language citations in PubMed, Scopus, and PsycINFO from database inception through January 17, 2022. The search syntax was initially developed for PubMed with the assistance of a medical librarian and later adapted for the other databases (complete search strategies for all three databases are provided in Appendix I, Table S1.1). This search identified 12 articles that examined both SI and LON as risk factors for memory impairment. Appendix I, Fig. S1 outlines the screening process and eligibility criteria, while Table S1.2 summarizes the extracted data.

Since the publication of my systematic review, I revisited PubMed using the same search terms for studies published between January 2022 and August 2024. However, I only discovered one additional article on the impact of both SI and LON on memory – my own study published on May 9, 2024 [53], which is described in Chapter 4. Several new articles published during this period investigated the effects of SI alone and LON alone on memory, and these are discussed in sections 2.7 and 2.8, respectively.

Of the 12 identified articles in the systematic review, four were cross-sectional [33,34,43,44] and eight were cohort studies [12,26,35–37,45,54,120]. The articles described research conducted in six countries (USA, Canada, Scotland, the Netherlands, Spain, England, and China), with sample sizes ranging from 378 [35] to 19,297 [45,120].

Regarding SI measures, three studies used a single measure of social network size [33–35]. The remaining studies employed various combinations of indicators: (1) social network size and frequency of interaction [45,120]; (2) social network size, living arrangement, and marital status [44]; (3) living arrangement and social activity participation [43]; (4) social activity participation and social network size [36,37]; and (5) marital status, social activity participation, and interaction frequency [12,26,54]. Despite these differences, all measures omitted one or more key indicators of SI, with none considering more than three. These ‘limited’ measures overlooked the multiplicity of different elements of SI, potentially leading to biased assessments of the true strength and direction of the association between SI and memory [38,53]. For instance, an individual with a small social network might not be socially isolated if they actively participate in social events, are married, and not retired [53]. Thus, SI should be examined using a multi-modal measure that aggregates many possible deficiencies in social engagement, rather than the absence of a single component [104].

For LON, 2 of the 12 studies used a single-item measure: one from the CES-D-10 Scale [54] and the other asking about ‘feeling lonely at the present moment’ [44]. Four studies used the DJGLS-6 [34–37] and six studies employed the UCLA-3 Scale. Memory was measured in various ways: one study [35] assessed verbal/episodic and working memory; two studies [12,37] evaluated verbal/episodic, working, and semantic memory; one study [44] did not specify the type of memory measured; and the remaining eight studies focused solely on verbal/episodic memory.

The results of the systematic review revealed that higher levels of SI and LON were linked to poorer memory performance in middle- and older-aged adults. The strongest negative effect on memory occurred when SI and LON interacted, followed by SI alone, and then LON alone. However, the magnitude and direction of reported associations exhibited considerable variation when measures of SI were separated into single components [78]. In particular, the effect sizes for social network size and social activity participation – the two most common SI indicators – varied widely. For social network size, all included cross-sectional studies demonstrated a positive association with memory, whereas the cohort studies reported mixed results, including positive, negative, and null associations. For example, Hülür [45] and Hülür et al. [120] observed a positive association between the number of friends and memory, but a negative association between the number of kin members (children and relatives) and memory.

On the other hand, most studies found positive associations between social activity participation and memory, though the effect sizes varied, ranging from Cohen's $d = 0.06$ (95% CI = -0.01, 0.13) to Cohen's $d = 0.16$ (95% CI = 0.07, 0.25). These variations in effect sizes can be attributed to differences in the composition of social networks (e.g., children, relatives, friends, neighbors, colleagues) and the types of social activities assessed in the studies (e.g., leisure activities, religious activities, clubs or fraternal organization activities) [78].

In addition, among the 12 memory-focused studies included in the review, only Fung et al. [34] examined the combined impact of SI and LON, while the rest treated each as independent risk factors. In Fung et al.'s [34] cross-sectional study of 497 adults aged ≥ 60 years, a significant negative association was found between 'LON x family network size' and memory ($\beta = -0.119$ [$p = 0.006$]), indicating that an increase in family network size was linked to further declines in memory scores among lonely individuals. However, the association between 'LON x friendship network size' and memory was weaker and non-significant ($\beta = -0.078$ $p = 0.074$), suggesting that friendship network size did not significantly modify the original negative impact of LON on memory. The study also reported a significant positive association between overall social network size and memory ($\beta = 0.126$, $p = 0.005$), while LON was significantly negatively associated with memory ($\beta = -0.165$, $p = 0.002$).

Finally, 10 out of the 12 articles had a moderate to high risk of bias, primarily due to high attrition rates (e.g., 40.2% in Lara et al. [12]), inadequate follow-up periods (i.e., ≤ 3 years) to detect changes in memory function [12,33–35,43,44], uncertainty about the comparability of exposed and unexposed groups, lack of clarity on whether participants were free of the outcome at baseline, unreliable or invalid exposure measurements, and missing details regarding study settings or participant demographics [78].

In summary, although published research increasingly supports the negative impact of SI and LON on memory, most studies have investigated these factors independently rather than in combination. Substantial variability also exists in SI measurement methods, with many studies relying on single-indicator measures rather than comprehensive, multi-modal approaches. Additionally, most studies were found to have moderate to high risk of bias, which raised questions about the validity of their results and complicated efforts to draw definitive conclusions about the relative impacts of SI alone, LON alone, and SI and LON together, on memory. Turning to memory, the reviewed studies used variable constructs to measure 'memory', although notable similarities existed in the assessment of specific subtypes of memory. For example, episodic memory was often measured through immediate and delayed recall tasks, and semantic memory was frequently assessed using word-association tests. Furthermore, many studies reported specific effect sizes for each memory subtype separately. Therefore, I drew my conclusions

about memory based on the reported effects for the specific memory subtype relevant to my study. In my research, memory was assessed through the RAVLT, focusing on episodic and working memory, specifically.

2.7 Individual impact of social isolation on memory

While examining SI and LON together is important, I also wanted to acknowledge the substantial surge of recent studies focusing on either SI or LON individually, and have highlighted some of the key findings below.

Mosen et al.'s [121] cross-sectional study involving 45,240 adults aged 54 years or over, examined whether a dose-response relationship existed between SI and memory, and found that severe SI was associated with the highest odds of memory loss (OR = 5.20 [95% CI = 4.75, 5.68]), followed by moderate SI (OR = 2.45 [95% CI = 2.32, 2.60]), compared to the non-isolated group.

In a cohort study by Meister and Zahodne [122], which followed 2,553 participants aged 65 years or over for 2 – 4 years, the researchers investigated how various aspects of social network structure (i.e., size, type, contact frequency) and quality (i.e., support, strain) related to performance across five cognitive domains: episodic memory, executive function, visuospatial ability, language, and processing speed. The study revealed that higher contact frequency with social network members was positively associated with better cognitive performance across executive function, visuospatial ability, language, and processing speed. However, it did not significantly impact episodic memory.

Meister and Zahodne's [122] finding contrasts with other studies reviewed in Cardona and Andres [109] and myself [78], but is supported by Fernández et al. [123]. Fernández et al. explored the effects of both social and intellectual activities on cognitive function in older adults and found that intellectual activities – such as reading, puzzles, and educational pursuits – were strongly associated with improved cognitive function across all domains, particularly memory. While social activities also had a positive impact on cognitive functions, their effects were less pronounced compared to intellectual activities. Social engagement appeared to primarily benefit cognitive domains related to social cognition and communication, such as language and executive function, rather than memory.

Adding to this nuanced understanding of social activities' effects on cognitive health, Han et al. [124] conducted a survey of 125 adults aged 60 or over to explore how different social participation patterns affect memory function. They identified three main patterns: entertainment-centered, work-centered, and family-centered, each impacting memory performance differently. Entertainment-centered activities had the most substantial positive effect on memory: those who regularly engaged in recreational activities showed better memory performance compared to those who were less active. These leisure

activities, which provide both mental and physical stimulation, support cognitive health by enhancing neuroplasticity, improving mood, and reducing stress. Work-centered participation's impact varied by location. In rural areas, continued paid work after retirement was linked to better memory outcomes, likely due to the routine and sense of purpose that work provides. Conversely, urban seniors who participated more in entertainment activities, rather than continuing to work, demonstrated better memory performance, possibly due to the broader range of cognitively stimulating social opportunities available in urban environments compared to rural settings. Family-centered participation, particularly among older adults involved in caregiving for grandchildren, did not show a positive impact on memory. In some cases, this type of participation was associated with declines in memory function, likely due to the stress and demands of caregiving, which may outweigh the cognitive benefits of social interaction.

2.8 Individual impact of loneliness on memory

Yu et al.'s [125] study involving 9,032 adults aged ≥ 50 years examined the long-term effects of LON (assessed biennially from 1996 to 2016) on memory, and found that a longer duration of LON was associated with lower memory scores and a faster rate of memory decline. Specifically, individuals who experienced LON for three or more study waves exhibited the most pronounced rate of memory decline ($\beta = -0.09$ [95% CI = $-0.12, -0.06$]), followed by those who experienced loneliness for two waves ($\beta = -0.05$ [95% CI = $-0.08, -0.02$]), and those who experienced it for only one wave ($\beta = -0.02$ [95% CI = $-0.05, 0.01$]). This association was more pronounced among women compared to men, and among adults aged 65 years or over compared to those under 65 years, highlighting the heightened vulnerability of these groups to the cognitive impacts of prolonged LON. The study underscores the necessity of addressing LON early, particularly from middle age, to prevent accelerated memory aging and associated neurocognitive disorders.

Supporting these findings, a larger longitudinal study by Cachón-Alonso et al. [126], involving 140,000 adults aged 50 or over from 28 European countries, corroborates the age-dependent relationship between LON and cognitive decline observed by Yu et al. [125]. Cachón-Alonso et al. [126], found that LON was particularly predictive of poorer performance in verbal fluency, numeracy, immediate recall, and delayed recall among individuals aged 65 or over, compared to their younger counterparts. The study also examined the influence of retirement status (a component of SI) on the relationship between LON and cognitive function, but found no consistent evidence that retirement status significantly modified this association, suggesting that the impact of LON on cognitive decline is relatively stable regardless of employment status in older adults.

Igarashi's [127] research, involving 4,095 participants from four datasets (Lancets – 2018; Lancets – 2023; Yahoo – 2023; Yahoo – 2024), provides additional insights into the relationship between

LON and socioemotional memory. The study reveals a negative memory bias among individuals with high LON, who tend to recall positive social episodes less effectively than those with lower LON. This bias is especially noticeable for positive or neutral episodes, while recall of negative episodes remains unaffected. This finding suggests that high LON individuals may struggle to remember positive social interactions, potentially perpetuating their sense of LON.

2.9 Conclusion

The existing literature demonstrates that SI, LON, and their combined effects each have an inverse association with memory. However, due to the limited number of studies that examine the combined influence of SI and LON, it is difficult to directly compare how their joint influence on memory differs from the individual impacts of SI or LON alone, making it difficult to determine which has a stronger effect. Additionally, substantial inconsistencies exist across studies, including variations in how SI is measured (with many studies omitting key indicators), the types of memory or cognitive constructs evaluated, sample sizes, and follow-up durations. These discrepancies contribute to variations in the strength and direction of reported associations. This is especially true for SI, as some studies suggest it has a greater impact on memory than LON, while others link SI more closely to language and executive function than to memory itself. Addressing these disparate findings is crucial for developing effective interventions to mitigate memory decline associated with SI and LON.

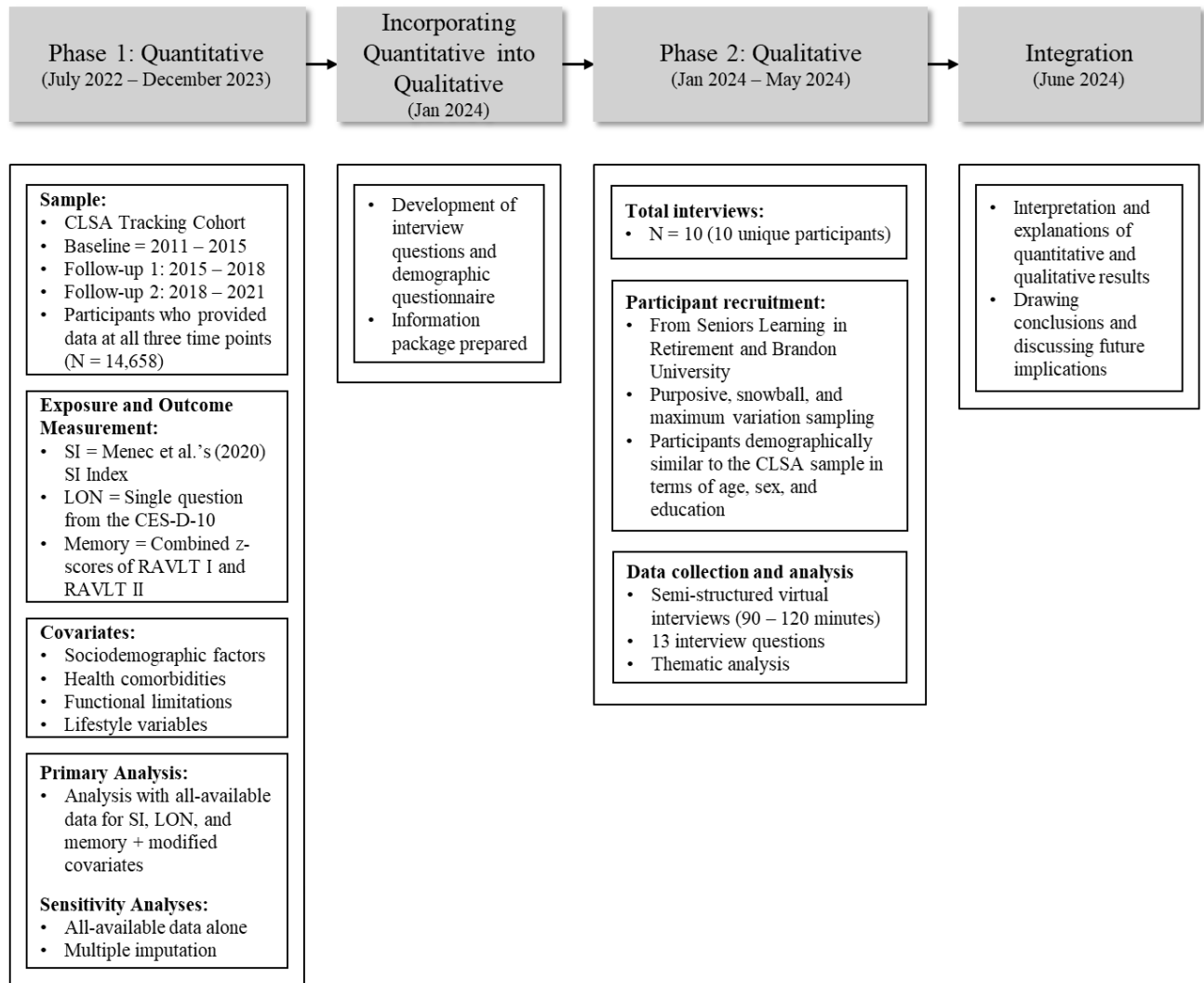
Chapter 3

Methods

This thesis utilized a mixed-methods, sequential explanatory design (see Fig. 2 for an overview of the research process). In the quantitative phase, data from the Canadian Longitudinal Study on Aging (CLSA) was analyzed to answer research questions A and B. For the qualitative phase, participants were sourced from the following community organizations: Seniors Learning in Retirement (SLR) in London, Ontario (<https://slrlondon.com/>), and Brandon University in Brandon, Manitoba (through a press release recruitment), to address research question C.

Figure 2.

Flow chart of the sequential explanatory mixed-methods research process



Notes.

Abbreviations: CLSA = Canadian Longitudinal Study on Aging; CES-D = Centre for Epidemiological Studies Depression Scale; LON = loneliness; RAVLT = Rey Auditory Verbal Learning Test; SI = social isolation

3.1 Philosophical paradigm: Pragmatism

This thesis was positioned within a pragmatic paradigm. Pragmatism promotes utilizing the most expedient research approaches and tools to address a study hypothesis and is not linked to a specific ontology (perspective on the nature of reality) or epistemology (relationship between the researcher and those being researched) [128,129]. Pragmatists focus on the research questions being studied and the results and implications of their research, rather than on the philosophical systems and methods preceding or surrounding the study itself [128,129]. To best address a set of research questions, pragmatists choose the data and methods (quantitative, qualitative, or both) they believe will produce the most valid and relevant results [128,130]. As a trainee researcher, I did not wish to depend solely on her own interpretation of the quantitative results without considering the individuals who formed the target population. Therefore, I made a pragmatic decision to employ a sequential, explanatory mixed-methods design to incorporate the viewpoints of middle-aged and older adults into her understanding and analysis of the quantitative findings.

3.2 Phase 1 (Quantitative phase)

3.2.1 Study setting/design

The CLSA is a nationwide, population-based panel study in Canada that enrolled 51,338 adults aged 45 to 85 years at baseline [131]. Participants are being followed for a minimum of 20 years, with assessments occurring every three years. The study aims to gain insights into the health and wellness of the aging population from a lifespan perspective, gathering extensive data on psychosocial, physical, cognitive/mental health, sociodemographic, clinical, functional, and lifestyle variables [132]. The primary goals of the CLSA are to identify risk and protective factors for healthy aging and provide data to guide policy and practice.

The CLSA includes two cohorts. The first cohort, known as the Comprehensive Cohort, consists of 30,097 participants recruited at baseline from areas within 25 to 50 kilometers of one of 11 data collection sites (DCS) located across seven provinces. These participants are interviewed both in their homes and at their local DCS. The second cohort, called the Tracking Cohort, includes 21,241 participants recruited at baseline from all ten provinces, who provide data through telephone interviews [131]. To date, the CLSA has released baseline (BA), first follow-up (FUP1), and second follow-up (FUP2) data to researchers. BA data were collected from 2011 to 2015, FUP1 data from 2015 to 2018, and FUP2 data from 2018 to 2021.

The thesis only utilized the Tracking Cohort data due to interruptions in data collection for 38.2% of the Comprehensive Cohort during FUP2. These interruptions were caused by physical distancing measures implemented in response to SARS-CoV-2 and COVID-19. Although the CLSA transitioned to telephone interviews as an alternative method of administering the memory tests for Comprehensive participants during the pandemic, evidence indicates that the mode of memory test administration could influence responses and score [133–135]. This raised concerns about the comparability of memory test scores across follow-up periods for the Comprehensive Cohort participants, as well as the validity of comparing results from the Tracking and Comprehensive cohorts. To mitigate this issue, the thesis exclusively used quantitative data from the Tracking Cohort, where telephone interviews continued during the pandemic.

3.2.2 Participant sampling and eligibility criteria

In 2009, the CLSA initiated recruitment for the Tracking Cohort by selecting participants from among those who had taken part in the Canadian Community Health Survey (CCHS) 4.1 on Healthy Aging [136]. Statistics Canada sought permission from CCHS participants to share their contact information with the CLSA, which then attempted to enroll individuals who agreed to share their contact information [137]. The CLSA adopted the CCHS eligibility criteria for all subsequent recruitment phases. Eligible participants had to fall between the ages of 45 and 85 years and had to be proficient in either English or French. Exclusions applied to individuals living in long-term care institutions (excluding independent living retirement homes and transitional living institutions), on First Nations reserves/settlements, or in the three territories; full-time members of the Canadian military or non-permanent residents (e.g., visa holders, those with transitional health care coverage); or those identified by CLSA staff as showing signs of cognitive impairment during the recruitment interview (e.g., inability to provide their name, age, or address; appearing confused or non-responsive when informed about the study) [132].

To supplement recruitment from the CCHS, the CLSA enrolled additional participants through provincial healthcare registration databases and random digit dialing [137]. In eight provinces, provincial health ministries randomly selected eligible individuals from the healthcare registration databases and distributed information packages about the CLSA via mail. Recipients were encouraged to directly contact the CLSA for more information about participating in the study. For random digit dialing, a national polling firm randomly selected and dialed landline telephone numbers nationwide. They screened whether the individuals who answered the phone met the CLSA's eligibility criteria and passed the contact information of interested individuals to CLSA staff. The staff then called these persons, explained the study in detail, and enrolled willing individuals [138]. Approximately 9% of those approached through healthcare

databases and random digit dialing agreed to join the Tracking Cohort, with similar enrollment rates observed across all provinces [137].

To ensure adequate participant recruitment across various population segments and facilitate subgroup analyses, the CLSA established 136 sampling strata. These strata were based on age categories (45-54, 55-64, 65-74, and 75-85 years), biological sex (male or female), province of residence, educational level (low versus higher education), and proximity to DCS (residing within 25 to 50 kilometers of a DCS or beyond this radius). Including 'proximity from DCS' strata in the Tracking Cohort was necessary to avoid recruiting the same individual into both the Tracking and Comprehensive Cohorts.

After participants were enrolled in the Tracking Cohort, trained CLSA interviewers utilized computer-assisted telephone interviews (CATI) [137] to gather questionnaire-based data for the quantitative study measures. The CLSA questionnaires are available here: <https://www.clsa-elcv.ca/data-collection>.

3.2.3 Study measures

3.2.3.1 Exposure (Combined social isolation and loneliness groups)

To measure social isolation, I employed Menec et al.'s [17] algorithm, which integrates several CLSA questions into a 5-point scale: (1) marital/cohabiting status; (2) retirement status; (3) living arrangement; (4) frequency of social activity participation over the past 12 months; and (5) contact with social network members within the past six months. These items are widely recognized in the literature as key indicators of social isolation [78] and are based on an earlier index designed for the English Longitudinal Study of Ageing [39].

Menec et al. [17] dichotomized several CLSA questions for inclusion in the index: marital status was single/widowed/divorced/separated versus married/common-law partner status; retirement status was retired versus not retired/partly retired; and living arrangement was living alone versus living with ≥ 1 cohabitant. For social activity participation, the CLSA questionnaire encompassed eight categories of activities: religious activities, sports/physical activities, educational or cultural activities (going to courses, concerts, museums, etc.), clubs or fraternal organization activities (Kiwans Club, Foresters, Royal Canadian Legion, etc.), community/professional association activities, volunteer or charity work, other recreational activities (hobbies, gardening, Bridge card games, etc.), and activities with family/friends outside of the household. For social network contacts, the CLSA questionnaire included five groups of social networks: friends, neighbours, relatives, siblings, and children.

Following Menec et al. [17], I developed a 5-point SI scale by assigning one point for each of the following criteria: (1) living alone and being single/widowed/divorced/separated; (2) being completely retired and reporting participation in one or fewer social activities per month; (3) having no visits or reporting visits with friends and neighbours less than monthly; (4) having no visits or reporting visits with children less than monthly; and (5) having no visits or reporting visits with family (relatives, siblings) less than monthly. Higher scores on the resulting 0 to 5 scale indicated a higher level of social isolation. Menec et al.'s 5-point scale expands upon the Berkman-Syme Social Network Index [41] and Steptoe Social Isolation Index [39] by including living arrangements and retirement status, which are recognized factors consistently associated with social isolation [18,31,38,42].

Scores were then dichotomized for analysis following Menec et al.'s [17] guidance: 0-1 indicated non-isolated status, while 2-5 indicated socially isolated status. This ≥ 2 cutoff was similarly applied in Steptoe et al.'s [39] Social Isolation Index. By setting this threshold, individuals meeting at least half the criteria were flagged as isolated, allowing for the inclusion of a broader spectrum of isolation experiences beyond just the most severe cases [38,42]. The dichotomization also ensured that each sub-level of social isolation had a sufficient number of participants for statistical power. In the original 5-point scale, 60.9% of the participants at BA were coded as 0 (not socially isolated), 29.7% as 1 (mildly isolated), 9% as 2 – 3 (moderately isolated), and < 1% as 4 – 5 (severely isolated). In addition, this dichotomization offered a structured method to combine the social isolation and loneliness variables into a four-level main exposure variable: only socially isolated, only lonely, both, and neither.

Regarding loneliness, the CLSA did not include a standalone measure of loneliness at BA. Therefore, I used the question from the 10-item Centre for Epidemiological Studies Depression Scale (CES-D-10) that inquired, "In the last week, how often did you feel lonely?" This question employed a 4-point Likert scale, where lower scores indicated higher levels of loneliness (1 = lonely all of the time [5 - 7 days]; 2 = occasionally lonely [3 - 4 days]; 3 = lonely some of the time [1 - 2 days]; 4 = rarely or never lonely [less than 1 day]). Responses scoring 1 - 2 were classified as experiencing LON, while scores of 3 - 4 were classified as not experiencing LON, consistent with prior research that used this CES-D-10 question to investigate the combined impact of loneliness and social isolation [17,18].

Finally, to establish the four exposure groups for SI/LON, I combined the separately dichotomized measures of SI (forward coded) and LON (reverse coded) in the following manner:

- Only socially isolated = SI scores 2 - 5 and LON scores 3 – 4;
- Only lonely = SI scores 0 - 1 and LON scores 1 - 2;
- Both isolated and lonely = SI scores 2 - 5 and LON scores 1 - 2; and

- Neither isolated nor lonely = SI scores 0 - 1 and LON scores 3 - 4.

Participants with incomplete data on either or both components of SI and LON were classified as having missing SI/LON data.

3.2.3.2 Outcome (Memory)

The CLSA measured the memory domain of cognition using a modified version of the Rey Auditory Verbal Learning Test (RAVLT). The CLSA chose this test because it is reliable (the range of test-retest correlation coefficients is between 0.51 and 0.86), it is a sensitive marker of pre-Alzheimer's disease memory impairment, and it can be administered in either English or French [6,88,90]. The CLSA modified the original RAVLT to keep within the time constraints of the Tracking interview. Compared to the original, the modified version excluded an interference test and decreased the number of recall administrations from five to two. Therefore, the modified RAVLT provides measures of episodic and working memory [139].

The CLSA protocol for administering the modified RAVLT produced two distinct memory assessments: (1) immediate recall memory, where participants heard a list of 15 words and recalled as many as possible within 90 seconds (RAVLT I); and (2) delayed recall memory, which involved participants recalling as many of the original 15 words as possible within 60 seconds, after a 5-minute interval from the initial administration without hearing the list again (RAVLT II) [140].

The CATI software recorded responses for both RAVLT sessions; two trained CLSA personnel independently reviewed the recordings and scored the responses. Any scoring discrepancies were resolved by a supervisor. Each staff member calculated separate raw scores for RAVLT I and RAVLT II by adding up the correctly recalled words from each session. One point was awarded for each correctly recalled word or similar-sounding variant (e.g., "collar" for "colour"). If a variant word was recalled in RAVLT I, participants needed to recall the same variant word in RAVLT II to receive a point for the delayed recall score [141]. Raw scores for both RAVLT I and II ranged from 0 to 15. Missing scores were assigned if participants declined to be recorded or technical issues rendered a recording unusable.

To standardize the raw test scores into z-scores ($\mu = 0$, $\sigma = 1$), I identified a subset of the Tracking Cohort who were considered cognitively healthy at each of the three timepoints, separately. This subset excluded individuals with self-reported memory problems, dementia or Alzheimer's disease, epilepsy, multiple sclerosis, Parkinson's disease, stroke or cerebrovascular accidents, or transient ischemic attack. Within this subset, participants were divided into French and English language groups. The sample sizes for the cognitively healthy subset were 12,233 at BA, 12,760 at FUP1, and 10,768 at FUP2. Mean and standard deviation values for the raw scores of RAVLT I and II were then calculated for each language subgroup in the cognitively healthy cohort (at BA, FUP1, and FUP2 independently), excluding participants

who switched languages during testing. These computed values were subsequently utilized in Equation 1 to calculate separate z-scores for all participants within each language subgroup [77]:

$$z = \frac{x - \mu}{\sigma} \quad (1)$$

where x = participant's raw score, μ = mean raw score in the healthy subsample, and σ = standard deviation of the mean raw score in the healthy subsample. After computing the z-scores, the language subgroups were merged into a unified sample for further analyses. Finally, the z-scores for RAVLT I and II were summed to generate a composite memory score for each participant at every timepoint. This composite score was utilized as the outcome variable in all regression analyses. Participants with missing data on one or both components of RAVLT I and II were categorized as having missing memory data.

3.2.3.3 Covariates

Based on Kang and Oremus's (2023) recent systematic review, which identified 12 published articles investigating the links between SI/LON and memory [12,26,33–37,43–45,54,120], alongside additional source material [18,111,119,142], the present study included the following four groups of covariates:

1. Sociodemographic attributes: age (45-54; 55-64; 65-74; 75-84 years), sex (male/female), education (less than post-secondary/post-secondary), province, area of residence (urban/rural), and annual household income (< \$20,000; \$20,000 to < \$50,000; \$50,000 to < \$100,000; \geq \$100,000);
2. Lifestyle variables: smoking status (no smoking for the past 30 days; \geq 1 cigarette in the past 30 days; \geq 1 cigarette every day for past 30 days), substance/alcohol use (never; \leq 1 time per month [multiple drinks allowed per occasion]; 1 - 3 times per month; \geq 1 time(s) a week);
3. Functional ability: assessed on a 4-point scale (1 = no functional impairment; 2 = mild; 3 = moderate; 4 = severe or total impairment);
4. Chronic health conditions: measured based on self-reported diagnoses across 10 broad health conditions listed below (excluding depressive symptoms) and dichotomized into those without any chronic conditions and those with one or more chronic conditions [143]; and
5. Depressive symptoms: measured as no/mild symptoms (scores 0 to <10) and moderate/severe symptoms (scores \geq 10) using the nine-item Centre for Epidemiological Depression Scale (CES-D), which excluded the loneliness question from the 10-item version [144].

Functional ability was a derived variable based on the level of assistance required in 14 basic and instrumental activities of daily living such as eating, dressing, showering, grooming, walking, getting

in/out of bed, getting to bathroom in time, using the telephone, using public transportation, shopping, doing house chores, taking medications, managing finances, and preparing meals [145].

The 10 broad health conditions were osteoarthritis, arthritis/rheumatoid arthritis, cancer, respiratory disease (asthma, chronic obstructive pulmonary disease, emphysema, bronchitis), cardiac/cardiovascular disease (high blood pressure, diabetes/borderline diabetes, congestive heart failure, angina, heart attack, myocardial infarction, peripheral vascular disease, stroke, mini-stroke, cerebrovascular accident, transient ischemic attack), neurological (memory problem, dementia, Alzheimer's disease, multiple sclerosis, Parkinson's disease, migraine headaches, epilepsy), gastrointestinal disease (stomach/intestinal ulcer, Crohn's disease, ulcerative colitis, irritable bowel syndrome, bowel incontinence, urinary incontinence), visual impairment (cataract, glaucoma, macular degeneration), mental health (anxiety disorder, panic disorder, phobia, obsessive-compulsive disorder, mood disorder, bipolar disorder, mania, dysthymia), and other conditions (allergy, osteoporosis, back problems, kidney disease, hypothyroidism, myxedema, hyperthyroidism, Grave's disease).

3.2.4 Data analysis

Our analysis utilized data from 14,658 participants who contributed information at all three time periods. Statistical analyses were performed using R v4.3.2 (The R Project for Statistical Computing, Vienna, Austria), with a significance threshold of $\alpha = 0.05$. The CLSA sample weights were excluded from this thesis because they have not yet been calculated for FUP2 and the regression analyses required data from all three time points. Additionally, the sample weights at BA and FUP1 were calculated for complete datasets and thus could not be used to compute accurate estimates of regression coefficients at the population level in the face of missing data. Computing 'missing data' weights is beyond the scope of this thesis.

3.2.4.1 Primary analytical sample (Modified AADA: AADA + MCA)

For the primary analysis, I utilized a modified 'all available data' approach (AADA) with the 14,658 participants included in all three study timepoints. AADA uses information from partially observed cases, such as those with data available at BA, yet missing at FUP1 and/or FUP2 (or vice versa). Therefore, the AADA approach can maximize sample size and improve statistical power, making it particularly beneficial for longitudinal studies with data attrition at one or more follow-up periods. In this modified version of the AADA, I only took the 'all available data' on SI/LON and combined memory, but not the covariates (which were later modified, as explained below), meaning individuals with complete data for at least one time period on both SI/LON and combined memory were included in the analysis. Importantly,

the missingness in my data was assumed to be missing at random (MAR), a condition under which the AADA approach is particularly appropriate and valid.

Given the comprehensive list of covariates described in Section 3.2.3.3 above, 4,611 participants had missing data on one or more of these covariates, although the missing proportion for most individual covariates was < 5%. Instead of limiting the analysis to participants with complete covariate data, I employed a ‘modified covariate approach’ (MCA) and added an extra response category labeled ‘missing’ to each covariate to retain participants with missing covariate data in the analysis. For example, the ‘annual household income’ covariate, originally with four categories, was adjusted to a five-level variable, with the additional category (‘missing’) assigned to participants who had missing income data. Finally, I integrated the AADA and MCA approaches to create the analytical sample for the primary analysis (AADA + MCA).

3.2.4.2 Descriptive analyses

Descriptive univariate analyses were performed on the primary analytical sample (‘AADA + MCA’ sample; $n = 14,208$) to compare the distribution of the memory outcomes and covariates across the four SI/LON groups. I also analyzed the mean memory scores across different levels of each covariate. For these descriptive analyses, memory responses were classified into three categories: ‘average memory’ (scores within < 1.5 standard deviations above or below the mean for combined memory), ‘high memory’ (combined z -scores ≥ 1.5 standard deviations above the mean), and ‘low memory’ (combined z -scores ≥ 1.5 standard deviations below the mean). The means and standard deviations were obtained from the healthy participant subset (at BA, FUP1, and FUP2), and all univariate analyses were performed using the Pearson chi-square test.

3.2.4.3 Regression analyses

Multivariable, mixed effects regression analyses were performed using R’s ‘lme’ function in the ‘nlme’ package [146], employing random intercept and time slopes in the regression models, along with an autoregressive, within-participant correlation structure (AR1). The AR1 structure is used when additional within-participant serial correlations are not covered by the inclusion of random effects, such as in this thesis.

I also examined various other within-subject error structures, including conditional independence (the default correlation matrix for most mixed effects model procedures/functions), compound symmetry, exchangeable, unstructured, and AR1 correlation matrices. However, these alternatives proved to be less appropriate: compound symmetry and exchangeable structures assume uniform variances/correlations across all time points; conditional independence assumes zero correlations within groups after accounting

for the model's random effects; and unstructured permits each observation to have its own correlation, providing excessive flexibility without imposing any constraints on the covariance structure.

During model selection, I evaluated several models and explored various specifications for random effects, such as testing for a random intercept only, a random time slope only, and both random intercept and slope together. Then, I selected the best-fitting model based on the lowest Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values.

The base model for this thesis regressed the combined memory scores onto SI/LON, sex, age, educational level, province, follow-up time, and SI/LON*time interaction. The covariates included in this base model were necessary to account for the complex survey design of the CLSA [147,148]. To account for potential confounding, I added four groups of covariates to the base model, in separate chunks, leading to five adjusted models [77]:

- Model 0 (base model) = SI/LON groups and sex, age, education, province, timepoint, and SI/LON*time interaction;
- Model 1 = Model 0 + other sociodemographic factors;
- Model 2 = Model 0 + functional impairment variables;
- Model 3 = Model 0 + lifestyle variables;
- Model 4 = Model 0 + health comorbidities; and
- Model 5 (full model) = Model 0 + all previously mentioned covariate chunks.

For all models, I used the least-squares means (LSMEANS) option within the 'lme' function. LSMEANS are used to compute the fixed effects means of the dependent variable (i.e., combined memory scores) for each level of the independent variable (i.e., SI/LON), while adjusting for covariates and interactions (i.e., sex, age, education, province, follow-up time, and the SI/LON*time interaction) [149]. LSMEANS computations also show the mean differences across levels, reflecting the average estimated change in combined memory score between any two levels of the SI/LON variable [17,149]. To reduce the family-wise error rate (i.e., the probability of discovering at least one false positive across multiple comparisons/tests), I implemented the Benjamini-Hochberg (BH) correction [150]. A detailed description of the BH method's application is provided in Table 4 of Chapter 4: Quantitative Results.

To evaluate model fit, I used influence models, which measure the impact of each observation on the parameter estimates, by generating diagnostic plots for restricted likelihood distance, Cook's distance, and variance-covariance parameters. Additionally, I assessed multicollinearity by calculating variance inflation factors.

3.2.4.4 Missing data

To evaluate the effect of missing data, two sensitivity analyses were performed: AADA only and multiple imputation. I applied the same regression analysis methods from Section 3.2.5.3 above to both sensitivity analyses.

Sample for Sensitivity Analysis 1 (AADA only): I removed participants with missing covariate data from the 'AADA + MCA' subgroup described in Section 3.2.5.1 above and subsequently performed a sensitivity analysis with just the AADA sample. As such, only participants who had at least one wave of complete data for all primary exposure (SI/LON), outcome (combined memory), and confounding variables were included in this sensitivity analysis.

Sample for Sensitivity Analysis 2 (multiple imputation): Secondary sensitivity analysis was conducted by applying multiple imputation via R's 'mice' package [151] to the main exposure and outcome variables, as well as all covariates, across the three time periods. Variables with < 2% change between periods (such as sex, education, province, and income) were considered time-invariant and imputed using the classification and regression trees (CART) imputation method within the fully conditional specification (FCS) framework. For the remaining variables, I used FCS with multilevel, linear mixed effects models (LMM), where each time-varying variable was imputed as an outcome variable within an LMM, with its distribution conditioned on all other variables in the dataset [152]. Each LMM accounted for between-subject heterogeneity by including a variance-covariance matrix between observations and subject-level random effects. This method has demonstrated superior predictive performance compared to other linear mixed effects-based imputation techniques and does not require independent observation assumptions [153].

I conducted 20 imputation cycles (each producing one dataset) at the item level, and scores consisting of multiple items were later derived through passive imputation. Item-level imputation replaced missing values for each individual item/variable with estimated values. Passive imputation then combined these imputed item-level values into a single summary score for multi-item variables, without performing any additional imputation. After completing the 20 imputation cycles, I performed separate regression analyses on each of the 20 imputed datasets and combined the results into a single set of regression coefficients using Rubin's rules [154].

3.2.4.5 Clinical significance

To evaluate the clinical significance of the quantitative findings, I converted the LSMEANS estimates from the fully adjusted model (Model 5) to Cohen's *d* using the formulas from Higgins et al. [155] and Nakagawa and Cuthill [156]. I then categorized the effect sizes as clinically non-significant (<

0.1) or significant (≥ 0.1) based on the average effect size value (Cohen's $d = 0.1$) reported in previous related systematic reviews on SI/LON, social support, memory, mild cognitive impairment, and global cognition [78,142,157,158].

3.2.5 Research ethics

The quantitative phase of this study received ethics approval from the University of Waterloo in February 2022 (ORE #43985). The CLSA also approved access to the data on January 7th, 2023 (application #: 2209001). The CLSA received ethics approval from the 11 institutions hosting DSC and operates in compliance with the Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans (TCPS2) [132]. Before data collection, all CLSA participants provided written, informed consent. To protect participants' confidentiality, the CLSA provided me with de-identified data, which I stored in password-protected folders on a secure server at the University of Waterloo. Only the pre-approved research team (student investigator and thesis committee) had access to this folder. The approved ethics application can be found in Appendix II.

3.3 Phase 2 (Qualitative phase)

The purpose of Phase 2 was to use qualitative methods to gain deeper insight into the associations between SI/LON and memory by asking persons who mirrored the CLSA sample to provide their opinions about the quantitative results. This procedure allowed me to explore distinctions between SI and LON, such as identifying practical examples of situations where participants might experience SI without feelings of LON, or vice versa, and to examine the factors contributing to these states of being. I aimed to enhance the interpretation of the quantitative findings by incorporating these perspectives of middle-aged and older adults, rather than relying solely on her own interpretive lens as a researcher (in mid-20s and not experiencing SI, LON, or memory issues) [80,159]. Additionally, the qualitative phase provided a platform for participants to discuss health and social resources that facilitated or hindered social integration, explore adaptation strategies to manage the memory effects associated with SI and LON, and address the policy implications of the research findings.

3.3.1 Methodology: Thematic analysis based on descriptive phenomenology

For my methodology, I utilized a combination of descriptive phenomenology and reflexive thematic analysis. Phenomenology emerged in the early 20th century and it has roots in both philosophy and psychology [160,161]. It was developed by philosophers who sought to describe and interpret the structures of human experience (e.g., things that happen to people based on geographical, occupational, or cultural contexts) and human consciousness (e.g., how people perceive the world, the meanings they attach to different experiences, their emotions, thoughts, and intentions) [160,161].

Phenomenology is a popular choice of methodology in explanatory sequential mixed methods research [161] because it aims to identify the shared characteristics of a phenomenon such as the relation between SI/LON and memory. This aim requires the researcher to possess some degree of initial knowledge and understanding of the phenomenon before qualitative data collection can begin. A preliminary quantitative study can provide this knowledge and understanding [161]. For instance, in applying phenomenology to this study, I asked participants to explain why they believed SI and LON might have different effects on memory, as well as how their individual impacts might differ from their combined effects. In doing so, participants were encouraged to recount their personal experiences of facing SI and/or LON in Canada, considering their specific age and sex groups, as well as other contextual factors. For those who had not experienced much SI and/or LON, I asked for their opinions on the subject, which could be based on personal beliefs and related experiences (e.g., moving to a new place, bereavement, observations of others). During the analysis of the interviews, I identified the common features in participants' experiences/perceptions regarding the quantitative results.

However, a full phenomenological analysis can be time-consuming and complex; therefore, some researchers have turned to thematic analysis as a more efficient, pragmatic alternative due to its flexible structure [162,163]. Thematic analysis still allows for the examination of a wide range of data while enabling researchers to incorporate key phenomenological techniques, such as bracketing and identifying meaning units [162,163]. Combining both methodologies enables researchers to capture participants' lived experiences, organize themes across diverse perspectives, and apply an adaptable, interpretive lens [162,163].

3.3.2 Participant recruitment and eligibility criteria

To participate in the qualitative phase, research participants had to be aged between 45 and 85 years, be able to communicate in English, and not have any overt signs of cognitive (e.g., Alzheimer's disease, other dementia) or sensory (e.g., visual, hearing) impairments that would prevent them from engaging fully in the research process. Additionally, I aimed to enroll participants who were demographically similar to the CLSA participants in terms of age, sex, and education. The age distribution in the CLSA was approximately: 20% aged 45–54, 30% aged 55–64, 30% aged 65–74, and 20% aged 75–85. The sample had an equal distribution of males and females, with 30% of participants having less than post-secondary education and 70% having completed post-secondary education. Using purposive and snowball sampling methods, I recruited ten individuals who met these eligibility criteria. In addition, I sought to achieve maximum variability in other demographic characteristics such as annual household income, marital status, living arrangement, retirement status, and exposure to SI/LON. By employing maximum variation sampling, I aimed to capture a diverse range of experiences and perspectives related to

SI, LON, and memory, providing a rich description of how these factors interact across different population groups.

Recruitment took place from February 1st, 2024, to March 13th, 2024, under the auspices of the following community-based sources: Seniors Learning in Retirement (SLR) in London, Ontario, and Brandon University in Brandon, Manitoba. According to Creswell and Creswell [128], sample sizes for phenomenological studies typically range from 5 to 25 participants, depending on items such as the research purpose and type of data collected (e.g., interviews, journals, poetry). Earlier memory-related phenomenological studies using semi-structured interviews have reached data saturation with ten or fewer participants [163–165]. Data saturation refers to the point at which no new information or themes are emerging from the data being collected, signifying that the researcher has gathered sufficient data to thoroughly understand the phenomenon being studied and that further interviews are unlikely to provide additional insights [128]. I began to reach data saturation around the seventh participant, as no new themes were emerging from the data after the fifth interview. However, to ensure I had likely captured sufficient depth and breadth of data, I recruited additional participants, ultimately including a total of 10 participants in my qualitative study.

Before the recruitment of participants, the qualitative phase of this study was approved by the University of Waterloo's Research Ethics Board (ORE# 45670). The approved ethics application is included in Appendix III. Both SLR and Brandon University confirmed they did not require additional ethics review to partner with me and facilitate recruitment.

For recruitment at SLR, I created an advertisement about the study in poster format (Appendix IV) and asked a staff member in SLR's research department to distribute this poster via email to all their registered members on my behalf. I decided to form a partnership with SLR because it provided learning-focused programs to retired and semi-retired individuals. These persons might be isolated or lonely and therefore interested in cognitive activities, making them potentially informative about the subject matter of the thesis. For recruitment at Brandon University, I created an email newsletter about recruitment (Appendix V) and sent it to the university's media team for a potential press release. Dr. Nancy Newall from Brandon University's Department of Psychology – one of Canada's leading loneliness researchers – leveraged access to the media team on my behalf through her established relationship from a previous COVID research project [22] where she successfully used a press release recruitment approach. Outside of facilitating recruitment, SLR and Brandon University had no further involvement in the study and were not informed about participants' levels of involvement. Refer to Appendix IV and V for the detailed content of the recruitment information.

The recruitment advertisements instructed potential participants to contact me directly using the provided contact information if they wished to learn more about the study. When contacted, I followed either a telephone or email script (depending on how each participant reached out) to screen and confirm the eligibility of the interested participants (refer to Appendix VI for the Email Script and Appendix VII for the Telephone Script). To the eligible participants, I provided a detailed explanation of the study and scheduled an interview if the person agreed to participate.

Snowball sampling took place after I conducted interviews with all participants recruited through purposive sampling (SLR or Brandon University). At the end of each interview with a participant recruited from SLR or Brandon University, I asked the interviewee to share her contact details with their connections and encourage these persons to reach out to her directly. I also told participants they could forward the names and contact information of their connections to her after obtaining permission. I then contacted each person on the referral list obtained through snowball sampling to screen their eligibility, explain the study, and arrange interviews with interested individuals. A snowball sampling approach is particularly useful when the target population is difficult to reach due to factors such as non-participation in community organizations or a lack of trust in research studies, which can include those who are socially isolated, lonely, or both.

3.3.3 Informed consent procedures

To the eligible and interested individuals, I emailed an information package outlining the research objectives, benefits, and risks, along with a written consent form (Appendix VIII), and asked them to sign and return the consent form electronically before their scheduled interview. Alternatively, participants had the option to provide verbal consent at the beginning of the interview, which was audio recorded and documented using an oral consent log. At the start of each interview, I reviewed the information package and consent form with the participant and answered any questions.

3.3.4 Data collection

I conducted an open-ended, one-on-one, semi-structured interview with each participant. This approach was chosen because it is ideal for allowing flexible, yet focused, conversations that enable in-depth participant-researcher engagement and the gathering of rich, detailed information about the phenomenon under study [128,160]. All interviews were conducted virtually via Zoom video conference or telephone calls for participants' convenience and to approximate the 'remote' nature of data collection in the CLSA's Tracking Cohort. Eight out of ten participants completed their interviews through Zoom, and two participants were interviewed through telephone calls. The interview time ranged from 90 to 120 minutes, and all sessions were audio-recorded. To transcribe the interviews, I used the live transcription

feature of Zoom and corrected any inaccuracies in the auto-generated transcripts immediately after each session. I also anonymized the transcripts by replacing participants' names and other identifiable information (e.g., names of people, places, etc.) with pseudonyms, and removed filler words (e.g., "like," "so," "uh," "umm") and grammatical errors.

Audio recording and live transcription only started after obtaining informed consent from the participant. Throughout the interviews, transcription, and data analysis processes, I kept a reflexive journal, noting her immediate thoughts, observations, and opinions about participant responses. The journal documented my preconceptions and reasoning behind the interpretation of certain words, phrases, and emotions, as well as her selection of specific codes and themes from the data set [80,159,166,167].

During the interview, I asked participants a pre-set list of 13 broad, open-ended questions (informed by my quantitative results) designed to explore their experiences and perceptions of SI and/or LON, as well as their thoughts on how these factors may affect memory (Appendix IX) [80,159,166,167]. Following Wengraf's [168] Biographic-Narrative-Interpretive (BNI) interviewing approach, I refrained from guiding or interrupting participants in the middle of responses unless they veered off topic. The intent was to allow participants to freely discuss the questions. While listening to responses, I paid close attention to specific keywords, emotions, and vocal tones used by participants. After each response, I initiated some follow-up probes to encourage elaboration on certain points. Examples of such probes included:

Original Questions	Probes
How do you personally define social isolation and loneliness? Can you describe a specific time when you felt isolated or lonely, or both? Can you please walk me through that experience, including the circumstances, emotions, and thoughts associated with it?	What makes you feel lonelier and how do these factors affect your thoughts, emotions, behaviours, and overall well-being?
How have your social connections changed over time? Can you share any experiences that led to a decrease or increase in how many people you meet or how frequently you interact with your social network?	Have you experienced any significant changes in your marital/cohabiting status, retirement status, or living arrangements (alone versus with others) over time? How have you experienced or felt the impact of these changes in your life, if there were any?

At the end of the interview, I asked each participant 11 demographic questions (Appendix X) to record sample characteristics.

3.3.5 Data analysis

The analysis of qualitative data (including interview transcripts and reflexive journal notes) followed a six-step process that commenced after transcribing the first interview [163]. I conducted a thematic analysis based on descriptive phenomenology, using an iterative approach where steps were

implemented after each interview and again upon the completion of all interviews. The initial step involved ‘bracketing’ my everyday knowledge – suspending presuppositions, biases, assumptions based on any theoretical, cultural, and/or experiential factors – to approach the data with an open mind [163]. For instance, I bracketed the assumptions formed from my quantitative findings to focus on participants’ personal experiences without imposing pre-existing categories. I also critically examined how my educational background in gerontology and laboratory medicine, which often emphasized the negative effects of social deficits on cognition, shaped my views. Additionally, I reflected on my professional experiences in clinical, mental health, and rehabilitation settings, where I observed social withdrawal among older adults, often accompanied by memory decline and poorer overall health. By bracketing these out, I allowed the participants’ descriptions to guide the analysis and reminded myself to remain open to alternative interpretations, such as the possibility that some individuals maintain cognitive resilience despite limited social contact, or that the relative impacts of SI and LON on memory may vary depending on individual circumstances.

The second step involved horizontalization, which focused on identifying exemplary interview quotes that best illustrated each participant’s experiences/perceptions [128]. To engage in horizontalization, I reviewed the transcripts through paragraph-to-paragraph and line-by-line readings of the entire text [169]. The third step was the development of meaning units, which are distinct segments of text that convey a specific idea or piece of information [163]. During this process, I identified sections of the narrative where the meaning shifted or changed. Each meaning unit captured a unique thought, experience, or concept, making it easier to analyze and understand the core messages in the data. These units were separated with a slash (/) and assigned a numerical identifier to help organize and track them throughout the analysis [163].

The fourth step involved the coding process, which used the NVivo (v. 13) software to label significant quotes and keywords with descriptors that highlighted: (1) experiences and risk factors relating to SI, LON, and memory changes; (2) specific memory decline observed in the combined isolated and lonely group, the only lonely group, and the only isolated group; and (3) strategies for addressing challenges associated with SI, LON, and memory decline [169]. In the fifth step, I compared the interview codes generated within and across all participant transcripts, side-by-side, and merged similar codes into new themes [162]. Then, I sent a summary document listing all themes (along with all relevant quotes for each theme) to Dr. Oremus and Dr. Oga-Omenka, to consolidate a final list of overarching themes across all participant data.

In the sixth step, these overarching themes were re-integrated with the interview quotes to generate detailed descriptions of each theme and the individual experiences that elucidated the themes. The descriptions obtained from this step outlined: specific life events that led to SI and LON (and how they

unfolded over time); the physical and emotional aspects of the experience (e.g., bodily sensations and emotions accompanying SI/LON and their effects on participants' daily lives); social, cultural, and environmental factors that shaped the phenomenon (e.g., the impact of living in a rural area or having a disability on SI/LON); and the personal significance of the experience (e.g., the sense of identity, purpose, and meaning that participants attached to their experiences) [128]. Finally, these thematic descriptions were compared with my quantitative findings, as well as with existing research and theoretical frameworks on SI, LON, and memory to synthesize a comprehensive overview of all essential and commonly shared features pertaining to their associations [128].

3.3.6 Data management

To protect participants' identities, only an identification number was used to identify audio/video recordings, notes, transcripts, and interviews. Participants were assigned a numerical code (i.e. P1, P2, P3, etc.) instead of their name. Other identifiable information, such as names of people in participants' social networks and any geographic locations mentioned in the interviews were replaced with pseudonymous words/representative descriptors (e.g., [friend group name], [mother-in-law], [city name], [mental health association], [theatre]) in the written transcripts. A master list, linking participants' ID number to their actual names, along with all other electronic files (e.g., recordings, transcripts, consent forms, reflexive notes) were stored in a password-protected folder on a secure UW server, created by the Faculty of Health Computing Unit. These files were only accessible by the pre-approved research team (myself and my supervisor). All qualitative data will be deleted five years after the end date of the project.

3.3.7 Ethical considerations

While no known risks are associated with participation in this research, I recognized that discussing cognitive health and the negative aspects of SI or LON might lead to emotional distress for some participants. Therefore, participants were permitted to withdraw from the study for any reason and at any time. They were also allowed to skip interview questions or stop answering questions at any time. Additionally, they had the option to request the deletion of specific parts of the recording during or after the interviews. Before data collection, participants were informed that any information shared before their withdrawal would remain in the study, be used for analysis, and that anonymized quotes could be formally reproduced (in the thesis and other publications), with their permission. Finally, I prepared a list of support resources and contact numbers to provide to participants if needed, although no participant ultimately requested these resources.

3.4 Integration

The integration of the quantitative and qualitative studies occurred at three main points of the thesis: (1) at the completion of quantitative analyses; (2) while merging data; and (3) when drawing conclusions.

3.4.1 At the completion of quantitative analysis

The results from the quantitative research guided the creation of the qualitative interview questions and influenced the selection of qualitative participants and sampling methods. For instance, purposive sampling was employed to ensure the qualitative sample represented the demographic diversity found in the quantitative data, with approximate matching to the age, sex, and education distribution of the CLSA sample. Additionally, I aimed to include at least one participant from each category of the four SI/LON groups to gather rich, detailed insights into the experiences of SI and LON. This approach helped to understand the complex contexts surrounding how SI and LON differentially affect memory function and how their individual impacts contrast with their combined effects.

3.4.2 Merging data

Integration occurred during comparison of the quantitative and qualitative results to identify any convergences, divergences, and contradictions between the two data sources. For instance, I examined specific codes that emerged from the qualitative data (e.g., stress, functional social support, cognitive engagement/activities) to see how they related to the experiences of SI/LON and their association with poorer memory performance. From this analysis, I developed overarching themes that explained the nature and underlying mechanisms behind the associations between SI and memory, and LON and memory, thereby deepening the understanding of the quantitative findings. This integration was then visually represented through a joint display table (see Chapter 6).

3.4.3 Drawing conclusions

Finally, integration took place during the formulation of comprehensive interpretations incorporating insights from both phases of the research. I explored how the qualitative data offer insights into why the combined effects of SI and LON are more harmful to memory than each condition individually. Based on this integrated understanding, I made informed recommendations for practice, policy, and future research.

Chapter 4

Quantitative Results

4.1 Analytical samples

4.1.1 Primary analysis (AADA + MCA)

From the 14,658 Tracking Cohort participants who provided data at all three time points, 14,457, 14,294, and 14,356 individuals provided information on SI and LON at the BA, FUP1, and FUP2 time points, respectively. Only 19 participants were excluded because they lacked SI and LON data for all three timepoints, leaving 14,639 participants with complete SI and LON data for at least one timepoint. For memory, at the BA, FUP1, and FUP2 timepoints, 12,089, 12,617, and 10,578 participants provided information on immediate- and delayed-recall memory, respectively. A total of 431 individuals were excluded because they did not have memory data for any of the three timepoints, resulting in 14,208 participants with complete SI, LON, and memory data for at least one timepoint. Since no participants were excluded for missing covariate data, the final sample for the primary analysis was 14,208 participants (96.9% of the 14,658 participants). The procedure for obtaining this sample is detailed in Fig. 3.

4.1.2 Sensitivity analysis 1 (AADA alone)

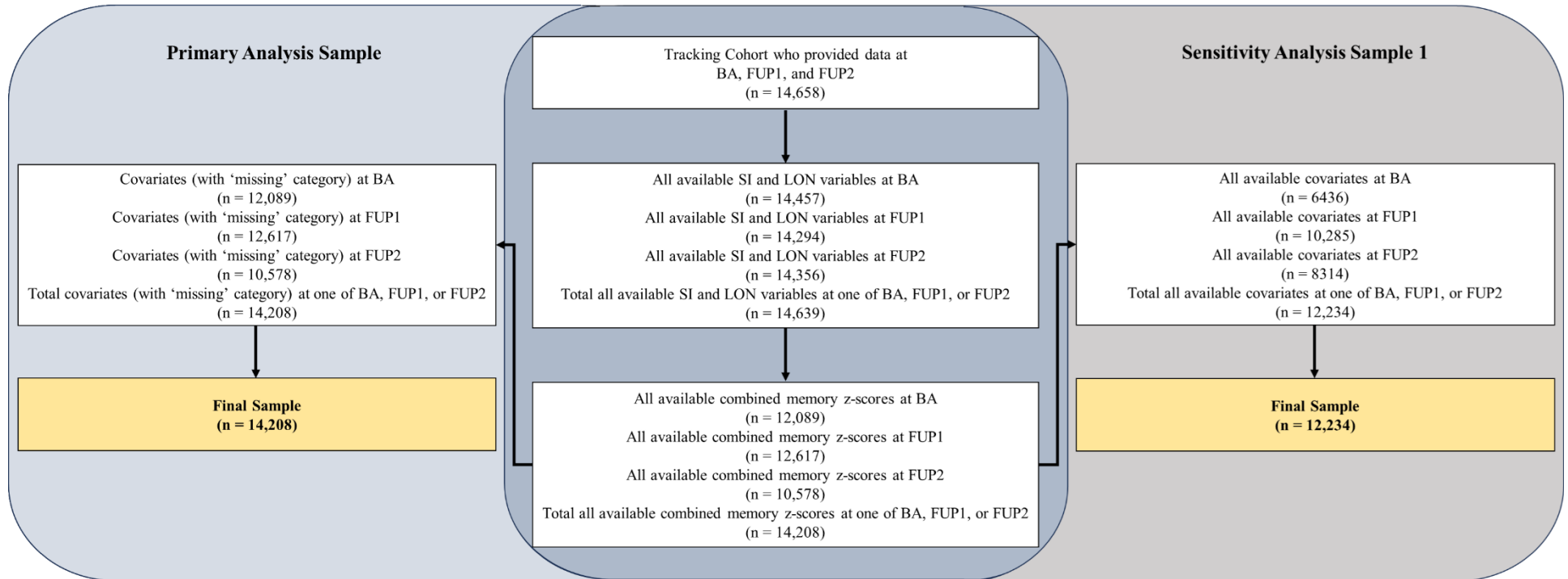
From the 14,208 participants in the primary analysis sample, those with missing covariate data at all three timepoints were excluded from the ‘AADA + MCA’ subsample. At the BA, FUP1, and FUP2 timepoints, 6,436, 10,285, and 8,314 participants, respectively, provided covariate data. A total of 1,974 of these individuals were removed from the ‘AADA + MCA’ subsample because they had missing covariate information (on the same covariate) at all three timepoints, resulting in 12,234 participants (83.46%) with complete SI, LON, memory, and all covariate data for at least one timepoint (Fig. 3).

4.1.3 Sensitivity analysis 2 (Multiple imputation)

For the second sensitivity analysis, I conducted 20 imputation cycles on the dataset of 14,658 participants who provided data at all three time periods.

Figure 3.

Analytical Sample Extraction Process



Notes.

Source: From *Exploring the differential impacts of social isolation, loneliness, and their combination on the memory of an aging population: A 6-year longitudinal study of the CLSA*, by Kang, J. W., Oremus, M., Dubin, J., Tyas, S. L., Oga-Omenka, C., & Golberg, M, 2024, *Archives of Gerontology and Geriatrics*, 125, 105483.

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Abbreviations: SI = social isolation; LON = loneliness; BA = baseline; FUP1 = follow-up 1; FUP2 = follow-up 2.

4.2 Descriptive univariate analyses

4.2.1 Social isolation/loneliness

The results of the descriptive analyses for the 'AADA+ MCA' sample are presented in Tables 1 and 2. In this sample, at the BA timepoint, 82.90% of participants were neither socially isolated nor lonely, 7.88% were only socially isolated, 7.98% were only lonely, and 1.23% were both isolated and lonely. At FUP1, 83.04% of participants were neither socially isolated nor lonely, 6.66% were only socially isolated, 9.04% were only lonely, and 1.26% were both isolated and lonely. At FUP2, 79.62% of participants were neither socially isolated nor lonely, 9.80% were only socially isolated, 8.81% were only lonely, and 1.77% were both isolated and lonely (Table 1).

4.2.2 Memory

Regarding memory, 87.59% (BA), 86.38% (FUP1), and 86.71% (FUP2) of participants had average memory; 8.43% (BA), 8.16% (FUP1), and 7.25% (FUP2) had high memory; and 3.98% (BA), 5.47% (FUP1), and 6.04% (FUP2) had low memory (Table 1 and Table 2).

Table 1.

Distribution of combined memory and covariates by social isolation/loneliness groups

	Baseline (n = 12,090)					Follow-up 1 (n = 12,617)					Follow-up 2 (n = 10,578)				
	Neither (82.9%)	Only SI (7.9%)	Only LON (8.0%)	Both (1.2%)	Total	Neither (83.0%)	Only SI (6.7%)	Only LON (9.0%)	Both (1.3%)	Total	Neither (79.6%)	Only SI (9.8%)	Only LON (8.8%)	Both (1.8%)	Total
Combined memory score (%)															
Average	87.02	86.46	87.98	84.78	87.59	86.11	85.60	85.45	81.02	86.38	87.19	84.86	85.41	81.82	86.71
High	9.40	7.50	6.74	8.71	8.43	8.81	6.90	7.71	8.29	8.16	7.58	6.56	6.12	2.14	7.25
Low	3.58	6.04	5.28	6.51	3.98	5.08	7.50	6.84	10.69	5.47	5.24	8.58	8.48	16.04	6.04
Age groups (%)															
45-54	31.63	21.09	27.67	24.83	30.40	14.62	11.19	11.57	11.32	14.08	5.12	3.38	3.54	4.28	4.79
55-64	33.52	31.58	34.30	30.20	33.39	35.95	29.40	34.09	36.48	35.35	33.53	33.17	31.65	30.48	33.28
65-74	21.20	27.49	20.73	21.48	21.66	30.12	36.67	28.13	29.56	30.37	36.21	33.17	29.08	33.69	35.24
75-85	13.49	19.62	17.10	23.49	14.38	17.20	19.40	22.26	19.50	17.83	20.21	23.14	24.46	20.86	20.88
Missing	0.16	0.21	0.21	0.00	0.17	2.11	3.33	3.94	3.14	2.37	4.93	7.14	11.27	10.70	5.80
Sex (%)															
Male	47.81	54.98	41.45	46.98	47.86	47.48	55.95	38.48	50.31	47.26	45.68	51.98	38.84	43.32	45.65
Female	52.19	45.02	58.55	53.02	52.14	52.46	43.93	61.35	49.69	52.66	54.32	48.02	61.16	56.68	54.35
Missing	0.00	0.00	0.00	0.00	0.00	0.07	0.12	0.18	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Education (%)															
Less than post-secondary	28.02	34.42	33.99	38.93	29.13	26.08	29.64	32.25	32.70	26.96	24.27	27.10	29.29	23.53	24.98
Post-secondary	70.92	64.74	65.39	61.07	69.87	72.97	69.76	66.52	66.67	72.09	74.70	72.13	69.21	75.40	73.97
Missing	1.07	0.84	0.62	0.00	1.00	0.95	0.60	1.23	0.63	0.95	1.03	0.77	1.50	1.07	1.05
Annual household income (%)															
< \$20k	3.26	5.56	9.64	16.11	4.11	3.03	4.40	9.64	13.21	3.84	2.98	3.76	7.73	12.30	3.64
\$20k to < \$50k	22.37	31.27	32.12	32.21	23.97	21.82	30.60	32.34	35.85	23.53	22.52	28.64	37.02	40.64	24.72
\$50k to < \$100k	36.73	34.10	33.68	26.17	36.15	36.81	33.81	29.89	23.90	35.82	35.61	33.56	27.68	24.06	34.51
≥ \$100k	32.55	22.88	18.13	15.44	30.42	32.80	26.19	19.72	17.61	30.98	30.92	26.81	16.52	12.83	28.93
Missing	5.10	6.19	6.42	10.07	5.35	5.55	5.00	8.41	9.43	5.82	7.97	7.23	11.05	10.16	8.21
Province (%)															
Ontario	25.12	17.31	21.24	14.77	24.07	23.46	18.10	20.60	14.47	22.73	23.75	16.68	19.85	20.86	22.66
Alberta	9.41	7.45	10.26	6.71	9.29	10.35	8.57	9.82	10.69	10.18	10.44	9.45	11.27	9.09	10.39
British Columbia	10.86	13.42	10.16	14.09	11.04	12.71	22.50	14.37	14.47	13.54	12.86	16.39	13.63	12.30	13.26
Manitoba	6.89	5.77	5.70	5.37	6.69	6.61	3.33	6.22	5.03	6.34	5.90	3.57	6.44	3.74	5.68
New Brunswick	6.21	7.87	6.74	4.70	6.36	5.96	7.98	5.70	8.81	6.10	5.92	6.56	6.44	5.88	6.03
Newfoundland	5.46	6.19	5.39	6.04	5.52	5.14	5.48	4.38	4.40	5.08	4.74	4.82	5.26	4.81	4.79
Nova Scotia	7.63	9.44	6.22	8.72	7.68	7.41	8.21	6.66	11.95	7.45	7.65	8.68	5.90	8.02	7.60
Prince Edward Island	5.44	5.88	4.35	6.04	5.39	4.81	6.55	4.29	8.18	4.92	5.34	4.82	4.40	2.67	5.16
Quebec	16.97	19.94	24.46	28.19	17.94	17.70	14.76	22.17	14.47	17.86	17.85	25.65	21.14	29.41	19.11
Saskatchewan	6.02	6.72	5.49	5.37	6.02	5.84	4.52	5.78	7.55	5.77	5.56	3.38	5.69	3.21	5.31
Missing	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Area of residence (%)															
Rural	23.02	25.81	21.55	23.49	23.13	17.95	19.40	16.13	17.61	17.88	17.47	20.93	14.48	16.58	17.53
Urban	66.26	63.59	67.36	65.77	66.13	73.50	71.19	75.02	71.07	73.46	74.77	70.97	76.82	76.47	74.61
Missing	10.73	10.60	11.09	10.74	10.74	8.54	9.40	8.85	11.32	8.66	7.77	8.10	8.69	6.95	7.87

Functional Ability (%)															
No ADL/IADL impairment	7.73	8.08	11.09	9.40	8.05	9.30	10.00	14.81	16.35	9.93	12.09	12.44	16.42	10.70	12.48
Mild impairment	91.16	89.51	86.53	83.22	90.56	86.98	84.29	79.40	77.36	86.00	84.45	82.35	73.61	73.80	83.10
Moderate impairment	0.70	1.57	1.66	6.04	0.91	1.49	3.10	2.63	3.14	1.72	1.95	2.41	6.22	10.16	2.51
Severe/total impairment	0.24	0.52	0.31	1.34	0.28	0.54	0.83	1.14	1.26	0.63	0.96	1.64	3.11	3.74	1.27
Missing	0.17	0.31	0.41	0.00	0.20	1.69	1.79	2.02	1.89	1.73	0.56	1.16	0.64	1.60	0.64

Alcohol consumption (in past 12 months) (%)															
Never	12.25	15.63	16.79	16.78	12.94	12.25	15.36	15.16	20.13	12.82	15.23	17.74	20.92	29.41	16.23
≤ 1 time per month	14.29	17.73	18.55	22.82	15.00	13.09	15.48	17.88	20.75	13.78	12.74	14.46	17.70	16.58	13.41
> 1 time per month	73.40	66.53	64.66	60.40	72.00	74.45	69.05	66.79	58.49	73.20	71.66	67.40	60.84	54.01	69.98
Missing	0.06	0.10	0.00	0.00	0.06	0.21	0.12	0.18	0.63	0.21	0.37	0.39	0.54	0.00	0.38
Smoking status (for past 30 days) (%)															
Never	60.45	62.43	57.51	53.02	60.28	93.55	92.02	90.97	84.28	93.10	94.63	93.54	91.09	88.24	94.10
≥ 1 cigarette in the past 30 days	1.57	1.47	1.76	3.36	1.60	1.73	1.41	2.13	0.63	1.74	1.23	1.16	2.25	1.60	1.32
≥ 1 cigarette every day	5.96	8.81	10.47	16.78	6.67	4.71	6.57	6.90	15.09	5.15	4.10	5.30	6.65	10.16	4.55
Missing	32.03	27.28	30.26	26.85	31.45	0.02	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.03
Depressive symptoms (%)															
No/mild	92.24	88.25	65.91	57.72	89.40	92.73	90.83	65.38	61.01	89.73	95.06	92.57	71.14	64.71	92.17
Moderate/severe	5.80	7.97	32.54	40.94	8.54	7.12	9.05	34.18	46.66	10.1	4.93	7.43	28.75	35.29	7.81
Missing	1.97	3.78	1.55	1.34	2.07	0.15	0.12	0.44	0.00	0.17	0.01	0.00	0.11	0.00	0.02
Chronic health conditions (%)															
None	10.81	7.87	7.67	6.04	10.26	7.08	4.88	4.47	3.14	6.65	4.77	3.57	1.39	3.21	4.33
≥ 1 chronic conditions	85.43	87.30	87.05	87.25	85.73	92.78	94.76	95.18	96.86	93.18	95.21	96.34	98.28	96.79	95.62
Missing	3.76	4.83	5.28	6.71	4.00	0.13	0.36	0.35	0.00	0.17	0.01	0.10	0.32	0.00	0.05

Notes.

Source: From *Exploring the differential impacts of social isolation, loneliness, and their combination on the memory of an aging population: A 6-year longitudinal study of the CLSA*, by Kang, J. W., Oremus, M., Dubin, J., Tyas, S. L., Oga-Omenka, C., & Golberg, M., 2024, *Archives of Gerontology and Geriatrics*, 125, 105483.

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For descriptive analyses, memory responses are categorized into three levels: ‘average’, ‘high’, and ‘low’ memory. The cut-offs for high and low memory were established as having scores that are ≥1.5 standard deviations above versus below the mean for combined memory (RAVLT I + II), respectfully.

Abbreviations: SI = social isolation; LON = loneliness; ADL = activities of daily living; IADL = instrumental activities of daily living

Table 2.

Distribution of covariates by combined memory

	Baseline (n = 12,090)				Follow-up 1 (n = 12,617)				Follow-up 2 (n = 10,578)			
	Combined memory scores											
	High (8.4%)	Average (87.6%)	Low (4.0%)	Total	High (8.2%)	Average (86.4%)	Low (5.5%)	Total	High (7.3%)	Average (86.7%)	Low (6.0%)	Total
Age groups (%)												
45-54	32.88	30.93	13.31	30.40	17.01	14.49	3.19	14.08	8.34	4.80	0.47	4.79
55-64	34.35	33.86	21.00	33.39	42.37	36.05	13.77	35.35	43.29	34.02	10.64	33.28
65-74	23.36	21.24	27.44	21.66	28.77	30.78	26.38	30.37	33.51	36.18	23.94	35.24
75-85	9.32	13.83	37.21	14.38	11.18	16.66	46.23	17.83	13.95	20.12	40.22	20.88
Missing	0.10	0.13	1.04	0.17	0.68	2.02	10.43	2.37	0.91	4.90	24.73	5.80
Sex (%)												
Male	28.46	48.51	74.62	47.86	22.93	48.05	71.01	47.26	21.90	46.13	67.29	45.65
Female	71.54	51.49	25.36	52.14	76.77	51.88	28.99	52.66	78.10	53.87	32.71	54.35
Missing	0.00	0.00	0.00	0.00	0.29	0.06	0.00	0.08	0.00	0.00	0.00	0.00
Education (%)												
Less than post-secondary	21.30	29.05	47.61	29.13	17.59	26.74	44.35	26.96	15.38	24.91	37.40	24.98
Post-secondary	78.12	69.89	51.98	69.87	81.73	72.32	54.20	72.09	83.31	74.05	61.66	73.97
Missing	0.59	1.07	0.42	1.00	0.68	0.95	1.45	0.95	1.30	1.04	0.94	1.05
Annual household income (%)												
< \$20k	3.24	3.99	8.52	4.11	2.92	3.76	6.52	3.84	2.87	3.38	8.29	3.64
\$20k to < \$50k	20.61	23.79	35.14	23.97	17.78	23.17	37.83	23.53	17.73	24.52	35.99	24.72
\$50k to < \$100k	34.35	36.35	35.55	36.15	34.99	36.09	32.90	35.82	35.98	34.81	28.33	34.51
≥ \$100k	35.03	30.66	15.38	30.42	38.58	31.32	14.35	30.98	36.51	29.36	13.62	28.93
Missing	6.77	5.21	5.41	5.35	5.73	5.66	8.41	5.82	6.91	7.93	13.77	8.21
Province (%)												
Ontario	21.10	24.25	26.40	24.07	24.39	22.48	24.20	22.73	21.90	22.93	19.72	22.66
Alberta	9.42	9.34	7.90	9.29	11.86	10.14	8.41	10.18	10.30	10.50	8.92	10.39
British Columbia	13.94	10.84	9.36	11.04	13.22	13.86	8.99	13.54	13.04	13.27	13.46	13.26
Manitoba	6.87	6.68	6.65	6.69	5.25	6.38	7.39	6.34	6.13	5.69	5.01	5.68
New Brunswick	5.40	6.38	7.90	6.36	5.34	6.15	6.52	6.10	5.22	6.04	6.89	6.03
Newfoundland	5.89	5.30	9.56	5.52	5.83	4.94	6.23	5.08	4.56	4.83	4.54	4.79
Nova Scotia	7.26	7.68	8.52	7.68	6.41	7.50	8.26	7.45	7.82	7.60	7.36	7.60
Prince Edward Island	5.50	5.36	5.82	5.39	3.79	5.00	5.36	4.92	4.43	5.17	5.95	5.16
Quebec	18.25	18.22	11.23	17.94	18.08	17.87	17.54	17.86	21.12	18.80	21.13	19.11
Saskatchewan	6.38	5.96	6.65	6.02	5.83	5.68	7.10	5.77	5.48	5.18	7.04	5.31
Missing	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.00
Area of residence (%)												
Rural	22.28	23.23	22.66	23.13	16.03	17.99	18.84	17.88	17.08	17.73	15.18	17.53
Urban	66.83	66.12	64.86	66.13	75.90	73.34	71.59	73.46	74.45	74.45	77.00	74.61
Missing	10.89	10.65	12.47	10.74	8.07	8.66	9.57	8.66	8.47	7.82	7.82	7.87
Functional Ability (%)												
No ADL/IADL impairment	6.97	8.17	7.90	8.05	9.43	9.87	11.59	9.93	11.34	12.52	13.30	12.48
Mild impairment	91.95	90.48	89.40	90.56	87.46	86.14	81.59	86.00	86.70	83.37	74.80	83.10
Moderate impairment	0.69	0.91	1.46	0.91	1.17	1.67	3.33	1.72	1.17	2.31	7.04	2.51
Severe/total impairment	0.19	0.25	0.83	0.28	0.29	0.56	2.17	0.63	0.39	1.22	2.97	1.27
Missing	0.20	0.19	0.42	0.20	1.65	1.76	1.30	1.73	0.39	0.58	1.88	0.64

Alcohol consumption (in past 12 months) (%)												
Never	13.05	12.46	23.08	12.94	10.30	12.61	19.86	12.82	15.25	15.81	23.47	16.23
≤ 1 time per month	15.60	14.83	17.67	15.00	14.29	13.61	15.65	13.78	14.34	13.17	15.81	13.41
≥ 1 time(s) a week	71.35	72.64	59.25	72.00	75.12	63.59	64.20	73.20	70.27	70.67	59.62	69.98
Missing	0.00	0.07	0.00	0.06	0.29	0.19	0.29	0.21	0.13	0.35	1.10	0.38
Smoking status (for past 30 days) (%)												
Never	53.29	60.84	62.79	60.28	92.61	93.10	93.77	93.10	93.61	94.08	94.99	94.10
≥ 1 cigarette in the past 30 days	2.06	1.57	1.25	1.60	1.85	1.75	1.30	1.74	0.65	1.45	0.31	1.32
≥ 1 cigarette every day	7.46	6.52	8.52	6.67	5.54	5.13	4.93	5.15	5.74	4.44	4.69	4.55
Missing	37.19	31.08	27.44	31.45	0.00	0.02	0.00	0.02	0.00	0.03	0.00	0.03
Depressive symptoms (%)												
No/mild	91.17	89.52	82.95	89.40	91.25	89.91	86.23	89.73	93.22	92.38	87.95	92.17
Moderate/severe	7.36	8.47	12.48	8.54	8.75	10.04	13.04	10.10	6.78	7.61	11.90	7.81
Missing	1.47	2.01	4.57	2.07	0.00	0.16	0.72	0.17	0.00	0.01	0.16	0.02
Chronic health conditions (%)												
None	11.68	10.27	7.07	10.26	9.14	6.63	3.33	6.65	5.87	4.31	2.82	4.33
≥ 1 chronic conditions	85.38	85.70	87.11	85.73	90.86	93.24	95.80	93.18	94.13	95.64	97.18	95.62
Missing	2.94	4.02	5.82	4.00	0.00	0.14	0.87	0.17	0.00	0.05	0.00	0.05

Notes.

Source: From *Exploring the differential impacts of social isolation, loneliness, and their combination on the memory of an aging population: A 6-year longitudinal study of the CLSA*, by Kang, J. W., Oremus, M., Dubin, J., Tyas, S. L., Oga-Omenka, C., & Golberg, M, 2024, Archives of Gerontology and Geriatrics, 125, 105483.

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For descriptive analyses, memory responses will be categorized into three levels: ‘average’, ‘high’, and ‘low’ memory. The cut-offs for high and low memory were established as having scores that are ≥1.5 standard deviations above versus below the mean for combined memory (RAVLT I + II), respectfully.

Abbreviations: ADL = activities of daily living; IADL = instrumental activities of daily living

Continuous memory scores were roughly normally distributed with some right skewness at all three timepoints (Fig. 4). The means of these scores were 0.10, 0.08, and 0.09 at BA, FUP1, and FUP2, respectively (Table 3).

Figure 4.

Distribution of Combined Memory Scores at Baseline, Follow-up 1, and Follow-up 2

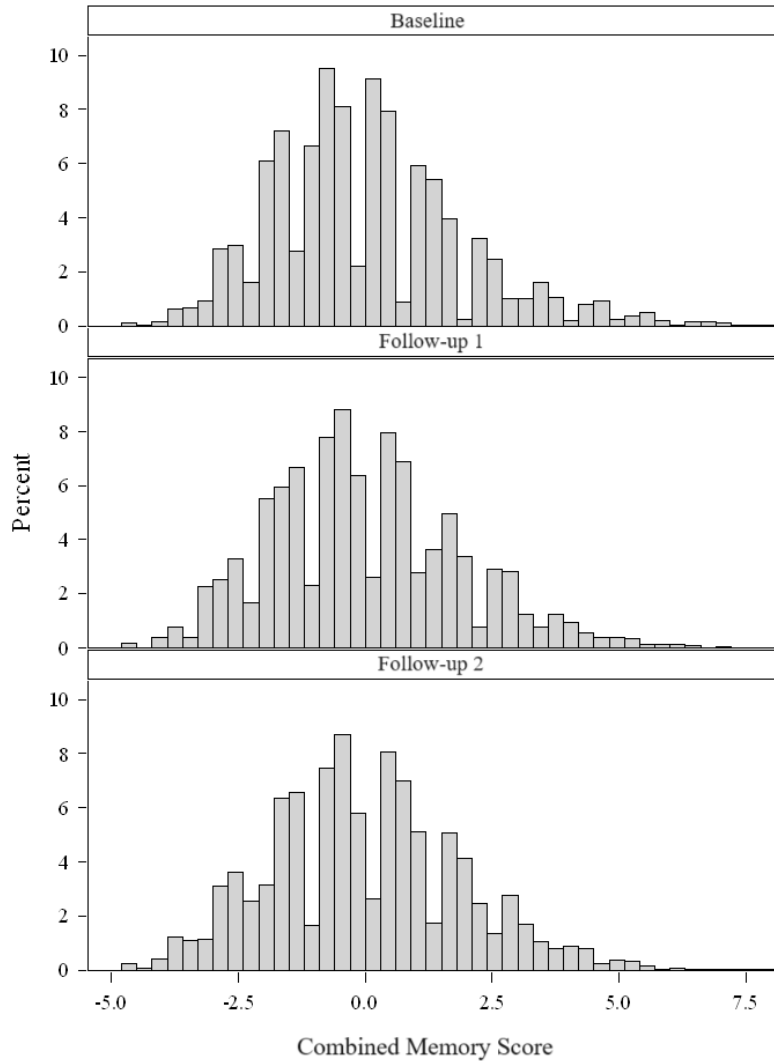


Table 3.

Continuous Combined Memory Scores at Baseline, Follow-up 1, and Follow-up 2

Memory score	Mean (SD)	95% CI	Median (IQR)	Minimum	Maximum
Baseline	0.10 (1.90)	(0.06, 0.14)	-0.29 (2.44)	-4.59	8.03
Follow-up 1	0.08 (1.88)	(0.04, 0.12)	-0.02 (2.46)	-4.55	8.08
Follow-up 2	0.09 (1.88)	(0.05, 0.13)	-0.05 (2.45)	-4.73	7.99

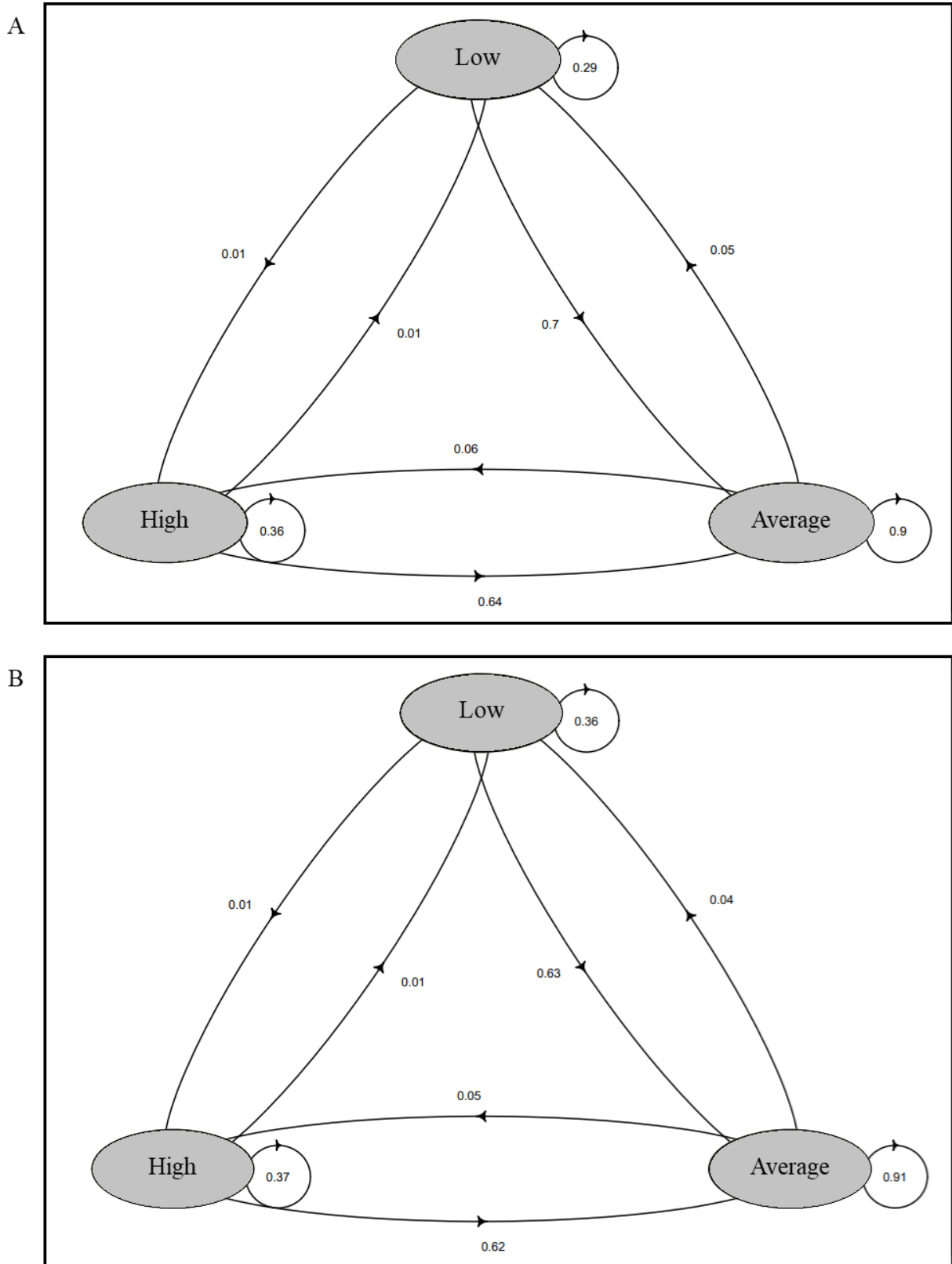
Notes. SD = standard deviation; CI = confidence interval; IQR = interquartile range.

4.2.3 Transition probabilities

Over the course of follow-up, most participants either remained in their initial SI/LON or memory response categories or transitioned into the reference category (neither isolated nor lonely; average memory) (Fig. 5A-B, Fig. 6A-B). For instance, 27% of those who were ‘only SI’ at BA stayed the same at FUP1, while 63% transitioned to ‘neither isolated nor lonely’. Among ‘only LON’ participants at BA, 31% remained in the same group and 61% moved to ‘neither’. For those who were ‘both isolated and lonely’ at BA, 17% stayed the same and 42% shifted to ‘neither’. Additionally, 87% of participants in the ‘neither’ category at BA remained there at FUP1. Regarding memory, 29% of those with low memory at BA still had low memory at FUP1, while 70% moved to average memory. Of those with high memory at BA, 36% remained in the same group and 64% moved to average memory. Furthermore, 90% of participants with average memory at BA maintained as such at FUP1. Similar transition patterns were observed from FUP1 to FUP2. These patterns – where participants with extreme values (very low or high memory, high SI/LON) at BA move towards more average values over time – could be explained by several factors. For instance, initial assessments might have been influenced by temporary factors like stress or illness, which could resolve over time, leading to an apparent improvement in SI/LON and memory. The initial assessment could have also acted as a wake-up call, prompting some participants who realized they had memory concerns to take actions to improve their cognitive health (e.g., engaging in more cognitive activities or taking better care of their physical/mental health). Additionally, participants may have experienced positive environmental or lifestyle changes (e.g., better social support, moving into a shared living arrangement) that helped reduce SI/LON.

Figure 5.

State Transition Probabilities for Combined Memory Groups Across Six Years of Follow-up



Notes.

Source: From *Exploring the differential impacts of social isolation, loneliness, and their combination on the memory of an aging population: A 6-year longitudinal study of the CLSA*, by Kang, J. W., Oremus, M., Dubin, J., Tyas, S. L., Oga-Omenka, C., & Golberg, M, 2024, *Archives of Gerontology and Geriatrics*, 125, 105483. <https://doi.org/10.1016/j.archger.2024.105483>. © 2024 Elsevier B.V. This is an open-access article under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives 4.0 International License (<https://creativecommons.org/licenses/by-nc-nd/4.0/>). This material is unchanged from its original form.

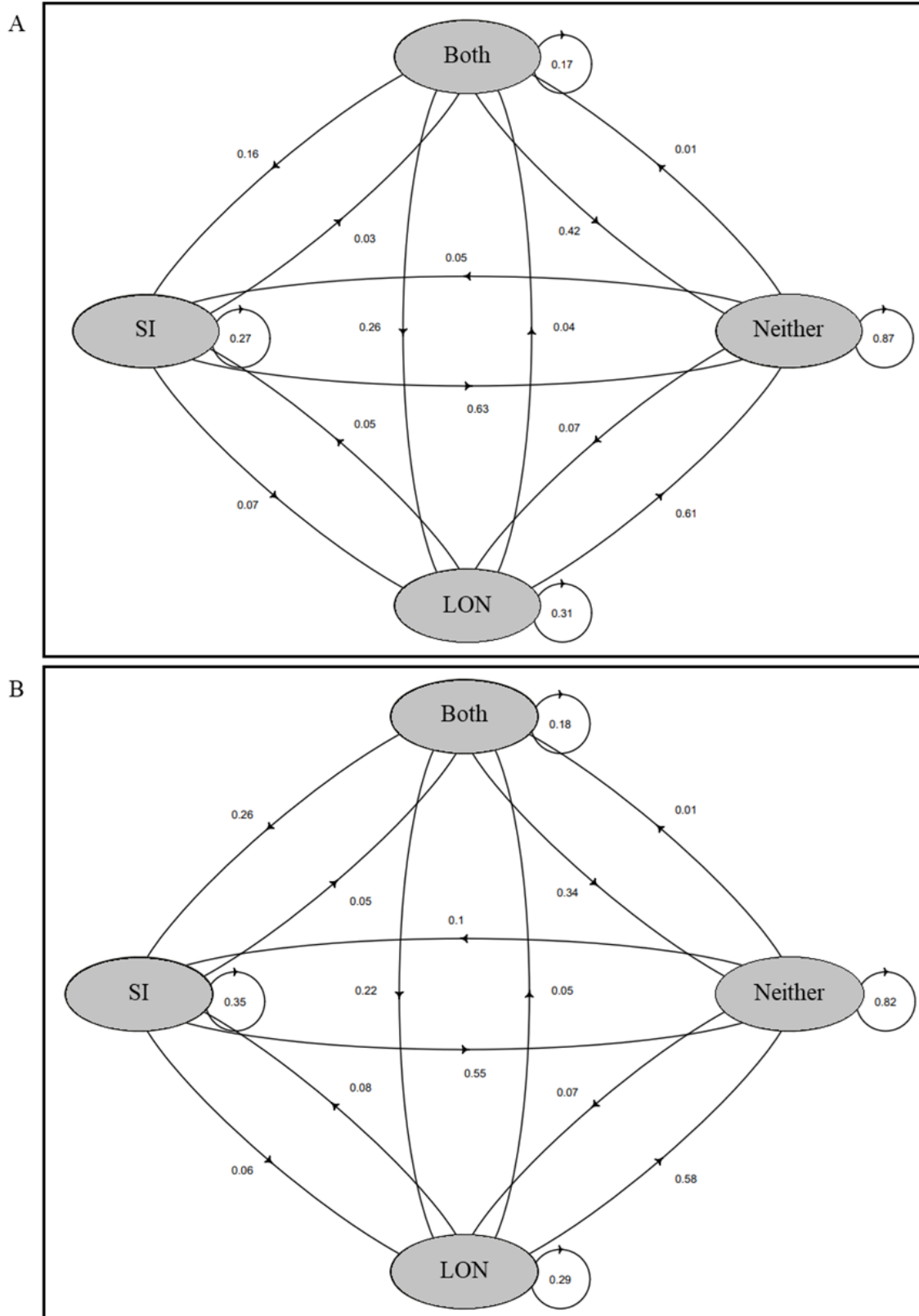
Figure 5 illustrates the transitions between memory groups (low, average, and high memory) over time. The arrows represent the direction of movement, with numeric values indicating the proportion of individuals who transitioned between different memory groups or remained within the same group.

A = Combined memory state transition probability: baseline to follow-up 1

B = Combined memory state transition probability: follow-up 1 to follow-up 2

Figure 6.

State Transition Probabilities for Social Isolation/Loneliness Groups Across Six Years of Follow-up



Notes.

Source: From *Exploring the differential impacts of social isolation, loneliness, and their combination on the memory of an aging population: A 6-year longitudinal study of the CLSA*, by Kang, J. W., Oremus, M., Dubin, J., Tyas, S. L., Oga-Omenka, C., & Golberg, M, 2024, *Archives of Gerontology and Geriatrics*, 125, 105483. <https://doi.org/10.1016/j.archger.2024.105483>. © 2024 Elsevier B.V. This is an open-access article under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives 4.0 International License (<https://creativecommons.org/licenses/by-nc-nd/4.0/>). This material is unchanged from its original form.

Figure 6 illustrates the transitions between combined SI/LON groups (neither isolated nor lonely, only socially isolated, only lonely, and both) over time. The arrows represent the direction of movement, with numeric values indicating the proportion of individuals who transitioned between different SI/LON groups or remained within the same group.

A = Social isolation/loneliness state transition probability: baseline to follow-up 1

B = Social isolation/loneliness state transition probability: follow-up 1 to follow-up 2

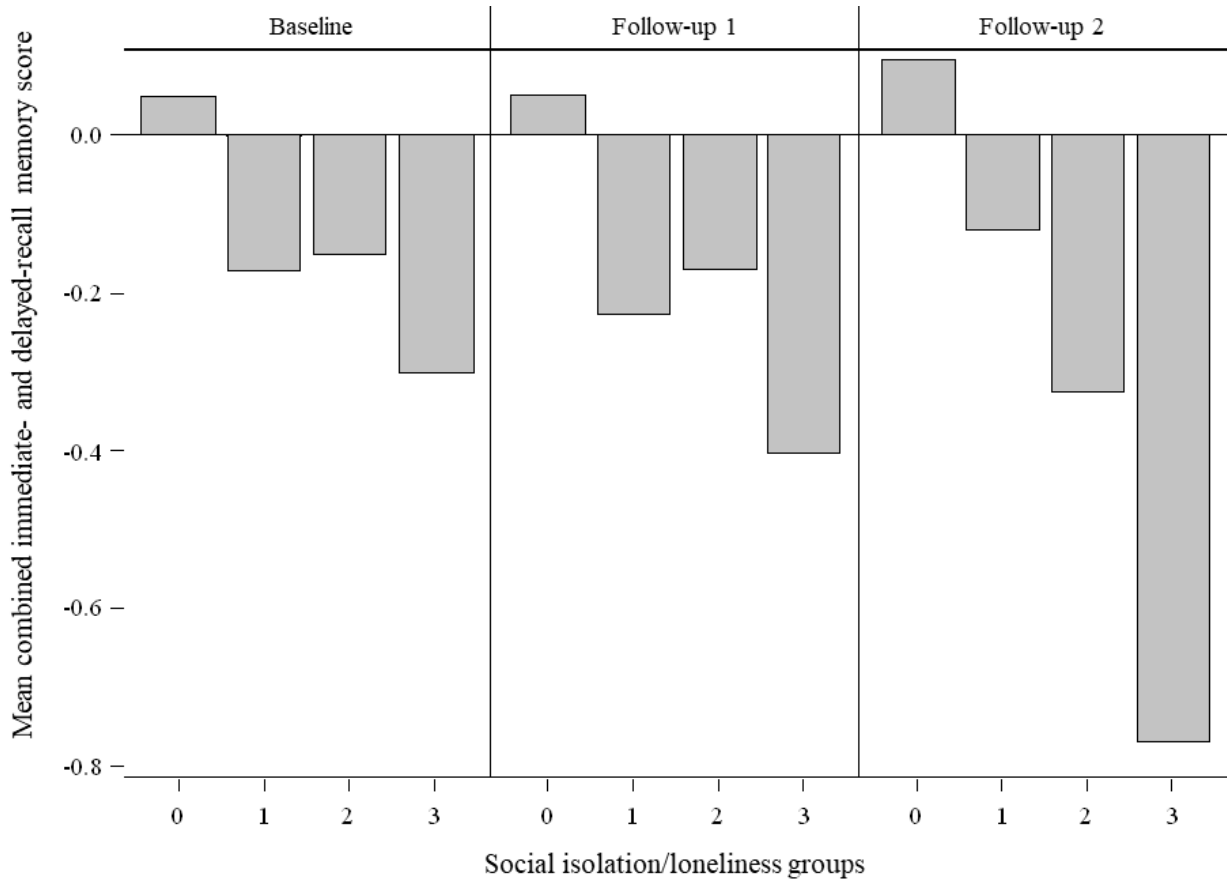
Abbreviations: SI = only socially isolated; LON = only lonely

4.2.4 Association between social isolation/loneliness and combined memory

SI and LON were significantly and inversely related ($p < 0.001$) to memory when comparing 'both' versus 'neither' SI/LON groups in the low memory group (Table 1). For example, the proportion of low memory was roughly double in the group experiencing both SI and LON compared to the group experiencing neither at BA ('neither'= 3.58%; 'both'= 6.51%) and FUP1 ('neither'= 5.08%; 'both'= 10.69%), and triple at FUP2 ('neither'= 5.24%; 'both'= 16.04%) (Table 1). Additionally, the 'both' group had a higher proportion of low memory than those experiencing either SI alone or LON alone at FUP1 ('only SI'= 7.50%; 'only LON'= 6.84%; 'both'= 10.69%) and FUP2 ('only SI'= 8.58%; 'only LON'= 8.48%; 'both'= 16.04%). However, at BA, the proportion of low memory was similar among the three groups of SI/LON ('only SI'= 6.04%; 'only LON'= 5.28%; 'both'= 6.51%) (Table 1). Moreover, the proportions of high memory in the 'neither' and 'both' SI/LON groups were roughly the same at BA ('neither'= 9.40%; 'both'= 8.71%) and FUP1 ('neither'= 8.81%; 'both'= 8.29%) (Table 1). Furthermore, when examining the continuous memory scores, the mean memory scores for the 'neither' and 'only SI' groups were higher at FUP2 compared to BA and FUP1, although the overall relationship between SI/LON and memory was inverse at each time point (see Fig. 7). Therefore, straightforward patterns were not obvious between SI/LON and combined memory.

Figure 7.

Mean Memory Score by Social Isolation/Loneliness Groups at Baseline, Follow-up 1, and Follow-up 2



N	10023	953	964	149	10477	840	1141	159	8422	1037	932	187
Mean	0.048	-0.17	-0.15	-0.30	0.050	-0.23	-0.17	-0.40	0.09	-0.14	-0.31	-0.74
Std Dev	1.89	1.87	1.84	2.16	1.88	1.96	1.89	2.13	1.88	1.94	1.89	1.89

Notes.

Source: From *Exploring the differential impacts of social isolation, loneliness, and their combination on the memory of an aging population: A 6-year longitudinal study of the CLSA*, by Kang, J. W., Oremus, M., Dubin, J., Tyas, S. L., Oga-Omenka, C., & Golberg, M, 2024, Archives of Gerontology and Geriatrics, 125, 105483.

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Social isolation/loneliness group 0 = neither isolated nor lonely; group 1 = only socially isolated; group 2 = only lonely; group 3 = both isolated and lonely.

Abbreviations: N = number of subjects; Std Dev = standard deviation

4.2.5 Association between covariates and social isolation/loneliness

As shown in Table 1, just over half the participants in the sample were female (52.14% at BA, 52.66% at FUP1, and 54.35% at FUP2), and about one-third of participants were aged 55–64 years (33.39% at BA, 35.35% at FUP1, and 33.28% at FUP2). As can be expected, a shift in the study sample's age distribution occurred over time, with a higher percentage of participants aged 65–74 and 75–85 years in FUP2 compared to FUP1 and BA (21.66% and 14.38% in BA; 30.37% and 17.83% in FUP1; 35.24% and 20.88% in FUP2). Nearly three-quarters of the participants had a post-secondary degree/diploma (69.87% at BA, 72.09% at FUP1, and 73.97% at FUP2) and most participants were from Ontario (24.07% at BA, 22.73% at FUP1, and 22.66% at FUP2), Québec (17.94% at BA, 17.86% at FUP1, and 19.11% at FUP2), or British Columbia (11.04% at BA, 13.54% at FUP1, and 13.26% at FUP2). Slightly more than one-third of participants reported annual household incomes between \$50,000 and \$100,000 (36.15% at BA, 35.82% at FUP1, and 34.51% at FUP2), while a little under one-third reported incomes over \$100,000 (30.42% at BA, 30.98% at FUP1, and 28.93% at FUP2). Regarding functional ability and health covariates, most participants reported mild impairment in ADLs/IADLs (90.56% at BA, 86.00% at FUP1, and 83.10% at FUP2), no/mild depressive symptoms (89.4% at BA, 89.73% at FUP1, and 92.17% at FUP2), and the presence of at least one chronic condition (85.73% at BA, 93.18% at FUP1, and 95.62% at FUP2). For lifestyle factors, most participants were non-smokers (60.28% at BA, 93.10% at FUP1, and 94.10% at FUP2), but drank alcohol more than once per month (72.00% at BA, 73.20% at FUP1, and 69.98% at FUP2).

Table 1 shows some notable differences in covariate distributions when stratified by SI/LON status. For instance, the 'only LON' group had a higher proportion of women compared to the 'neither', 'only SI' and 'both' groups. In terms of age, education, and health comorbidities (excluding depression), the 'neither' group appeared younger, more educated (except in FUP2), and reported fewer chronic conditions than the other SI/LON groups, which did not exhibit clear patterns on these three variables. Regarding functional impairment, the largest proportion of participants in each of the four SI/LON groups reported mild impairment. However, the proportions of moderate impairment and severe/total impairment were the lowest in the 'neither' group, and the highest in the 'both' group, with no significant differences between the 'only SI' and 'only LON' groups. Additionally, the 'neither' group had the highest annual household income (i.e., highest proportion of \geq \$50,000), the mildest depressive symptoms (i.e., highest proportion of no/mild symptoms), and the lowest smoking frequency (i.e., lowest proportion of ≥ 1 cigarette every day). For these three covariates, the 'neither' group was followed by the 'only SI' group, then the 'only LON' group, and lastly the 'both' group. In terms of alcohol consumption, the 'neither' group drank the most frequently, followed by the 'only SI' group, the 'only LON' group, and the 'both'

group, which potentially suggests that in the CLSA sample, alcohol may have been mainly consumed for social reasons rather than as a coping mechanism. These patterns for age, sex, income, functional ability, lifestyle variables, depressive symptoms, and other health comorbidities were fairly consistent across the three timepoints.

4.2.6 Association between covariates and memory

Similarly, memory scores tended to be in the average or high range among younger females, and individuals in these memory groups generally tended to possess a post-secondary education (Table 2). In contrast, the low memory group contained a more even distribution of persons with less than post-secondary and post-secondary education levels. For annual household income, levels shifted from high to low income, moving from the high memory to the average memory to the low memory groups. Regarding functional impairment, most people reported mild impairment, but the low memory group had higher levels of moderate and severe/total impairment compared to the average and high memory groups. Concerning health comorbidities, while the majority of participants reported no/mild depressive symptoms, this proportion was smaller in the low memory group compared to the average and high memory groups. Additionally, the low memory group had the highest proportion of individuals with other chronic conditions (excluding depression), although most people in all memory groups reported having at least one chronic condition. These patterns remained consistent across BA, FUP1, and FUP2 (Table 2). Males made up 74.62% (BA), 71.01% (FUP1), and 67.29% (FUP2) of the low memory group, but only 28.46% (BA), 22.93% (FUP1), and 21.90% (FUP2) of the high memory group.

In terms of the age category, 37.21% (BA), 46.23% (FUP1), and 40.22% (FUP2) of the low memory group were aged 75-85 years, whereas this age group represented only 9.32% (BA), 11.18% (FUP1), and 13.95% (FUP2) of the high memory group. Regarding education, 47.61% (BA), 44.35% (FUP1), and 37.40% (FUP2) of the low memory group had less than post-secondary education, compared to 21.30% (BA), 17.59% (FUP1), and 15.38% (FUP2) of the high memory group. For income levels, 15.38% (BA), 14.35% (FUP1), and 13.62% (FUP2) of the low memory group had an annual household income of \geq \$100,000, in contrast to 35.03% (BA), 38.58% (FUP1), and 36.51% (FUP2) of the high memory group. Concerning functional ability, 2.29% (BA), 5.50% (FUP1), and 10.01% (FUP2) of the low memory group had moderate or greater impairment in ADLs/IADLs, whereas this level of impairment only accounted for 0.88% (BA), 1.46% (FUP1), and 1.56% (FUP2) of the high memory group. Regarding depression, 12.48% (BA), 13.04% (FUP1), and 11.90% (FUP2) of the low memory group had moderate/severe depressive symptoms, compared to 7.36% (BA), 8.75% (FUP1), and 6.78% (FUP2) of the high memory group. In terms of overall health status, only 7.07% (BA), 3.33% (FUP1),

and 2.82% (FUP2) of the low memory group had no chronic conditions, compared to 11.68% (BA), 9.14% (FUP1), and 5.87% (FUP2) of the high memory group.

4.3 Regression analyses

4.3.1 Research question 1: Base model

The regression analyses for the primary analytical sample consistently showed an inverse relationship between each SI/LON group and memory, across the base model and all five adjusted models: the ‘both’ group had the lowest memory scores, followed by the ‘only LON’ group, ‘only SI’ group, and ‘neither’ group (Table 4). For example, in the base model, the memory LSMEANS estimates were: ‘both’ = -0.51; ‘only LON’ = -0.41; ‘only SI’ = -0.31; and ‘neither’ = -0.26. In addition, the base model revealed statistically significant differences in memory between four pairwise comparisons of SI/LON groups: (1) ‘neither’ versus ‘only LON’ (difference= -0.15 [BH-corrected p-value= 0.00]); (2) ‘neither’ versus ‘both’ (difference= -0.25 [BH-corrected p-value= 0.00]); (3) ‘only SI’ versus ‘only LON’ (difference= 0.10 [BH-corrected p-value= 0.02]); and (4) ‘only SI’ versus ‘both’ (difference= 0.20 [BH-corrected p-value= 0.01]).

Figures 8A and 8B depict the changes in memory scores over time for each of the four SI/LON groups. Over six years of follow-up, memory scores declined in the ‘both’ group, but increased in the other three groups on average. Nonetheless, these increased scores remained negative at the follow-ups, indicating that each SI/LON group was still associated with lower memory scores. These trends were consistent across all models, whether unadjusted or adjusted (Table 4).

Table 4.

Regression Analysis Results - Comparisons of Social Isolation/Loneliness Groups for Combined Memory

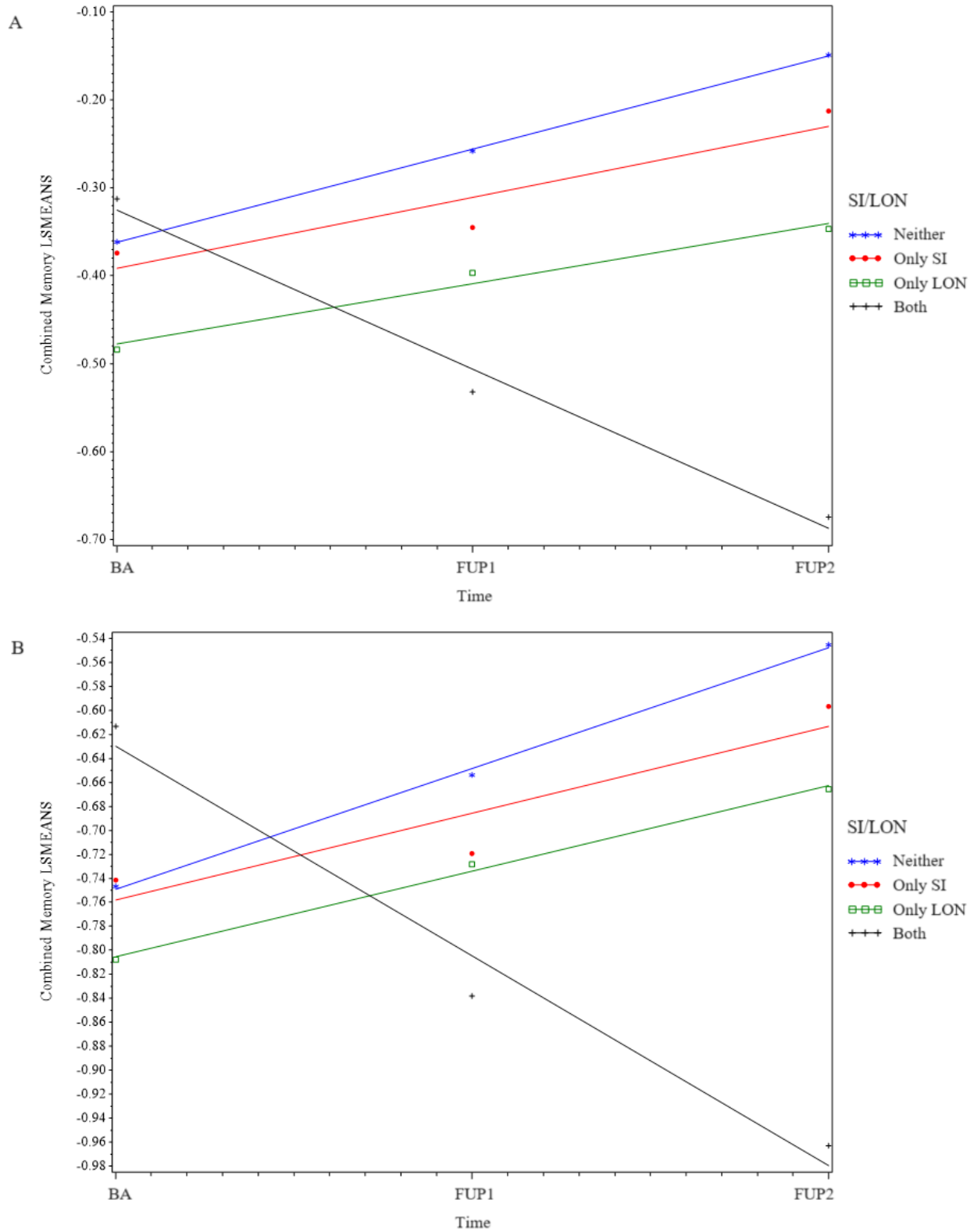
Least Squares Means for Combined Memory Scores							
SI/LON groups	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5	
Neither socially isolated nor lonely	-0.26 (-0.63, 0.12)	-0.31 (-0.68, 0.07)	-0.51 (-0.89, -0.13)	-0.27 (-0.65, 0.12)	-0.44 (-0.82, -0.05)	-0.65 (-1.05, -0.25)	
Only socially isolated	-0.31 (-0.69, 0.07)	-0.35 (-0.73, 0.03)	-0.56 (-0.94, -0.17)	-0.31 (-0.70, 0.07)	-0.49 (-0.88, -0.10)	-0.69 (-1.09, -0.29)	
Only lonely	-0.41 (-0.79, -0.03)	-0.43 (-0.81, -0.05)	-0.65 (-1.03, -0.27)	-0.41 (-0.80, -0.02)	-0.55 (-0.94, -0.17)	-0.73 (-1.13, -0.34)	
Both socially isolated and lonely	-0.51 (-0.91, -0.11)	-0.51 (-0.91, -0.11)	-0.74 (-1.15, -0.34)	-0.50 (-0.91, -0.09)	-0.64 (-1.05, -0.23)	-0.80 (-1.22, -0.39)	
Differences of Least Squares Means (for Combined Memory Scores)							
SI/LON groups	Benjamini-Hochberg Critical Value ((k/m) α)	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Neither socially isolated nor lonely vs. only socially isolated	5/6 x 0.05 = 0.04	-0.05 (0.08)	-0.05 (0.14)	-0.05 (0.11)	-0.05 (0.12)	-0.05 (0.11)	-0.04 (0.26)
Neither socially isolated nor lonely vs. only lonely	1/6 x 0.05 = 0.01	-0.15 (0.00)	-0.12 (0.00)	-0.14 (0.00)	-0.15 (0.00)	-0.12 (0.00)	-0.09 (0.00)
Neither socially isolated nor lonely vs. socially isolated and lonely	2/6 x 0.05 = 0.02	-0.25 (0.00)	-0.20 (0.00)	-0.23 (0.00)	-0.24 (0.00)	-0.21 (0.00)	-0.16 (0.03)
Only socially isolated vs. only lonely	4/6 x 0.05 = 0.03	0.10 (0.02)	0.08 (0.07)	0.09 (0.03)	0.10 (0.02)	0.07 (0.11)	0.05 (0.24)
Only socially isolated vs. socially isolated and lonely	3/6 x 0.05 = 0.03	0.20 (0.01)	0.16 (0.04)	0.18 (0.02)	0.19 (0.01)	0.16 (0.04)	0.12 (0.12)
Only lonely vs. socially isolated and lonely	6/6 x 0.05 = 0.05	0.10 (0.20)	0.08 (0.28)	0.09 (0.22)	0.09 (0.23)	0.09 (0.24)	0.07 (0.35)

Source: From *Exploring the differential impacts of social isolation, loneliness, and their combination on the memory of an aging population: A 6-year longitudinal study of the CLSA*, by Kang, J. W., Oremus, M., Dubin, J., Tyas, S. L., Oga-Omenka, C., & Golberg, M, 2024, Archives of Gerontology and Geriatrics, 125, 105483. <https://doi.org/10.1016/j.archger.2024.105483>. © 2024 Elsevier B.V. This is an open-access article under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives 4.0 International License (<https://creativecommons.org/licenses/by-nc-nd/4.0/>). This material is unchanged from its original form.

Least squares means estimates are shown, with their 95% confidence intervals in brackets. For differences of least squares means, p-values are presented instead of 95% confidence intervals to facilitate comparisons with the Benjamini-Hochberg (BH) critical values. BH method sorts the p-values from all conducted tests in ascending order (i.e., from the smallest to the largest values) and then computes the BH critical value using the formula: $\frac{k}{m}(\alpha)$, where k = rank of each p-value, m = total number of tests, and α = significance level. The subsequent step identifies the highest k rank for which the sorted p-value is less than the corresponding BH critical value, and all p-values up to this k rank are deemed statistically significant. Statistically significant values are bolded (p<0.05 or p<BH critical value). In this thesis, the BH critical values were identical across Models 0 to 5 because the rank order of p-values (i.e., k) was the same across all models. The p-value for the test comparing the neither vs. only LON groups was the smallest (k = 1), followed by the p-value for the neither vs. both groups (k = 2), then the p-value for the only SI vs. both groups (k = 3), the p-value for the only SI vs. only LON groups (k = 4), the p-value for the neither vs. only SI groups (k = 5), and finally, the p-value for the only LON vs. both groups was the largest (k = 6). Model 0 = controls for age, sex, education, province, follow-up time, and SI/LON*time interaction. Model 1 = Model 0 + area of residence + annual household income. Model 2 = Model 0 + basic and instrumental activities of daily living. Model 3 = Model 0 + alcohol consumption + smoking status. Model 4 = Model 0 + clinical depression + other chronic conditions. Model 5 = Model 0 + all other sociodemographic, functional ability, lifestyle, and health-related covariates.

Figure 8.

Regression Coefficients (Least-Squares Means) from Multivariable Mixed Effects Analyses Between Combined Memory and Social Isolation/Loneliness Groups



Notes.

Source: From *Exploring the differential impacts of social isolation, loneliness, and their combination on the memory of an aging population: A 6-year longitudinal study of the CLSA*, by Kang, J. W., Oremus, M., Dubin, J., Tyas, S. L., Oga-Omenka, C., & Golberg, M., 2024, *Archives of Gerontology and Geriatrics*, 125, 105483. <https://doi.org/10.1016/j.archger.2024.105483>. © 2024 Elsevier B.V. This is an open-access article under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives 4.0 International License (<https://creativecommons.org/licenses/by-nc-nd/4.0/>). This material is unchanged from its original form.

A = This graph represents the base model, adjusted for age, sex, education, and province.

B = This graph represents the full model, adjusted for age, sex, education, province, area of residence, annual household income, 14 basic and instrumental activities of daily living, alcohol consumption, smoking status, clinical depression, and 37 other chronic conditions.

Parameter estimates are derived from least squares regression of the combined memory scores.

Abbreviations: SI = social isolation; LON = loneliness; BA = baseline; FUP1 = follow-up 1; FUP2 = follow-up 2

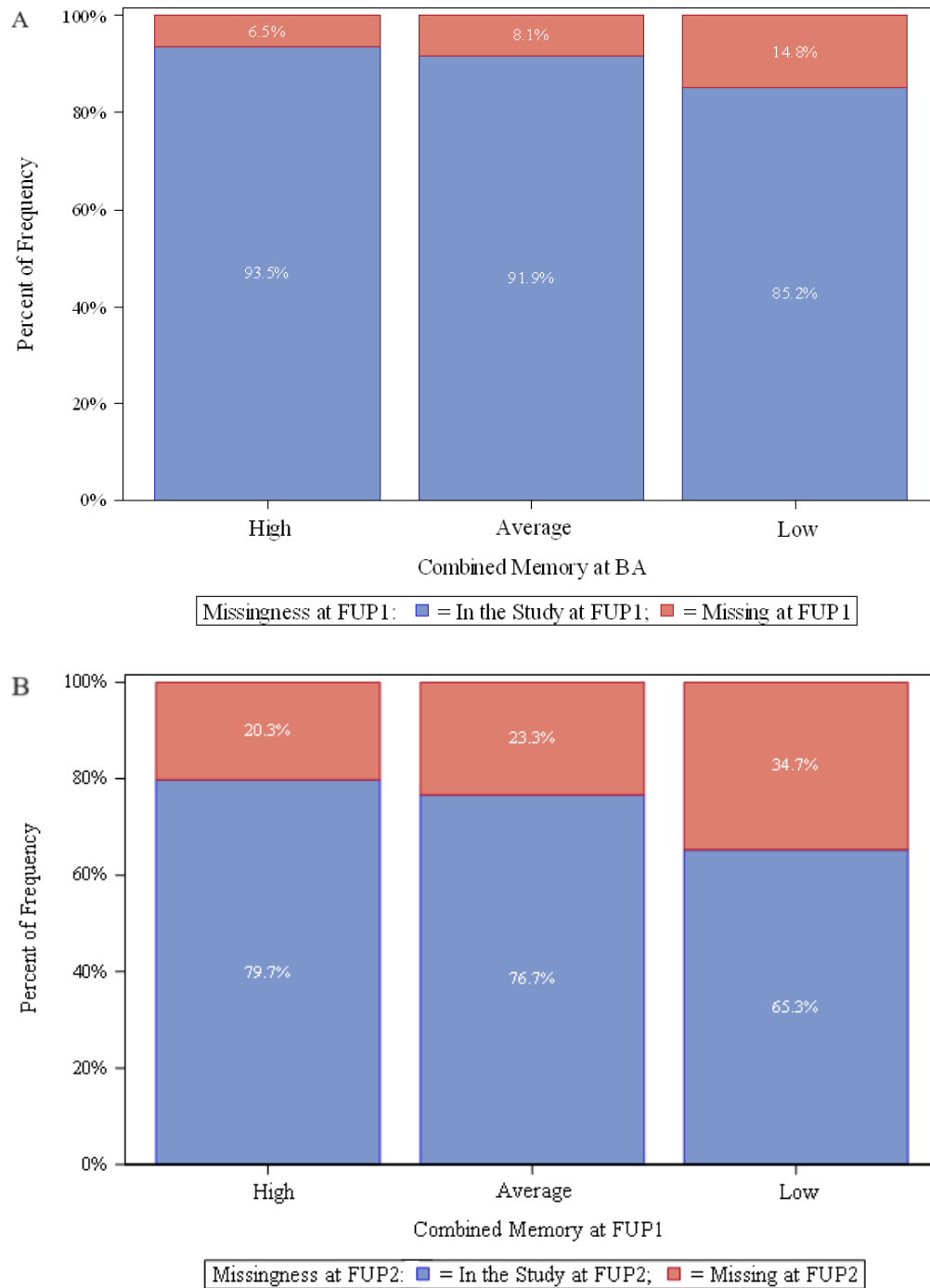
4.3.2 Attrition bias

Attrition bias in the memory outcome may explain why the inverse impact on memory weakened over time in the ‘neither’, ‘only SI’, and ‘only LON’ groups. Participants who entered the CLSA in the low memory group at baseline were more likely to drop out at both FUP1 (attrition rate for low memory [ARLM] = 14.8%; attrition rate for average memory [ARAM] = 8.1%; attrition rate for high memory [ARHM] = 6.5%) and FUP2 (ARLM = 34.7%; ARAM = 23.3%; ARHM = 20.3%) (Figure 9 A-B). Consequently, the apparent “improvements” in memory over six years were likely due to the fact fewer individuals with low baseline memory scores remained in the study over follow-up. Regarding the SI/LON groups, the dropout rates for the ‘both’ group (Figure 10 A-B) were slightly higher than the other three groups. However, this difference in dropout rates was not as pronounced as that seen with the memory variable.

Despite the attrition bias, memory deterioration over time was still evident in individuals initially classified in the ‘both’ group at BA. If the attrition bias had been smaller, the observed impact of being both isolated and lonely on memory might have been much greater. Therefore, the attrition bias likely skewed the findings for the ‘both’ group toward the null. Nevertheless, the results indicate that experiencing both SI and LON had a more substantial negative effect on memory than experiencing either condition alone, even among cognitively healthier individuals.

Figure 9.

Attrition Bias for Combined Memory



Notes.

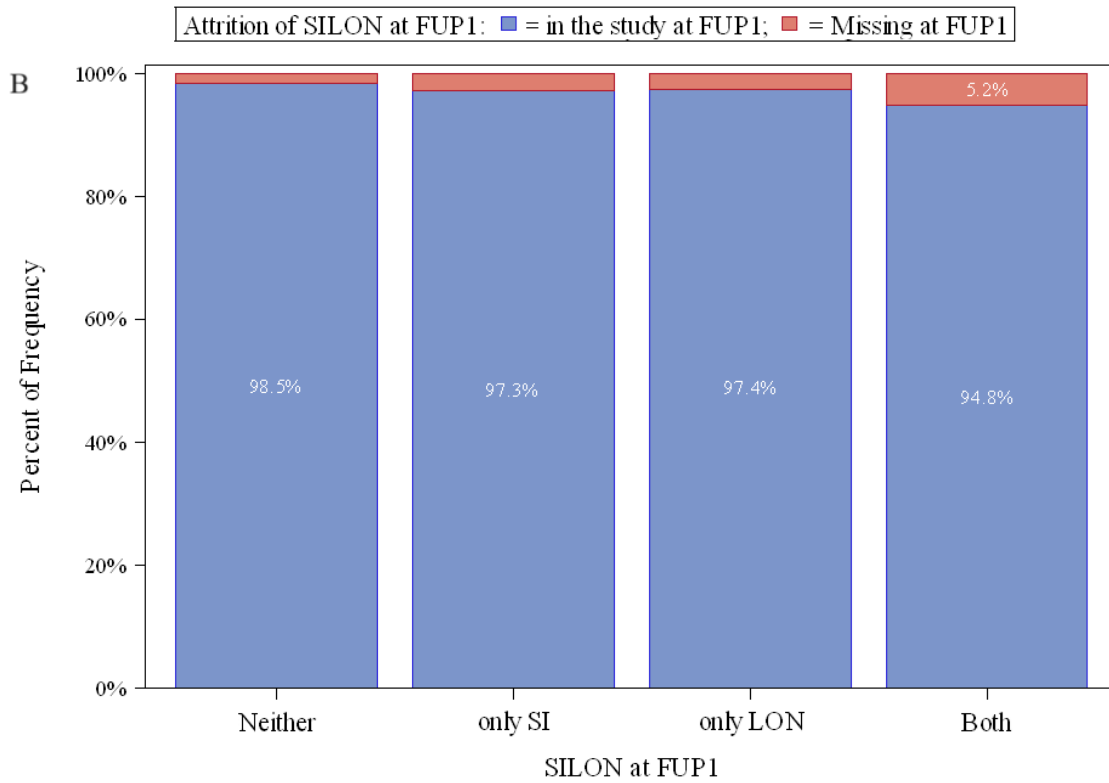
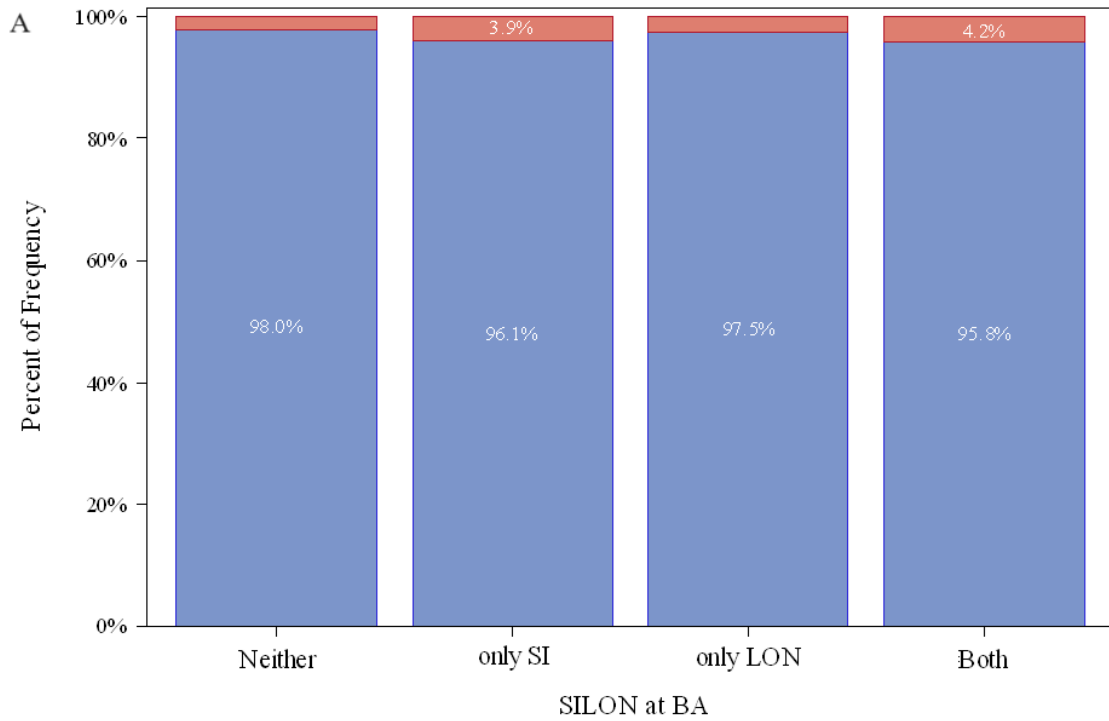
A = In/Out of Study at FUP1 by Distribution of Combined Memory Response at BA

B = In/Out of Study at FUP2 by Distribution of Combined Memory Response at FUP1

Abbreviations: BA = baseline; FUP1 = follow-up 1; FUP2 = follow-up 2

Figure 10.

Attrition Bias for Social Isolation/Loneliness



Attrition of SILON at FUP2: ■ = in the study at FUP2; ■ = Missing at FUP2

Notes.

A = Attrition at FUP1 by Distribution of SI/LON Response at BA

B = Attrition at FUP2 by Distribution of SI/LON Response at FUP1

Abbreviations: SI = social isolation; LON = loneliness; BA = baseline; FUP1 = follow-up 1; FUP2 = follow-up 2

4.3.3 Research question 2: Covariate models

Upon examining the covariate adjustments (Table 4), the adverse impact of all SI/LON groups on memory intensified after controlling for functional impairment (memory LSMEANS for ‘neither’ [LSMEANSneither]= -0.51; LSMEANSonly SI= -0.56; LSMEANSonly LON= -0.65; LSMEANSboth= -0.74) (Model 2) and in the full model (LSMEANSneither= -0.65; LSMEANSonly SI= -0.69; LSMEANSonly LON= -0.73; LSMEANSboth= -0.80) (Model 5, Table 4). Conversely, adjusting for lifestyle variables (Model 3) produced memory LSMEANS similar to those in the base model. The statistically significant differences in memory observed between the ‘only SI’ and ‘only LON’ groups, as well as between the ‘only SI’ and ‘both’ groups, in the base model became non-significant when adjusting for sociodemographic (Model 1) or health factors (Model 4), and in the full model (Model 5). Throughout all six models, no statistically significant differences in memory were found between the ‘neither’ and ‘only SI’ groups, or between the ‘only LON’ and ‘both’ groups (Table 4). This suggests that LON poses a greater risk to memory than objective SI alone, and the combination of both factors is particularly detrimental.

4.4 Sensitivity analyses

When comparing the findings from the primary analysis to the sensitivity analysis 1 (‘AADA’ alone), the LSMEANS estimates for all four SI/LON groups decreased in magnitude across all six regression models (Table 5). Additionally, the differences in memory between the ‘only SI’ and ‘only LON’ groups weakened and were no longer statistically significant (Table 5). However, the memory differences between the ‘neither’ and ‘only LON’ groups, the ‘neither’ and ‘both’ groups, and the ‘only SI’ and ‘both’ groups remained statistically significant. In sensitivity analysis 2 (multiple imputation), only the differences in memory between the ‘neither’ and ‘only LON’ groups, as well as between the ‘neither’ and ‘both’ groups, remained statistically significant (Table 5). Notably, these two pairwise comparisons showed significant memory differences across the primary analysis and both sensitivity analyses.

The multiple imputation approach involves imputing variables with uncertainty, which results in somewhat variable imputed values (in contrast to mean imputation). This variability can lead to wider confidence intervals compared to analyses using all available data, despite a modest increase in sample

size (in this specific study). Moreover, the LSMEANS estimates were usually smallest in magnitude in the multiple-imputed sensitivity analysis, compared to the primary analysis and sensitivity analysis 1 (Table 5).

Despite the differences between the primary and sensitivity analyses, all three approaches consistently showed that the SI/LON groups maintained the same pattern of memory scores across all six regression models: decreases in memory were more pronounced in the group that was both isolated and lonely, followed by the ‘only LON’ group, the ‘only SI’ group, and finally the ‘neither’ group. These analyses emphasize the robustness of this hierarchy across different sets of covariates and analytical methods.

Table 5

Sensitivity Regression Analyses Results - Comparisons of Social Isolation/Loneliness Groups for Combined Memory

Least Squares Means for Combined Memory Scores							
SI/LON groups		Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Neither socially isolated nor lonely	All Available Data Alone	-0.12 (-0.16, -0.08)	-0.20 (-0.25, -0.16)	-0.45 (-0.54, -0.36)	-0.17 (-0.24, -0.10)	-0.26 (-0.37, -0.14)	-0.57 (-0.71, -0.42)
	Multiple Imputation	-0.10 (-0.15, -0.06)	-0.16 (-0.21, -0.10)	-0.31 (-0.40, -0.21)	-0.12 (-0.21, -0.02)	-0.17 (-0.31, -0.02)	-0.33 (-0.52, -0.14)
Only socially isolated	All Available Data Alone	-0.17 (-0.25, -0.09)	-0.24 (-0.32, -0.16)	-0.50 (-0.60, -0.38)	-0.21 (-0.31, -0.12)	-0.30 (-0.43, -0.17)	-0.60 (-0.76, -0.43)
	Multiple Imputation	-0.16 (-0.25, -0.07)	-0.20 (-0.30, -0.10)	-0.36 (-0.48, -0.23)	-0.17 (-0.29, -0.05)	-0.22 (-0.39, -0.05)	-0.37 (-0.57, -0.16)
Only lonely	All Available Data Alone	-0.26 (-0.34, -0.19)	-0.31 (-0.39, -0.23)	-0.58 (-0.69, -0.47)	-0.30 (-0.40, -0.21)	-0.35 (-0.48, -0.23)	-0.63 (-0.78, -0.47)
	Multiple Imputation	-0.26 (-0.35, -0.17)	-0.28 (-0.38, -0.18)	-0.45 (-0.57, -0.33)	-0.27 (-0.39, -0.15)	-0.30 (-0.45, -0.14)	-0.42 (-0.62, -0.23)
Both socially isolated and lonely	All Available Data Alone	-0.42 (-0.59, -0.25)	-0.44 (-0.62, -0.27)	-0.73 (-0.93, -0.54)	-0.45 (-0.63, -0.27)	-0.50 (-0.79, -0.30)	-0.75 (-0.97, -0.53)
	Multiple Imputation	-0.34 (-0.56, -0.11)	-0.34 (-0.56, -0.11)	-0.51 (-0.74, -0.28)	-0.34 (-0.59, -0.09)	-0.36 (-0.61, -0.12)	-0.46 (-0.73, -0.20)
Differences of Least Squares Means for Combined Memory Scores – Benjamini Hochberg Correction Applied							
SI/LON groups		Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Neither socially isolated nor lonely vs. only socially isolated	All Available Data Alone	-0.05 (0.19)	-0.04 (0.32)	-0.04 (0.24)	-0.04 (0.24)	-0.05 (0.31)	-0.03 (0.44)
	Multiple Imputation	-0.06 (0.10)	-0.04 (0.20)	-0.05 (0.13)	-0.05 (0.13)	-0.05 (0.12)	-0.04 (0.29)
Neither socially isolated nor lonely vs. only lonely	All Available Data Alone	-0.14 (0.00)	-0.10 (0.00)	-0.13 (0.00)	-0.13 (0.00)	-0.10 (0.01)	-0.06 (0.04)
	Multiple Imputation	-0.16 (0.00)	-0.12 (0.00)	-0.14 (0.00)	-0.15 (0.00)	-0.13 (0.00)	-0.09 (0.00)
Neither socially isolated nor lonely vs. socially isolated and lonely	All Available Data Alone	-0.30 (0.00)	-0.24 (0.01)	-0.28 (0.00)	-0.28 (0.00)	-0.24 (0.01)	-0.18 (0.10)
	Multiple Imputation	-0.23 (0.00)	-0.18 (0.03)	-0.21 (0.01)	-0.22 (0.01)	-0.20 (0.01)	-0.14 (0.09)
Only socially isolated vs. only lonely	All Available Data Alone	0.09 (0.07)	0.07 (0.15)	0.09 (0.09)	0.09 (0.09)	0.05 (0.12)	0.03 (0.52)
	Multiple Imputation	0.10 (0.03)	0.08 (0.09)	0.09 (0.04)	0.10 (0.03)	0.07 (0.12)	0.06 (0.22)
Only socially isolated vs. socially isolated and lonely	All Available Data Alone	0.25 (0.01)	0.20 (0.02)	0.24 (0.01)	0.24 (0.01)	0.20 (0.04)	0.15 (0.11)
	Multiple Imputation	0.17 (0.04)	0.13 (0.12)	0.15 (0.07)	0.17 (0.05)	0.14 (0.10)	0.10 (0.25)
Only lonely vs. socially isolated and lonely	All Available Data Alone	0.16 (0.09)	0.14 (0.20)	0.15 (0.10)	0.15 (0.11)	0.14 (0.23)	0.12 (0.20)
	Multiple Imputation	0.08 (0.38)	0.06 (0.50)	0.06 (0.47)	0.07 (0.42)	0.07 (0.43)	0.04 (0.63)

Notes. Least squares means estimates are shown, with their 95% confidence intervals in brackets. For differences of least squares means, p-values are presented instead of 95% confidence intervals to facilitate comparisons with the Benjamini-Hochberg (BH) critical values. BH method sorts the p-values from all conducted tests in ascending order (i.e., from the smallest to the largest values) and then computes the BH critical value using the formula: $\frac{k}{m}(\alpha)$, where k = rank of each p-value, m = total number of tests, and α = significance level. The subsequent step identifies the highest k rank for which the sorted p-value is less than the corresponding BH critical value, and all p-values up to this k rank are deemed statistically significant. Statistically significant values are bolded ($p < 0.05$ or $p < \text{BH critical value}$).

Model 0 = controls for age, sex, education, province, follow-up time, and SI/LON*time interaction. Model 1 = Model 0 + area of residence + annual household income. Model 2 = Model 0 + basic and instrumental activities of daily living. Model 3 = Model 0 + alcohol consumption + smoking status. Model 4 = Model 0 + clinical depression + other chronic conditions. Model 5 = Model 0 + all other sociodemographic, functional ability, lifestyle, and health-related covariates.

4.5 Clinical significance

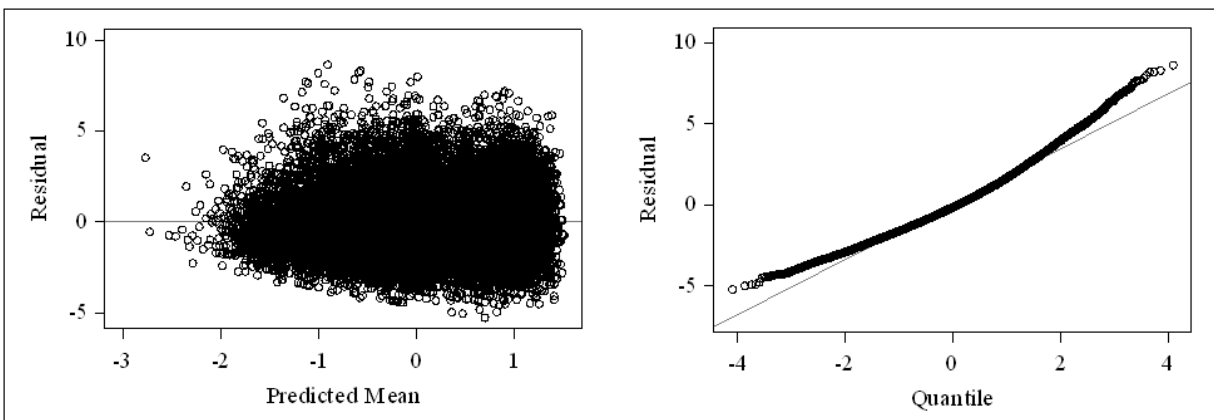
When applying the Cohen's $d = 0.1$ threshold to the full model (Model 5) of the primary analysis to assess the clinical relevance of this study's findings, clinically significant negative associations were identified between memory and the 'both SI and LON' group (Cohen's $d = -0.31$ [95% CI: -1.22, -0.39]) and the 'only LON' group (Cohen's $d = -0.12$ [95% CI: -1.13, -0.33]). However, no clinically significant association was found with the 'only SI' group (Cohen's $d = -0.03$ [95% CI: -1.09, -0.29]).

4.6 Diagnostic models

Figures 11 and 12 illustrate that the assumptions of linear mixed effects regressions were reasonably met for the full model in the primary analysis. In the residual versus predicted mean plot of Figure 11, the residuals were fairly randomly scattered along the horizontal line at 0, indicating adherence to the homoskedasticity assumption. Additionally, the normality assumption was satisfied based on the pattern of residuals in the Q-Q plot (Fig. 11), which align fairly closely with a straight line at a 45-degree angle.

Figure 11.

Residual plot

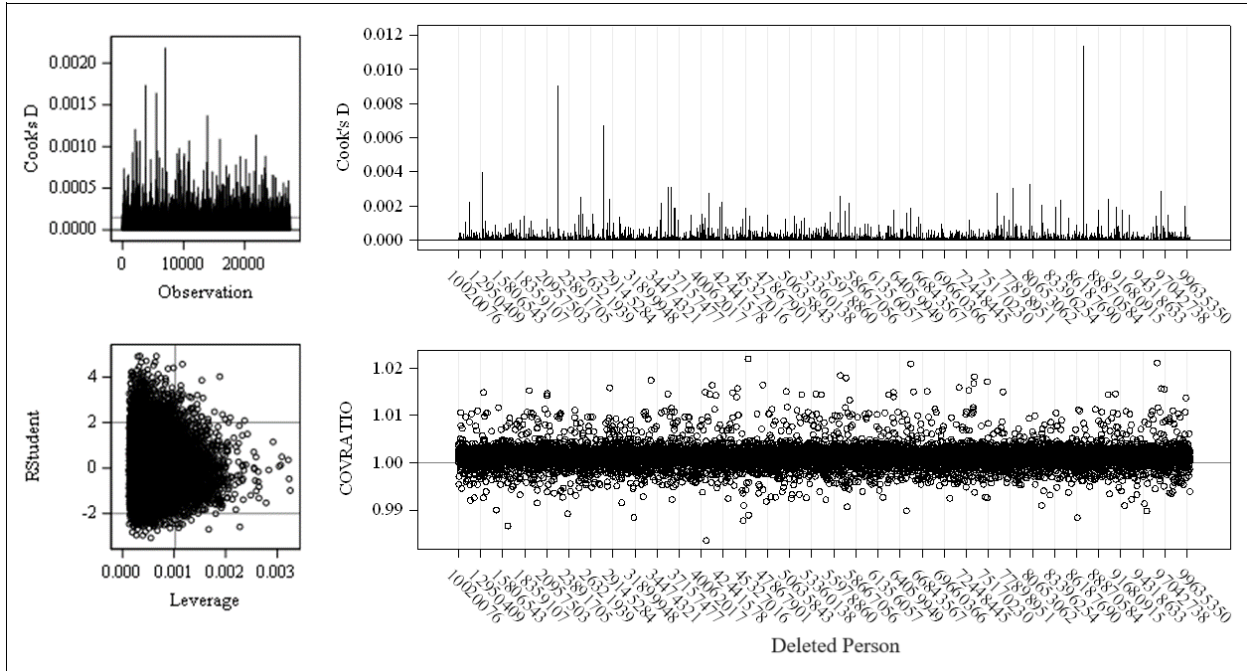


Notes. Residual vs Predicted Mean Plot (left); Q-Q Plot of Residuals (right)

Furthermore, our analysis did not identify any influential outliers because all data points remained within the Cook's distance threshold of 1. Additionally, the variance-covariance matrix exhibited ratios close to 1, indicating that individual observations had minimal influence on estimates of variances and covariances (Fig. 12). Multicollinearity was also not a concern, as indicated by the fact Variance Inflation Factors (VIF) for the explanatory variables were all below 10 (Table 6).

Figure 12.

Influence Models



Notes. Cook's D Model (top), leveraged statistics (bottom left), and CovRatio Model (bottom right)

Table 6

Variance Inflation Factors for Explanatory Variables

Explanatory Variables	Variance Inflation Factor
Time	1.06996
SI/LON	1.11530
Sex	1.06604
Age	1.23068
Education	1.09425
Annual household income	1.31807
Area of residence	1.02167
Province	1.01122
Functional ability	1.01771
Alcohol consumption	1.08190
Smoking status	1.03950
Chronic health conditions	1.04015
Depressive symptoms	1.11640

Chapter 5

Qualitative Results

Chapter 5 provides an overview of the participants' demographic information from Phase 2 of this thesis (the qualitative phase), while also presenting the key themes that emerged from the thematic analysis of the semi-structured interview data. As shown in Table 7, the study involved 10 Caucasian participants aged 47 to 81, with a slight majority of females. Most had post-university education and earned between \$25,000 and \$50,000 annually. Participants were evenly split between being married and living alone. Most were retired, and experiences of SI and LON varied among the group.

The overarching themes that emerged from participants' interviews are summarized in Fig. 13. The qualitative interviews revealed three key themes that illuminate the foundational experiences (essences) distinguishing SI from LON, alongside five key influences (or experiences) shaping the risk profiles for both SI and LON. Additionally, three themes emerged that highlight shared experiences and contextual elements influencing memory changes over time. The interviews further identified three themes that contrast the relationship between 'SI and memory' and 'LON and memory.' These themes provided insights into the underlying dynamics, suggesting that LON may have a more profound negative impact on memory than SI. Moreover, the interviews revealed two themes explaining why those who are both isolated and lonely have worse memory than those experiencing either factor alone. Lastly, the qualitative data revealed six themes about potential strategies and policy reforms for addressing challenges associated with SI, LON, and memory changes.

Table 7.

Participants' demographic information

Participant's ID Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Recruitment Site	SLR	SLR	SLR	Brandon University	SLR	SLR	SLR	SLR	Brandon University	Snowball Sampling
Age	81	66	76	70	64	74	80	79	58	47
Biological Sex	Male	Female	Female	Female	Male	Female	Male	Male	Female	Female
Racial or Ethnic Group	Caucasian	Caucasian	Caucasian	Caucasian	Caucasian	Caucasian	Caucasian	Caucasian	Caucasian	Caucasian
Level of Education Completed	Post-university degree	Completed university	Post-university degree	Post-university degree	Non-university diploma	Post-university degree	Post-university degree	Non-university diploma	Post-university degree	Post-university degree
Annual Household Income	> \$100,000	\$25,000 - \$50,000	> \$100,000	\$25,000 - \$50,000	\$25,000 - \$50,000	\$25,000 - \$50,000	\$50,000 - \$100,000	< \$25,000	< \$25,000	\$25,000 - \$50,000
Marital Status	Married	Married	Married	Married	Divorced	Divorced	Widowed	Married	Single	Common-law partner
Living Arrangement	Living with 1 cohabitant	Living with 1 cohabitant	Living with 1 cohabitant	Living with 1 cohabitant	Living alone	Living alone	Living alone	Living with 1 cohabitant	Living alone	Living alone
Retirement Status	Completely retired	Completely retired	Completely retired	Partly retired	Completely retired	Partly retired	Completely retired	Completely retired	Completely retired	Not retired
Social Activity Participation (at least once a month, within the last 12 months)	a, b, c, d, e, f, g, h	b, c, d, f, h	b, c, d, f, h	a, b, c, f, g, h	b, c, d, e, f, g, h	b, c, d, e, g, h	b, c, d, g, h	g	b, c, d, g, h	b, e, g, h
Monthly Visit with Social Network Groups (in the past six months)	Children; siblings; other relatives; neighbours; friends	Children; Siblings; friends	Children; siblings; other relatives; neighbours; friends	Children; siblings; other relatives; neighbours; friends	Neighbours; friends	Other relatives; neighbours; friends	Siblings; other relatives; neighbours; friends	None	Other relatives; neighbours; friends	Neighbours; friends
Overall Social Isolation Status Based on Menec et al.'s 5-Point Likert Scale	Not socially isolated (score 0)	Not socially isolated (score 0)	Not socially isolated (score 0)	Not socially isolated (score 0)	Moderately socially isolated (score 2)	Not ~ mildly socially isolated (score 1)	Moderately socially isolated (score 2)	Severely socially isolated (score 4)	Moderately socially isolated (score 2)	Moderately socially isolated (score 2)
Loneliness Frequency (in the last week)	Rarely or never (< 1 day)	All the time (5 – 7 days)	Rarely or never (< 1 day)	Rarely or never (< 1 day)	Occasionally (3 – 4 days)	Some of the time (1 – 2 days)	Rarely or never (< 1 day)	Rarely or never (< 1 day)	Occasionally (3 – 4 days)	Some of the time (1 – 2 days)
Overall Loneliness Status Based on CESD's 4-Point Likert Scale	Not lonely (score 4)	Severely lonely (score 1)	Not lonely (score 4)	Not lonely (score 4)	Moderately lonely (score 2)	Not ~ mildly lonely (score 3)	Not lonely (score 4)	Not lonely (score 4)	Moderately lonely (score 2)	Not ~ mildly lonely (score 3)

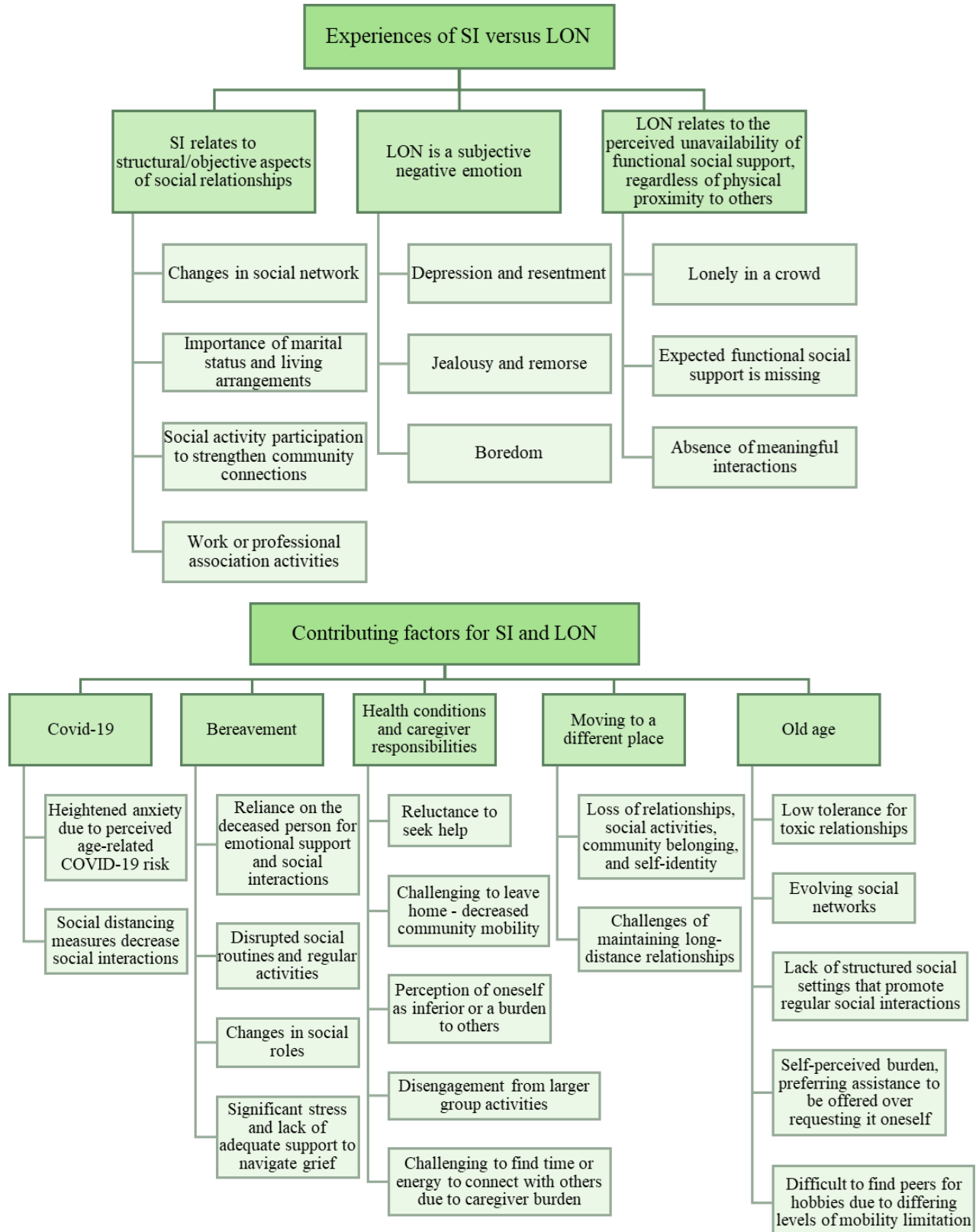
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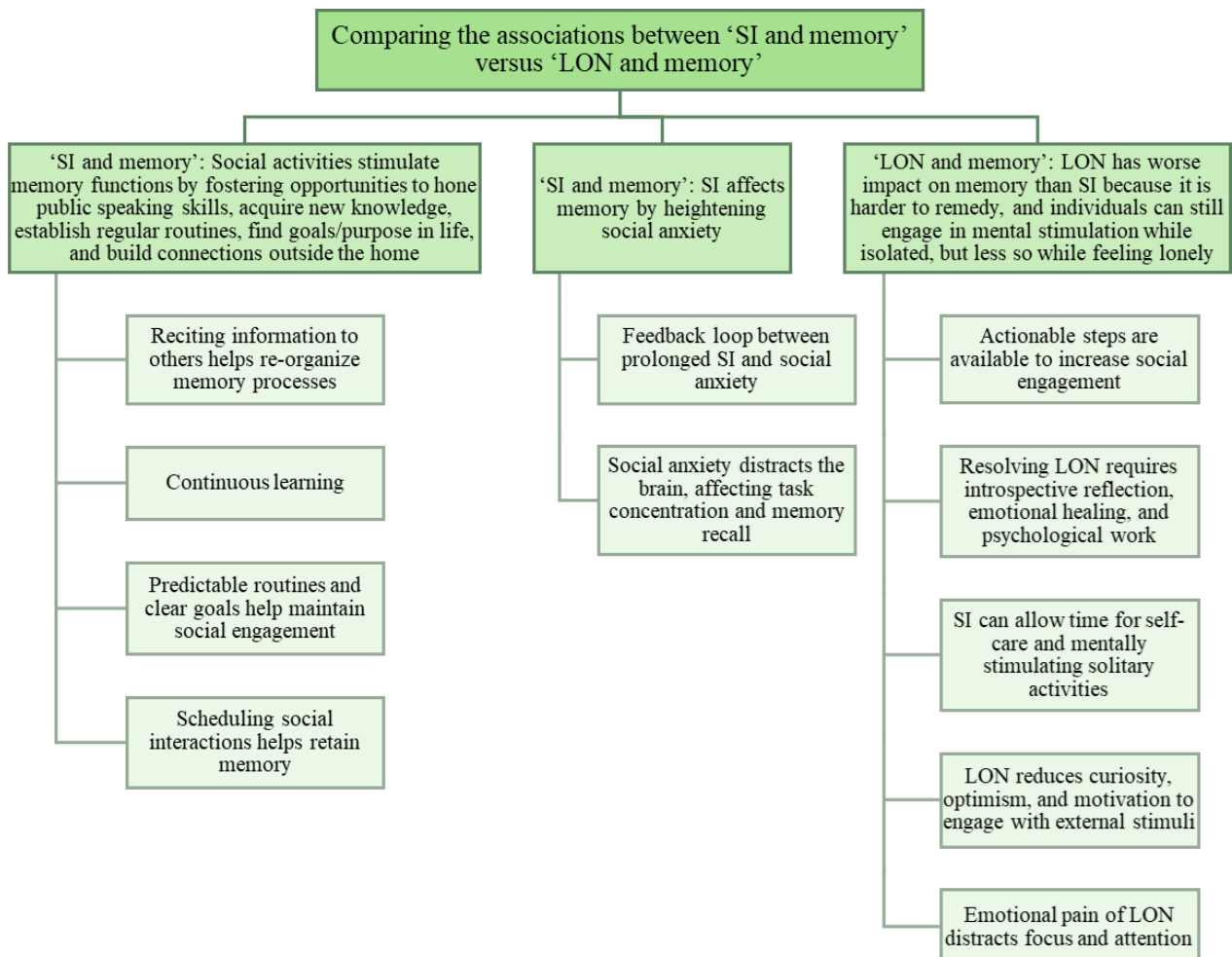
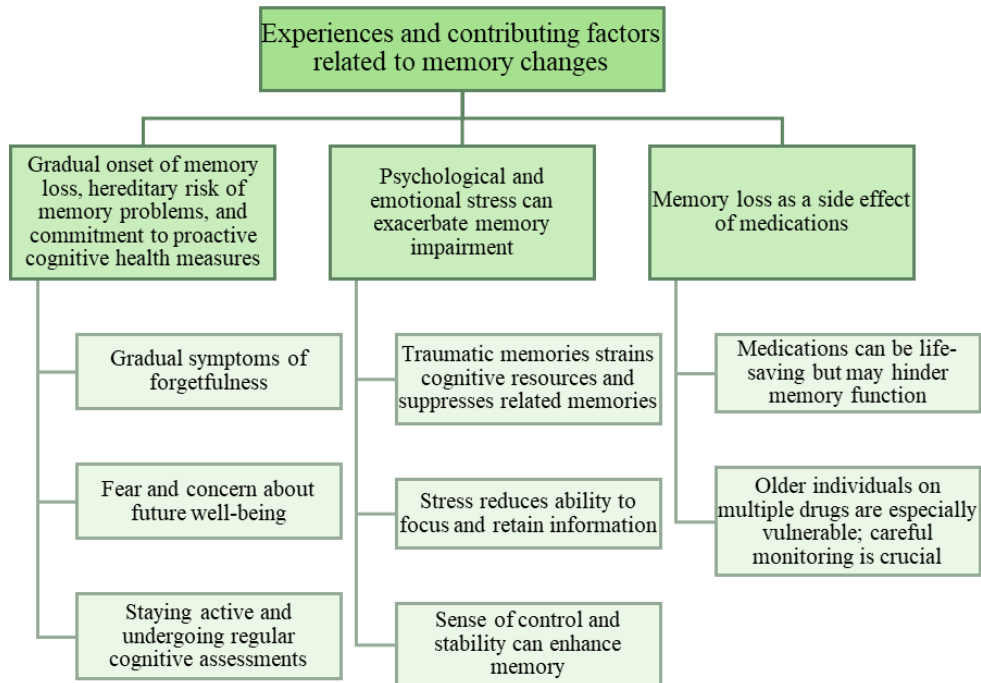
a = Religious activities; b = sports/physical activities; c = educational/cultural activities; d = clubs/fraternal organization activities; e = community/professional association activities; f = volunteer/charity work; g = other recreational activities; h = activities with family or friends outside of household

Abbreviations: SLR = Seniors Learning in Retirement; CESD = Center for Epidemiologic Studies Depression.

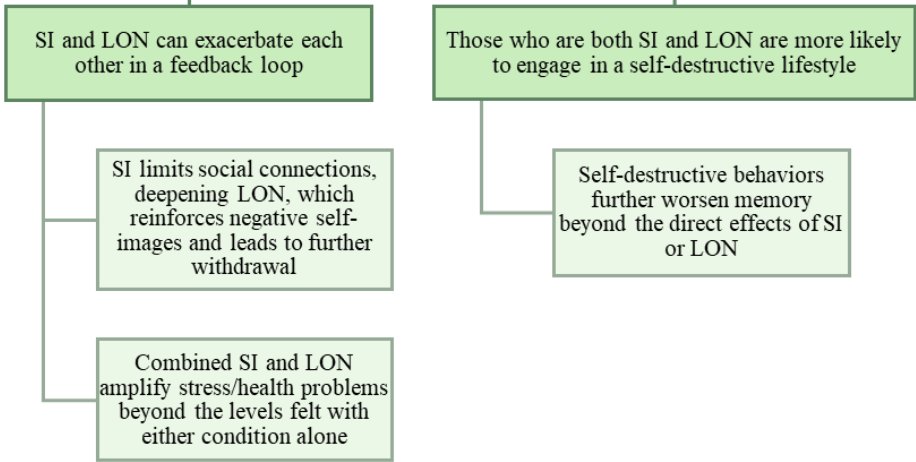
Figure 13.

Code tree summarizing themes, sub-themes, and codes

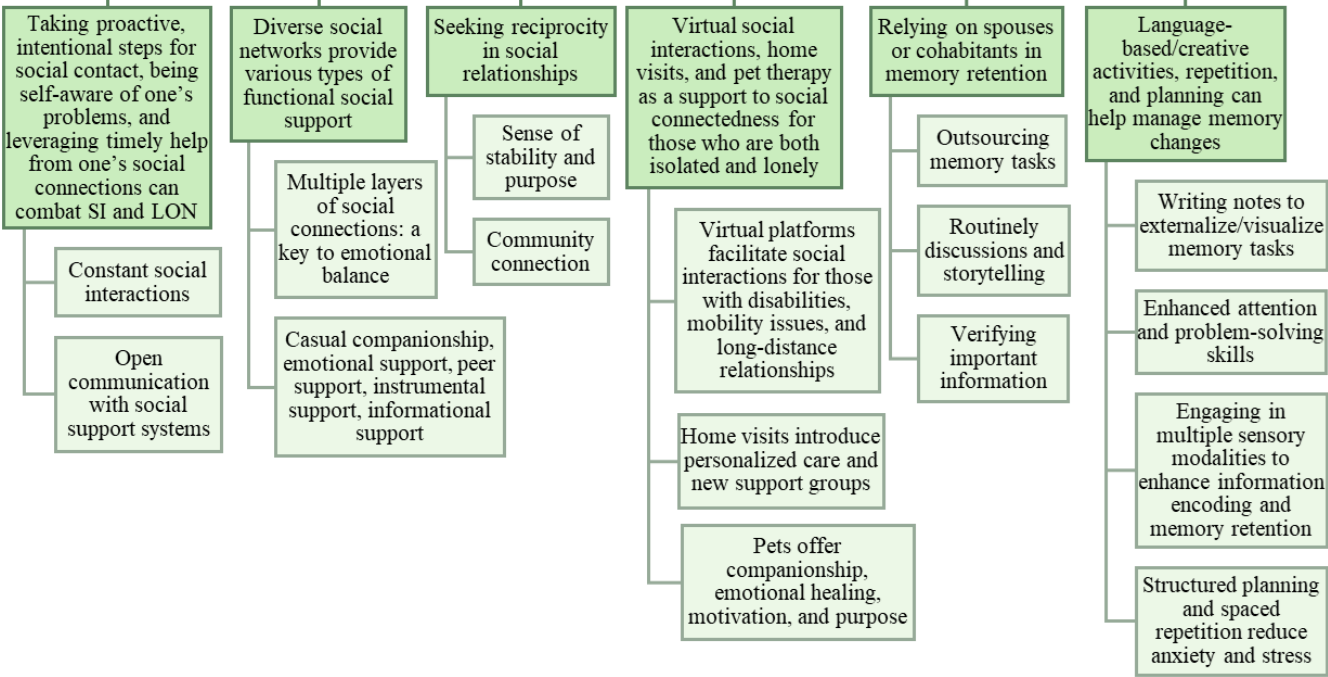




Memory decline in the combined isolated and lonely group



Strategies for addressing challenges related to SI, LON, and memory changes



Notes.

Abbreviations: SI = social isolation; LON = loneliness.

5.1 Experiences of social isolation versus loneliness

This theme identified the fundamental elements of SI and LON based on the descriptors provided by the participants. The aim was to understand how participants personally perceived and described their experiences of SI and LON, and how they differentiated between the two concepts. This theme is divided into three subsections, as follows:

5.1.1 Social isolation relates to structural/objective aspects of social relationships

Four out of five participants who were socially isolated emphasized that they became aware of their isolation when they experienced decreased social interaction frequencies or reductions in the size of their social networks. Some participants noted that these changes were often accompanied by a shift in network composition, where old social connections were replaced with new relationships:

“I feel like there has been a decrease in my social network size. And I've had to replace a lot of my older social interactions with the Seniors Learning in Retirement (SLR) group I mentioned, the exercise group, and the Kiwanis club.” (P1)

“I think social isolation is sort of being alone, maybe not alone-alone, but like not having a lot of interactions, social interactions, right? I think they are probably opposite, and I've certainly lost contact with more people as I've aged, and nowadays, I just meet with people less often.” (P10)

Three out of five socially isolated participants also remarked on the importance of marital status and living arrangements for SI, describing how living alone and not being married can lead to fewer regular or daily social interactions, even when they maintain good relationships with neighbours and friends:

“I'm not married. I'm an only child, and I have no children of my own. So, I do live alone, and I happen to live in a community that has great neighbors, but they are all considerably older than me. So, I often don't see anyone on the street even. So, it's interesting in that regard, in that I do feel isolated, not necessarily lonely but alone a lot of the time.” (P5)

“Another variable aspect I should mention is that I'm in a relationship, but my fiancée is in the army. So, I live alone, and he's actually in the special forces and he's deployed. So, we rarely, almost never see each other in person. [...] During COVID and like with the nature of his work, we didn't see each other for like 3 years over that period. And then, with less meetups with friends and whatever, I got very isolated and lonely actually.” (P10)

Five participants highlighted the role of engaging in social activities to mitigate feelings of SI and strengthen their sense of connection to the community. For instance, P6 and P9 described how

participating in various social groups (e.g., cycle club, SLR) and activities (e.g., movie nights, social gathering with friends, volunteering, bowling) cultivated a sense of belonging and camaraderie within their communities:

“I think the thing that probably made the biggest difference for me in terms, social isolation or lack thereof, was that I joined a cycle club here in the city. I've always been a cyclist, I used to run a cycle tour business. It was one of the many different things that I did when I lived up north. But anyway, so I joined a cycle club for maybe 6 or possibly even 8 years ago now, I've lost track. But anyway, I've formed quite a solid group of friends through that cycle club. I also belong to a group here called SLR, and they have social activities as well. I am in a group that's called [friend group name] and once a month, we go to the [theatre] and see a movie and then we go out afterwards and have a beer or whatever, have a drink, talk about the movie, that sort of thing. Yeah, so I go to various social activities through that group.” (P6)

“Social isolation to me is not participating in things that you used to like to do. Like if you were involved in a community for volunteering or something, and you stopped doing that. Those kinds of things, like if you were an avid bowler, for example, and you gave up bowling and so you didn't have that sense of connection and community. It can also mean like your friends calling you to go for lunch for coffee and turning them down because you just aren't feeling great.” (P9)

Participants emphasized the importance of work or professional association activities for maintaining social connections. Some described how, upon retiring or discontinuing other social activities, they endeavored to sustain their social engagement by substituting their former activities with alternative options, such as physical activities, educational/cultural activities, and involvement in clubs/fraternal organizations, or volunteer/charity work:

“I lost all my connections at the university on retirement. And that was not just my students but fellow faculty and so on as well. I still try to go into the occasional research seminar and that sort of thing, but it's really outside my life. So, I got pretty isolated, but a friend of mine said, ‘you should join us for a call in the SLR.’ And that's been a godsend because participants there give lectures on topics I know nothing about whatsoever, and they do their own research. You're going to lecture on some topic you wish you had visited but never had the chance to before. I'm also part of the Kiwanis club, which is essentially a group of men and women who get together and raise money for many children, and our main activity is the Kiwanis Music Festival. And what else am I doing nowadays? Well, I'm also doing exercises. So, my day starts at 7 am in the

morning, and I join an exercise group, and we're all bunch of old farts who wish we had more exercise, but we can't do much, so it's mainly walking.” (P1)

“In 2014, I retired from my job. And I had a great job, and I had a fairly close-knit staff. And I was a general manager of a community development agency, and we had a staff of about 8 people, just in a small town in Northern Ontario. And so, they were coworkers, but they were also friends. So, after retirement, there was a short phase in my life where I felt more isolated. So, I decided I needed to continue to work part time.” (P6)

“Most of my life, I guess any kind of social thing I had would be in work. So, where I meet with people is at where I work. I work by myself, and I worked as a carpenter, all that sort of business. So that was where my social thing was. I'd usually be with, say a couple of friends, one or 2 friends I would have, there's not a huge bunch of people that I knew and hung with. So that was my friends and socials. Now since I stopped working, you know, I don't have that type of thing. I guess for a while, I was working or doing yoga with a group but that also ended. So now, it's really just about 0 people I connect with.” (P8)

5.1.2 Loneliness is a subjective negative emotion

In contrast to the objective descriptors used to describe the experiences of SI, all participants noted that LON was an internal and subjective experience:

“I think that loneliness is more internal. Like I said, you don't have to be alone. It's inside of your head, you can feel very, very lonely, even in a crowd, right?” (P2)

“I think that feeling lonely is so internal. And it's almost like it can be a self-fulfilling prophecy. You're feeling lonely so you don't reach out, so you feel lonelier, and that's what I see around me. And for me, [back] in my 20's, it was a time when I had many connections, but I think I was looking for something, probably a mate, and I felt very lonely and very unable to connect. And friends were not as important as this business of finding, in my case, a man in my life. And so, then I married, and I still felt lonely, and the marriage broke up and I had 2 children by then. And then, I began to understand that the loneliness was very subjective, that it had really nothing to do with my objective state, that took a while to understand.” (P3)

All participants who identified as feeling lonely one or more times a week discussed how LON manifested as a complex and dynamic mixture of multiple negative emotions, rather than a simple feeling. Most participants likened these negative emotions to feelings of depression and resentment:

“Oh my gosh. I hate it here. That's another problem. I mean, it's contributing to my depression and loneliness. My husband grew up here in this house. He knows [city name] well, the weather issues and all that. But I grew up in Southern California and then we together moved to Hawaii for 20 years. So, I've never lived with these weather issues. It's like, what the heck? It's so awful outside. I mean, it's so depressing and gloomy. I mean, gloomy, that's the word. We've had gloomy days in Hawaii but not like this. This just goes on and on for days and it's awful. Yeah, so that's been a problem. And like the depression and the anxiety, you know, all these things sort of layer on and contribute to loneliness. They almost go hand in hand.” (P2)

“Loneliness is like withdrawal and implying a negative feeling, so maybe it's related to depression or something along those lines.” (P3)

“I think that loneliness is maybe connected to some neurological chemical or maybe connected to depression. I think they are sort of similar things.” (P10)

Others brought up feelings of jealousy and remorse directed toward self, others, current circumstances, or decisions made, while describing the experience of LON:

“I'm jealous, I'd love to live in Hawaii. [...] I feel like I've been trapped here. Now I feel like it's almost like I'm paying my penance for all the 20 years of living in Hawaii. Now this is what I get. It's like a punishment almost. It's terrible. It's terrible because my husband's a very nice person and you would love him, everybody loves him, but you know, the fact that he wanted to come back here and live out his life here. [...] My spirit, I feel like my home is Hawaii, not here. And I'll never recover from that because I'll never be able to live in Hawaii again. So that's hard, you know, it's a hard thing to accept.” (P2)

“I feel lonely if I know that some of my friends up north are getting together, because I used to belong to a dinner club. So, the dinner club continued after I left and so sometimes when I know that the dinner club is getting together and they're gonna do something fun and so on, then I sort of feel like I wish I lived there again, you know, that's something I'd love to go to and would like to be there. So, sometimes you feel sorry for yourself for specific things like that. Or sometimes, when I hear my daughter and her children upstairs, you know, obviously having a good time, laughing at whatever they're doing, and I'm not a part of it, then I feel like, ‘poor me, stuck all alone. I live down here.’” (P6)

“Loneliness for me is feeling unhappy. I mean, I look at other people around, and they've got this wheelchair thing, they've got maybe one leg, it's all screwed up looking, you know, but they're

still going around, meeting people, and I'm not. So, there's this whole, 'oh poor me' thing. I can't do this. And lately, I have to think too is, 'oh boy, I'm watching a lot of TV.' And years ago, I used to really think watching TV, you can just feel like you're going into a coma. It's like, 'oh good, I don't have to think about my problems or whatever it is.' Just wipes it out, don't have to think, don't have to worry. It's like a distraction from your reality." (P8)

Three participants associated feelings of boredom with LON. They noted that their sense of LON intensified when they didn't have activities to keep them occupied. Some stressed the link between reduced social activities and LON, while others pointed out that engaging in any kind of activity—whether social or solitary—was effective for combating LON:

"So, loneliness happens sort of after 7 o'clock at night or on Sundays. I thought about this a bit before talking to you and trying to figure out when do I feel lonely, and that's pretty much when it happens. I think for Sundays, it's because there's really no Zoom sessions, there's not a lot of things open to go to. I get really bored, so I tend to do those things on days when I know there will be people around. And after 7 o'clock at night, I guess I feel lonelier when the people I invite over have to leave and I'm in bed early at nighttime. Like everybody else kind of goes back to their own life, and I'm left with nothing else to do. When you get older, going out in the dark at night, it's lost this appeal to me. I used to have no problem with that, but I guess now it's harder to drive in the dark and so you just find yourself at home more often." (P5)

"Even if it's just getting out of my house and getting in my car and turning the music on and just going for a drive in the country, that tends to kind of help get me out of my state of being lonely, because it puts my thoughts into a different perspective. And it reminds me that there's more to me out there. So, if I'm feeling lonely, sometimes that's what I'll do. And then it just kind of helps pick me up a little bit. You know, taking that time in nature, and music is one of my passions. So that's something that really helps kind of reconnect me to what I need to do to stay healthy." (P9)

5.1.3 Loneliness relates to the perceived unavailability of functional social support, regardless of physical proximity to others

All participants who experienced LON shared that they became conscious of their LON upon recognizing the insufficiency in the quality of their social connections. This awareness often stemmed from the unavailability of emotional support, especially when they anticipated such support but found it missing:

"They [P1's husband's brother and his family] live really close by, but I thought we were going to be closer. I thought there was gonna be a lot more interaction with those people, like that was

gonna be my family. But they're not, it's not happening [...] I have felt kind of abandoned by the other people that were gonna be my support system here. And you know, it's not their fault. I don't blame them. I don't need to have bad feelings about people, but that's been hard and contributing to my loneliness.” (P2)

“I think the time that I would say that I've been loneliest in my life was when I was in an unhappy marriage, and I was certainly not isolated. I was living with my ex-husband, I had 3 children, and I was working full-time, so I was not socially isolated in any way at the time, but I felt very lonely. You know, I just felt very lonely and very alone with all of the emotional shit that I was dealing with, and my ex-husband wasn't really emotionally available for me. [...] I don't think he intentionally isolated me, but he wasn't able to provide that emotional support at the time I very much needed. So, it was a difficult time and it made me come to terms with the fact that I was not really getting what I needed out of the relationship. So, feeling as though the people that should care for you and the people who are in the position where ostensibly they should care about what's going on with you, but who you can't elicit any of that emotional support when you feel you need it, that's probably the definition of loneliness for me, or certainly it's the time in my life that I think I would have been most sort of consistently lonely for an extended period of time.” (P6)

Participants discussed how the absence of social support from their networks led to feelings of alienation, not belonging, or disconnection from others, even when they were in close physical proximity. They described how LON can manifest in social settings as the absence of meaningful interactions, even while being surrounded by people. This manifestation highlighted deficiencies in relationships, making their sense of LON more pronounced. In other words, participants acknowledged that LON is distinct from SI but felt that LON could arise from a lack of functional social support:

“I think in my sister-in-law's case, for instance, she was never completely isolated because her husband at that time was still living and was with her and one of the grandkids was living with them. But she was sitting at the kitchen table in the corner, feeling lonely, doing nothing. Same thing now, she's in hospital still doing nothing. I don't know if they said 10 words a day to each other, even though they lived in the same house.” (P4)

“I could still be lonely while interacting in those instances. And I'm not sure that it's necessarily coming from me as much as it comes from other people not communicating. So, I often find myself in situations where I'm the one who has to be the outspoken one to encourage others to talk, which doesn't help with my own loneliness, because if I really think about it, I can still be

lonely whilst talking to others. I often feel that way. I can be in the room with a bunch of people and still feel very much alone.” (P5)

“Being away and not having the ability to be around my people, I was quite young so that was my first real time away from my family for any significant period. And I mean, the dynamics of living in a group setting too were challenging. And so, I experienced some challenges there and you know, I did feel lonely and isolated even though I had 12 other people living in the same house as me. You know, you can be in the house full of people and still feel lonely.” (P9)

5.2 Contributing factors for social isolation and loneliness

This theme is broken down into five subsections demonstrating the specific factors that make middle-aged and older adults more vulnerable to SI and/or LON, as outlined below.

5.2.1 COVID-19

At the time of the study (follow-up 2 of the CLSA), COVID-19 acted as a barrier to social interactions and decreased participants’ engagement in social activities:

“We arrived April 1st, 2020, in Seattle. And if you remember, that was the epicenter of the entire COVID thing, with all the nursing homes and all that, that's where it all started. So, we already had this all planned, to go to see Seattle and drive our car over, you know, and we were going to go to all the national parks and have this wonderful trip across the country. That all just went down. And then, when I got here to [city name], I wanted to get into a choral group, like singing. I love to sing, you know, I've been told I'm a pretty good singer, but it's something that I'd like to do with a group. But everything was shut down because of COVID and that went on and on and on.” (P2)

“I do have a great network of friends and that sort of thing, which had you know, not gotten smaller, but had less interaction because of COVID, I mean I literally spent the first 10 months of COVID without actually seeing another human being, like literally. Before COVID, I was really active, always outside doing things with my friend group in Nairobi [Kenya], but then COVID happened and at the same time, I lost my job. So, like even with my coworkers, that connection was somewhat severed except for the few that I really put in effort into maintaining. So that was a very weird time as it was for everyone.” (P10)

These restrictions on social interactions not only contributed to increased SI, but also were accompanied by feelings of LON. Participants experienced heightened anxiety as they perceived themselves to be at greater risk of contracting COVID-19 and falling ill due to their age. Consequently,

participants were stringent in self-imposing social distancing measures. Their adherence to regulations naturally hindered their ability to interact with their social networks, leading participants to express a heightened longing for social connectedness and resulting feelings of LON during the COVID-19 pandemic:

“I felt that I wanted to see my mom because when you're that age, not that at that point she was ill, she was still very active and lived in her own house and everything, but I still had always gotten into the habit of making or putting aside leftovers from our meals, putting them to freeze and then dropping them off at her place. So, I figured pandemic or not, I'm going to see her and I'm going to bring the box. So, I left it outside the door, and we'd kiss through the window. And at one point, I brought a bed sheet, a king-sized bed sheet, tossed it over myself and I said, “mom, I'm coming in and I'm gonna give you a hug through the sheet.” And that was a really, really good connection. It felt good, there was the need to connect. So, the physical distancing regulations during COVID was hard for me with my kids and grandkids, but especially with my mom. You know, I figured, for the kids they've got their own lives. There's 4 of them in each household. They're busy, they're still doing things. But mom lived alone and had nobody, no neighbors, no nothing. And yes, we did have the Skype, but I really felt for her. I felt for her, although she never complained, she never did about anything.” (P4)

“I'm really isolated because of COVID. I was very strict at the beginning of COVID about where I went, who I talked to, and even to this day, 4 years later, I'm still 6 feet away from people and wearing a mask when I'm not comfortable in a situation. I'm being strict because I did lose a friend to COVID within the first 8 months of the pandemic. So that set me off on that path. And then now, I find that if I do let my guard down, I end up with a cold. I have it cross-fingers that I haven't got COVID yet. I'm even at the point of like questioning people like subtly so they don't realize I'm doing it but, you know, sort of where you've been and who you've been with kind of thing? Yeah, so of course that's contributed to loneliness, right? Because you're conscious all the time of who you're talking to and how close you are to people.” (P5)

5.2.2 Bereavement

Participants also mentioned that bereavement can exacerbate SI and LON because they had previously relied on a deceased person for companionship, emotional support, and social interactions. Bereavement therefore disrupted participants' established social routines and regular activities that were once shared with the deceased. With their loved one's passing, participants experienced a profound sense of LON and SI:

“I can certainly relate to feeling lonely and the isolation. The other day, I saw a picture of my wife and I, and we were skiing in Colorado, and that was like 5 years ago. You know, she and I were like best friends, and we always relied on each other and did things together. But she’s passed away and not here anymore and I’ve been drinking more since then. So, I feel lonely when I access her things, you know? It definitely feels like a bigger old house when I’m here by myself and see her old stuff. Or when I’m answering emails about her and seeing stuff on Facebook from years ago when she was still here.” (P7)

In particular, P3 shared her view that bereaved individuals may withdraw entirely from social interaction as they navigate their grief, and this withdrawal could further isolate them from sources of support that can help manage LON:

“This friend of mind who has just recently lost her husband has been, it’s been very interesting watching because he died suddenly, they were quite a couple, they had their differences, but they were certainly connected. Then he died horribly, you know, of COVID in the hospital, one of these awful things. And I see that she’s just not meeting people anymore. I think she’s lost her drive to socialize.” (P3)

P3 also noted that the death of a loved one could lead to changes in social roles within families and social circles. For example, P3 expressed apprehension about being left alone in the event of her husband’s passing, because her husband currently handled all household maintenance tasks. Without his support in this area, P3 anticipated experiencing feelings of LON:

“My husband is 84 now and he’s healthy, but he is 8 years older than I am, and so I will probably outlive him, and there is still the fear that I have, that kind of loneliness that has basically gone away in the past 40 years will return. So, it’s a pretty deep emotion. When my husband dies and I am left in this house, the question of loneliness may be something that has nothing to do with social connectedness, but I will be too much responsible for the workings of a house, and the yard, and I have a good sized garden, but my body is giving out a little bit and so, you know, how will that work, like will loneliness mean that I’m unsupported or that I always have to pay somebody to do something for me?” (P3)

In discussing how bereavement can often bring about a significant amount of stress and grief, some participants talked about how this experience of loss can be compounded by the lack of adequate support to navigate their grief, which can intensify these challenges and result in enduring detrimental effects on their mental health:

“When she [P2’s mother-in-law] died, she just collapsed in my arms. She was on the bed sitting up and she just collapsed into my arms. I guided her onto the floor, and she was not breathing. Her eyes were wide open. Her mouth was wide open. So anyway, that’s a thing that happened to me in 2019, so you know, I should be over it but it’s still, it’s kind of a source of my anxiety, depression, and my obsession with death and dying. And I’ve encountered many more deaths. My best friend, she died at 56 of bladder cancer. I couldn’t go to her ceremony because of COVID. She lived in San Francisco, and that was a huge grieving episode for me that I had no one to share it with really or help me deal with it. And when I talked to this therapist, she kinda just said, well, you have sort of a degree of PTSD. You have all these things that your brain is still always processing and it’s a trauma situation.” (P2)

“My only sister died at 47, she was sick for several years before that with breast cancer. And I was in my early 40’s, and as I said, I was working full time, I had 3 kids at home, I was married, blah, blah, blah, all of that. But in terms of being able to access any sort of emotional support for the grieving that I was experiencing from my ex-husband, I simply wasn’t able. So, that was the lowest point of my life, I was in so much grief and pain, and I was so lonely.” (P6)

5.2.3 Health conditions and caregiver responsibilities

Health conditions and caregiver responsibilities were additional concerns identified by participants as exacerbating SI and LON. For example, participants described how they would refrain from talking about or seeking support for their illnesses due to reluctance to reveal their vulnerable sides or because of the fear of being judged or misunderstood based on societal stigmas surrounding their health conditions. Hence, their health conditions led to heightened SI, LON, and feelings of alienation:

“I have a disability which is that I’m deaf on my left side, so I can’t hear and it’s an invisible disability, but I’ve always felt a little bit out of the mainstream, and I didn’t let anybody know about this when I was kid and teenager and even into my 20’s. And so, I always had to accommodate, like I had to have somebody on my right side because I’m deaf on the left side and do it in such a way that nobody would notice.” (P3)

“I used to be much more of an extrovert at one point in my life, but in 2014, I had a debilitating illness, and I was completely paralyzed from breastbone down. And I was 3 months in the hospital, and you know, this is 10 years later and I’m still recuperating. And during that time, there was no social connection. I didn’t even want people to see me the way I was. I was in excruciating pain. It was awful. In fact, I’ve told my boys and my husband that never again are they to bring measures to keep me alive. I’m glad I am, I guess, now, but what I had to go through

the first 2 years was just awful. And I would never, ever want to do it again. So, there was no, or very little interaction, I accepted some people, you know, after a number of times my son would say, because he really looked after me and he said, 'you know, your brother has been calling me every day. He really, really wants to see you, and it's not to come to see the circus clown, like he really wants to see you.' And so, I would give in, that sort of thing. So, he knew where I was and I didn't want people to see me in pain or me having to put up some façade or be on drugs so much that I can't even converse, to control the pain and then I'm not there." (P4)

Some participants added that their health conditions made it more challenging to leave home and be mobile in the community, thus exacerbating their SI:

"I think isolation is physical, like that really can happen physically to you. Like when you can't go out the house. I mean, heaven forbid, you know, someone who's bedridden or can't get out. I mean, how isolating is that?" (P2)

"A year ago, my eyesight started going bad, so I can't drive anymore. And I used to ride a motorcycle years ago, so I do wish I could just get on my bike and hit the road and just go. I can't do that now in my new life. Like from my perspective, it's more challenging to go out because I have vision problems." (P7)

In particular, P7 expressed feeling as though he had lost his previous level of functionality due to his visual impairment, which contributed to feelings of LON as he perceived himself as inferior compared to others:

"I still have my regular socials but there are times when I still get lonely. Here's another little example; I was trying to fix a camping gear, and it was a simple fix, I just needed to put the screw back on and put it back together. But I couldn't find the screw that fell out and I couldn't find the hole to put the screw in through. But I had a buddy that I had lunch with. So, he came back and put the screw in, because I couldn't find it myself. So, I'm thankful for him for doing that, but it feels like I'm a lesser person than I was before, yet life would go on." (P7)

Others discussed how experiencing an illness completely changed the way they think and interact with people, making them more introverted. They disengaged from larger group activities, partly out of a fear of being a burden or from feeling overwhelmed by larger group settings:

"I guess that [experiencing paralysis] really changed my habits, my way of thinking, and my ways of doing things. I now prefer my own little bubble. You know, being disabled for the better part of 2014-2015, it was very difficult to go out; having to always have someone there to help

me, having to tote a wheelchair, then a walker, and not being able to drive or walk anywhere was really difficult. We were living on an acreage then. So, isolation was basically imposed. It was much easier for me to stay home and just do physio gradually, adding a few household tasks. I did have people dropping by; my mom came to help out for a few weeks after my long hospital stay of 3 months. But I was very tired and not well and really did not want to have visitors that much. As I gained mobility, I felt much more confident in my own surroundings than in other places.” (P4)

“My dad was an outgoing person. But my dad is bipolar, right? So, he recedes in those days. And so even though he lives in a retirement home where he’s supposed to go for meals to a common area, where you can sit at the table with other people, I think he often either doesn’t go, so he isolates himself, or he goes but he doesn’t talk to anybody, which is very strange because he never used to be that way. I mean, my dad was a teacher and quite outgoing and you know, he was a friendly guy, and he had no problem talking to people. So, I think that change in his personality is connected to the disease, being bipolar.” (P10)

Caregiver responsibilities also disrupted participants’ social interactions and contributed to SI. Participants explained that it became more challenging for them to find time or have the energy/motivation to connect with others when they were focused on caring for a sick loved one. Caregiving duties also created uncertainty and unpredictability in participants’ schedules, thereby increasing the difficulty of committing to social engagements:

“I have another friend who is quite socially isolated now that I think about it. She intentionally isolates herself. She has been doing so more recently. I think partly because her husband is sick. I was telling you that one of my friends, her husband’s quite sick. I think that’s part of the reason why she’s not going out and seeing friends and joining in with things as much as she would have done formerly.” (P6)

“I decided to retire from coaching because it was a commitment, and I was just feeling like here I’m working full time, trying to do these commitments, and I’m getting older, and I just need to reduce that workload. And my parents were aging too and so a lot of my time right now is helping my parents. Spend time with them. It’s taken up a lot of my time over the last few years. So, I tend not to want to commit to stuff because I just never know what my schedule is going to be like. I was on my way to go to something yesterday afternoon, and my dad called and said the doctor wanted us at the hospital, and I was like, ‘drop that and away we go.’ So, I just don’t want to be

committed to a degree that I can't fulfill that obligation. And when my mom first went in the hospital, my dad was at there all the time.” (P9)

5.2.4 Moving to a different place

Participants frequently mentioned that relocating to a new area was associated with a sense of loss, such as losing touch with established relationships and social activities, thereby making it difficult to adapt to new surroundings and circumstances. Participants expressed experiencing heightened SI and LON during this adjustment period:

“I was socially isolated when I first moved here because really the only people that I knew in the city were my daughter and granddaughter. And I got to know people later on, but initially that's who I had. And I was lonely in addition to that because I was missing my relationships with my whole group of friends. You know, my whole group of friends when I lived in the community in northern Ontario, we participated in hiking group, I belonged to a dinner club. I mean I just had a lot of activities and friends. So yeah, it was quite a dramatic change.” (P6)

Some participants highlighted several specific challenges in maintaining long-distance relationships. These included difficulties in relating to each other's daily lives due to living in different regions, navigating time-zone differences, and the financial costs or time commitments required to visit one another. Participants had to continuously invest effort to bridge the physical distance and sustain their previous relationships, which led to considerable emotional strain, LON, and SI:

“There's a huge time difference in Hawaii. It's 5 h or 6h depending on the time of year. That's a huge thing to try to stay connected with people, when there's a big time difference. So, my conversations with my children are here and there, it's very intermittent. My daughter is doing contract work as a nurse, and so she's always on a different schedule and in a different place and you know, I can't just call her on a whim. She kind of has to reach out to me and say, 'hey, is this a good time to talk?' And it just doesn't happen as often as you think it would. It's weird because we were always really close, and my son, we lived like, I'm not kidding you, 30 feet apart in Hawaii. So, he was physically close. We were emotionally close. He would come over, give me a hug, and whatever. We were a close pair of mom and son. And now that is just gone. I mean, that's Hawaii, you know, it's a million miles away. It might as well be the moon. And then my friends, I mean, with the physical distance, we just rarely talk, they're so far away and it's so different now. And I'm Canadian now and it's just like I'm an alien. I can't, it's just really hard to relate.” (P2)

“For me to get home, it required a flight from where I lived down to Vancouver and then over to Winnipeg in order to come back to Brandon. So, it was a full day of travel for me to get home. And driving was not an option, it would have taken me the better part of 2 to 3 days to get home. So that is also what I classify as social isolation because you live so far away from your immediate family or your loved ones, that it's expensive and difficult to be with them. And I was quite lonely and depressed then too. The depression was diagnosed when I was living up in the northwest BC. And it was difficult because I had that realization of, I don't really have anybody who really knows me here. I didn't have anybody that I could really connect with because everybody that I knew was probably a work colleague in some way, shape, or form. So, it was hard.” (P9)

“I absolutely equate or relate, I guess, my recent social isolation to my circumstances of moving to Kenya, coming here alone, and trying to set up a new life and that sort of thing. [...] Now, I don't see any of those people anymore. Again, I'm not there physically. So maybe I talk to them a little bit less often, and it just requires a little bit more effort to sort of keep in touch.” (P10)

Participants also described how relocating resulted in the loss of workplace and community engagement, and the cherished memories associated with those groups, which had all contributed to their sense of identity and belonging:

“When we moved from Hawaii after being there for 20 years to here, where you know, I never lived here before, I had only visited, what happened is I lost all those things associated with my business, of course, but then also my family was there, my son and his wife, and then friends, of course. Friends that you have over many years of living in an area, and my home, which was the home that we built together and decorated together and always made the improvements together, my husband and I. So, we sold our house to move here, it was like gone from your life, which is, it's kind of a big thing when you contribute to it for over so many years. And then moving to a different country, I mean it hasn't been easy because that community I had in my small town that I lived in was my community. You know, people knew me, I knew them.” (P2)

“I left the place where I lived for 43 years. And my large group of pretty solid friends and coworkers and so on. And I moved to a city where I didn't know anybody because even though I had done my master's here, that was in the 1990s and so people move on, right? So that was a pretty dramatic change for me. Yeah, it was an eye opener in fact in many, many ways, to move to a city where I didn't have an existing group of friends and to no longer be working, so not even any coworkers near me.” (P6)

5.2.5 Old age

Lastly, participants discussed how old age can present obstacles to forming new social connections. As people grow older, they often develop a low tolerance for toxic relationships and become more selective about whom they allow into their lives. However, this heightened discernment can lead to or fuel SI:

“I think as you age, you become a little more curmudgeon, as they call it or whatever’s the word. You think you know about everything and think everybody’s a bunch of idiots and why aren’t they doing it my way? You know, you do get that. So, it’s hard to make friends when you get older, you just don’t. I’m sorry but I’m judgmental about people and oh my god, I’m a terrible person and I can’t put up with other people’s crap.” (P2)

“To be honest, I think that when you get to a certain age, you tell yourself that you no longer want to put up with people who don’t bring you joy. So, in the past 2 years, I’ve called out a few people. Sounds terrible, but you know what? They’re not bringing me joy, so I don’t need their troubles in my brain. So, I kind of am on my own, and have made myself lonelier just by doing that, thinking that I would run into other people that may be more interested in what I’m doing. [...] I have a higher tolerance for loneliness from being an only child my whole life. So, I’d rather just deal with that than deal with people who are toxic and being a bad influence. So, for me, the being alone part is more persistent than my emotional feelings of loneliness.” (P5)

P6 added that as one ages, it becomes increasingly necessary to make a conscious effort to prevent SI from persisting because social networks evolve over time (e.g., people move away, pursue their own lives), and relying solely on former connections becomes impractical. Therefore, it becomes crucial for older adults to proactively seek out new social relationships. However, older adults often lack structured social settings (e.g., school or work environments) where regular social interactions occur naturally, making it challenging for them to access opportunities to forge new connections. Therefore, individuals who are more introverted may find it easier to remain isolated and face LON, rather than venture out of their comfort zone and cultivate new social circles:

“Social isolation, it requires more effort to not let that persist. You really have to think, ‘okay, get off your butt and actually join a group or arrange to go and meet somebody to a coffee shop or whatever.’ But you’ve got to really work at it. It wasn’t hard to work at where I lived before, and I had a circle of friends and associates and when I had coworkers and all that kind of stuff. But now, the older I am, the more I have to work at it. Yeah, it’s easy to get isolated at an older age, don’t let that happen. [...] For my husband, certainly one of the challenges he’s facing is that he’s

living in a facility where he doesn't know the people. It's not the people that he's known all his life and that's hard. I've come to realize how hard that is at this stage in your life to forge new relationships. It's just so much easier to rely on the relationship that you've always known. And prior to moving here, to the retirement living facility here, you know, he lived up north as well. That was where we lived and raised our children. So, the people that he knew there, he'd known all his life. But when you're thrown into a situation where they're not around, they're just not accessible, then it's probably just a lot easier for him to stay in his room and watch television than it is to make the effort to try and forge some new relationships. I can see that if I were in that situation, it might be true for me as well. I'm more of a social person than he is but yeah, I can see that I would find that difficult too. So, I would say the biggest challenge for him is probably the effort that it takes to make new friends and form new relationships. At this stage in your life, it feels like hard work. I mean, it's not easy at any time, but I think it gets harder because it's like a muscle that you haven't exercised, and there's less social settings.” (P6)

As participants aged, they started to view themselves as burdensome or as lacking the ability to keep up with certain activities or groups, and these negative perceptions about their old age acted as barriers to participants' engagement in social activities. Participants were reluctant to burden others and preferred assistance to be offered rather than having to request it themselves. Therefore, when help was extended, or they were invited first, this helped them maintain their social interactions:

“I have to remember to not always be in my shell and to reach out to people who need help, but who feel that they don't want to ask. They prefer somebody to offer help because they don't necessarily want to inflict all of their angst and burden on others. So, I get out of my shell and go see those people when I know about it.” (P4)

“Me and like other people around my age, I don't like to ask for help. I prefer if help is offered if that makes sense at all. But I'm regularly interacting with my neighbours and because of that it's become easier for me to ask for help. That's always been difficult for me to do, but people are always telling me, just call me. And so, I've sort of softened my approach and ask for help from time to time.” (P7)

“Social isolation for me happens because I don't want to be a burden to other people, or people don't want to hear about my sad story all the time. So, I tend to socially isolate when I'm not feeling mentally well.” (P9)

Participants also expressed increasing difficulty in finding peers to share hobbies or engage in activities with as they grew older, leading to feelings of LON even during interactions with others. For

instance, participants noted that aging brought on reduced mobility for their friends, which limited these friends' participation in community activities. However, the extent of mobility limitation varied among their social circles, making it challenging to find someone who can engage in participants' desired activities at similar levels:

"I'm a little more physically capable than most of my friends. They're a little slower, and you know, with the walkers, and knee problems. I mean, I have knee problems, but they've got back problems, allergies, and all these things that keep them from being more active. But I like to hike, I like to bike, I like to walk, I like to kayak, you know, I'm a physically active person. They're older first of all, but anyway, we don't have everything in common." (P2)

"The only thing I find hard, and that might be for other seniors too, is finding people in sort of your own age group to spend time with. That's a struggle. So maybe that's part of when I do feel lonely. It's like I don't have a lot of people my age to sort of reach out to. And having peers around is helpful in sharing similar experiences. It's like I do have some friends who are younger, but they're not interested in what I'm doing, and my older friends aren't, you know, necessarily able to keep up with me when I go for a hike in the woods, right? [...] And again, I think the age group plays a factor there, right? Like I think you said 45 was your lowest age in your study. So, somebody between 45 and 55 might have a better chance at finding something they like to do and finding people to be social with. But when you get to be sort of 65 and older, then it's more challenging, you know, there's less of us. And I find that, I mean, I do belong to a couple of groups where there are a number of people who like to do the same things I do, but what happens is they already have their friend group. And they already, you know, they do associate with you whilst you're in that same activity, but the loneliness happens when you leave that. So, I would love to have solutions, but I don't know that our society is set up in a way to gather people together based on age. You know, there are groups that are like SLR and whatnot that are age-related but that's just a one-off social thing. I mean, not that I'm looking to build communes, but having communities of people of the same age would be fabulous. And if you make those kinds of connections at a younger age, then as you grow older, those people kind of go with you." (P5)

5.3 Experiences and contributing factors related to memory changes

This theme delves into participants' personal narratives regarding changes in their memory over the past six years and identifies the key factors they perceive as having contributed to memory decline. This theme is divided into three subsections, as follows:

5.3.1 Gradual onset of memory loss, hereditary risk of memory problems, and commitment to proactive cognitive health measures

While none of the participants were facing significant memory impairment, when prompted to share their experiences or perspectives on memory loss, participants noted a gradual progression of memory decline for them and others in their social circles, often beginning with subtle symptoms such as struggling to recall names, locations, and tasks at hand:

“I don't have a memory for names anymore. Yeah, I can't remember anyone's name. I've lost it all, it's hopeless.” (P1)

“My husband was a high school teacher and then a community college teacher here, and I watched his memory begin to decline and what went first was the names, so names of students. That's when he retired when he couldn't remember names and now, he struggles to get back there and remember the name, so everything stops while he tries and figures it out. And now, I'm noticing a little bit in him of, like I'll find the soy sauce in some weird place that, you know, we always put it in the refrigerator door but all of a sudden, it's somewhere else. So, who knows where that's going to lead, but watching his memory decline almost step by step and of certain things, and he will still remember act four scene two of Hamlet and be able to quote five or six lines or an incident of his childhood or who was left on the Titanic on the starboard side.” (P3)

“You know, we all do the walk into the other room thing and can't remember what the heck we went there for. You have to go back a couple times, you know? But I think that's just age related. But now, I even notice with like driving, and maybe this is a more serious memory thing. So, if I'm driving across the city to the other side, sort of part way there I'll say, 'where the heck am I going again and how do I get there?' And I have to stop the car, and I stop my thinking and say, 'okay, this is where I'm going, and I know how to get there.' But like that never happened before.” (P5)

Some participants disclosed that they had a family history of Alzheimer's disease, and expressed that the hereditary risk of memory problems instilled feelings of fear, dread, and concern about their future well-being, because they witnessed firsthand the potential progression and debilitating effects of memory loss:

“I have family history, a strong family history of Alzheimer's. My mother ultimately died from Alzheimer's and her mother died of a stroke, but she had signs of dementia before she died. I don't think it was ever diagnosed as Alzheimer's, but she clearly was suffering from early dementia. And apparently my mother's grandmother, she told the story of how she got to such a state that they had to keep her locked in her bedroom in the farmhouse where they live because if

she got out, she'd wander out into the fields, and they would lose her and so on. So, I think there's a strong genetic connection there. So, I've always been worried about my memory. My mother lived with Alzheimer's for 10 years and yeah, it was hell. So, I've always been really worried that that would be my fate.” (P6)

Participants took proactive measures to mitigate their perceived risk, such as committing to staying active (socially, physically, and intellectually) and undergoing regular cognitive health assessments, to safeguard their memory. This proactive stance illustrates how a genetic risk of memory loss can impact an individual's approach to cognitive health and well-being, as well as their daily lifestyle choices:

That's [Alzheimer's disease] something that I know is part of my family. It could happen, it's in my background so I keep it in check. I don't know that we can avoid getting it if it's something that is hereditary. I don't know, I haven't really pursued the matter that much, but I did have a test done at the clinic with my doctor and they did the first test, I don't know what it's called anymore. Anyway, she said, 'go home, don't worry about it.' So, it's okay. You know, I did it just to be okay.” (P4)

I have sort of vowed early on, years and years ago, to do whatever I could to try and make sure that I kept myself active, socially active, physically active, and intellectually active. Yeah, cause God knows, you know, we need whatever help we can get. Losing my memory is a scary prospect for me. It's the thing that worries me and scares me the most.” (P6)

5.3.2 Psychological and emotional stress can exacerbate memory impairment

Participants discussed how stress, trauma, and a sense of loss of control worsened their memory impairment. For example, P2 discussed how her post-traumatic stress disorder (PTSD) affected her memory, explaining that the necessity to suppress traumatic memories resulted in the suppression of other related memories as well. Such suppression could lead to memory impairment because the brain is constantly under strain to manage and compartmentalize these unwanted memories, thereby reducing cognitive resources available for other tasks:

“With my PTSD, I think that there's a lot of things I want to forget but I can't be dwelling on all this stuff all the time. I need to sweep it under a rug somewhere, put it in the back of my memory, and get on with what's in the front and what's important. So yeah, I do think for sure that these things that happened to us between, you know, 6 years, 5 years, whatever, I think my memory has definitely gotten worse, and the more things that happen to you that are traumatic, the more things you want to forget. I mean, isn't that what the post traumatic stress disorder is? You have

all these things in your memory that you don't want, that you need to keep them at bay so that you can function. And I think that's what's happened to me. Like there's a lot of things and then other things just get piled in there too. You know what I'm saying? Like, okay, a bad thing happened in 2019, the date was September 19th of 2019. I know exactly the day, but maybe a lot of other things that happened around that same time are just buried with it. Like it all got shoved in the back of that filing cabinet where I don't wanna pull it out and look at it. So, I think some of the traumatizing things which have contributed to my loneliness and isolation, have had an impact on my memory. It's sort of like I'm subconsciously suppressing any events that happened around that time.” (P2)

Similarly, P3 recounted how the stress from going through a divorce led to a noticeable decline in her memory. The emotional turmoil and constant worry during that period (about social judgments and managing her young children) impaired her ability to focus and retain information. She noted that over time, as her life stabilized and stress levels decreased, her memory improved:

“When I was going through the divorce and separation with these small children, my memory really declined. I could feel it here, in myself. But that's a whole element of stress that of course comes into our lives when something like that happens, and I was very worried then that I would never get back the comfort of my own mind and memory, but of course eventually it returned as things settled down. And I feel now, looking back, this is still the kind of element of stress that I was, I think my mind was always busy churning out whether those people liked me or not, or whether those people were likable, whether I wanted to like them or get more involved in them. So there was a lot of extraneous, what I call monkey brain stuff going on, and so my memory and my ability to focus on what I wanted to learn was impaired because of that.” (P3)

She further mentioned that her memory has remained relatively stable after her divorce, attributing this stability to the lower levels of stress in her current life, where she feels more in control with a supportive family and balanced social activities. This reduced stress level has allowed her to focus better during her social interactions and engage in memory-enhancing activities like puzzles, positively impacting her overall memory:

“I think that my memory itself, the retentive part, has actually not declined in a way that I see in other people, for example, my husband. He's not in dementia or Alzheimer but he's losing certain features of memory and I'm not. I don't know if I will, but I think that part of the reason is that I am under much less stress. Before, I was a single parent for a while. As a kid, I was always trying to figure out my place and so not really listening in classes and not really retaining information.

But now, certainly with my short-term memory, things like what I'm doing, where I'm going, how it's going to happen, and names, are in fact easier for me to recall now than they used to be, or at least as easy. And so, I think that the comfort and the feeling of groundedness that the social connections have given me also relieves a kind of stress level, so I don't have to worry about so many things. And you know, I have a blessed life. My kids are all healthy, grandkids too, we're all doing well. And so, I can concentrate on what's good about the day and what I need to remember. And the social activities I'm currently doing, it's a nice level of social activity so I don't feel overwhelmed by, you know, I've got to invite this person back, I've got to do this, I've got to do that. It's a nice balance and I feel that I'm in control of it, well given the parameters of anybody in control of anything. And so, it means that, if I look ahead at a week, for example, and need a day just to myself, I can organize that. And what that means is I can then go more slowly, attend more carefully to whatever it is I'm trying to learn. And I have the time to like, I do some sort of memory activities as well. And so, we're all doing Wordle and crosswords and keeping that up.”
(P3)

5.3.3 Memory loss as a side effect of medications

During the interviews, several participants discussed the intricate connection between medication usage and memory decline, particularly in the context of managing either their own health conditions or those of individuals within their social circles. They acknowledged that while medications could be life-saving and essential for managing chronic health conditions or pain, its usage often comes with side effects that could hinder memory function:

“And I suffered from aphasia, but the aphasia thing only came two years down the road because my physical symptoms were so vivid, of so much concern, and the memory thing was attributed to the amount of drugs that I was on because when I left the hospital after three months, I had three 8 x 10 bottles of medication I was taking. It was absolutely crazy, everything was in there. So, my memory was affected and then one of my friends posted on Facebook, she's a speech therapist. She posted on aphasia, and I read this, and I said, 'that's me!' I can tick, tick, tick, tick, I can check all these things. So I was in bed, it was probably 10:30 at night and I messaged her, and I said, 'do you want to take care of me? Do you want to see if I'm one of those?' And she said, yes. So, I did participate, and I helped through with aphasia camps. My aphasia had gotten better over time, but the first assignment was a thank you note, writing a thank you note. It normally takes what? 5 min. But it took me half a day to write a thank you note.” (P4)

“I was on a lot of morphine, so it was great for pain, it really really helped a whole lot. But then, I have to start thinking whether my brain is just older and wearing away, or whether the medications I’m taking are making me lose memory, and I’m kind of nervous about that.” (P8)

In particular, P10 highlighted the importance of careful monitoring and management of medication regimens, particularly for individuals who are on multiple drugs, to balance the benefits of treatment with the potential risks for memory and overall cognitive health, especially in older adults who are already vulnerable to memory impairments:

“Oh my god, he’s taking like a million medications. He’s just not healthy at all, he’s massively obese and just has lots and lots and lots of health issues. And he’s older, well 78, which is not that old compared to others, but in terms of that age and where he’s at, he’s not healthy. I mean, literally, he’s on, I would say, 10 different things, you know, there’s a list. Like every four hours, you gotta give him a new pill of some kind, and you know, I think that can’t not have an impact on his memory. I mean, technically, I know those pills are keeping him alive or making him feel more comfortable, but sometimes, I wonder whether it’s really, if there’s a give and take or a plus minus, because he’s really losing his memory a lot.” (P10)

5.4 Comparing the associations between ‘social isolation and memory’ versus ‘loneliness and memory’

This theme is organized into three subsections. The first two sub-themes examine the effects of SI on memory, while the third sub-theme focuses on the impact of LON on memory, providing a nuanced understanding of how each condition individually and distinctively affects memory. The third sub-theme also includes participants' explanations of why they believe LON has a more detrimental effect on memory function than SI.

5.4.1 ‘SI and memory’: Social activities stimulate memory functions by fostering opportunities to hone public speaking skills, acquire new knowledge, establish regular routines, find goals/purpose in life, and build connections outside the home

Participants, when prompted to reflect on the relationship between SI and memory, conveyed that the lack of social activities during isolation may contribute to memory decline. They noted that social activities offered opportunities to refine public speaking skills (e.g., leading discussions and presenting information in social settings) during conversations, which required participants to organize their thoughts and recall specific details (e.g., names, dates, and past events), thereby stimulating memory processes. Reflecting on these conversations afterward also served as a cognitive exercise, strengthening the neural pathways associated with the recalled information and enhancing memory retention:

“In the case of the nonfiction book club, for each book, they want a person to lead the discussion and a person to do a bio on the author. So, I volunteered to do the bio on the author for our next book, China Unbound, which is interesting. So anyway, they do require you to participate in, where you stand up and you make some sort of presentation, which I did with the music course too. And maybe I can get more comfortable doing that. It's hard, you know, public speaking kind of thing.” (P2)

“Even doing something like this interview with you, volunteering to do it, having an interest in doing it, and seeing where, as I'm talking, where I'm thinking, and I will of course reflect on this conversation after our call is over. So, I think it'll rejoin my memory.” (P3)

Participants also discussed how social activities, such as attending lectures and participating in community or professional association events, provided opportunities for continuous learning and challenged them to intellectually engage with external information rather than focusing solely on themselves. Participants believed that this ongoing exposure to new information could aid in maintaining memory as they age:

“I do note-taking for students who have disabilities, mostly hearing disabilities, hearing loss. So yeah, I've been doing that for six or seven years now and I like it because I get an opportunity to meet students and go to campus and attend lectures on courses that I otherwise wouldn't take. It really feeds me intellectually I would say. So, that hopefully keeps my brain a little sharper than it might otherwise be. I think just having to be there at 8:30 in the morning on campus and then having to focus on a lecture on a subject that I don't really know anything about and, you know, that sort of thing. I think it is having an effect on my memory, it's probably beneficial. I mean, I think of my ex-husband who stays in his apartment in that retirement living facility that he's in. And other than going downstairs to the dining room to have dinner once a day, I don't think he really interacts at all. And he spends most of his time watching television. I think that's basically how he spends most of his time, and I observe that his memory is not doing so well.” (P6)

“I belong to [mental health association], and I sit on that steering committee as well. And I actually was involved in a Safe Talk presentation on Thursday. So I'm still doing a bunch of stuff still and it gives me something to focus on. Something to research. I mean, when I'm doing stuff for health checks, for example, I get newsletters in my email inbox, and I read about stuff. And then when I read about stuff, I'm kind of an information hound, so I've got to go look it up and I've got to learn more. That's kind of where I go and so it helps me to just stay less self-focused and more externally focused.” (P9)

Participants also mentioned that social activities (including those related to work) helped maintain their memory by providing regular routines or structure to their lives, allowing them to keep their minds active with predictable schedules. These activities also offered a sense of purpose and direction in life, as they often involved pursuing interests, contributing to causes, or building relationships within their communities. Having clear goals/purpose motivated participants to stay actively engaged in these activities:

“We ran a business in Hawaii for 20 years. My husband is an orthotist and prosthetist, and I did all the paperwork, the administrative part of it. I'm the one that helped us get paid by insurance. There's no OHIP, you have to have insurance. Somebody has to bill that service that you provided, that was all me and it was very personal, because [P2's husband] did the work and then I saw that we got paid. So, there was a lot of effort put into doing that. It was my purpose, you know, in life. And I can honestly say my memory was better at that time. So, all these things that have happened, all of the moving and all of the dismantling our business, and even the improvements at our home, a lot of times I think, how did I do that? How did that happen? Who did we contact? What person did this job and what person did that job? Even putting it together now, to try to even relive or think about how it all came down, like folded out, it's hard. And the little things about memory which are just a mess like right now, I was just in my filing cabinet just a little while ago because I'm looking for a piece of paper that I know I've seen. I know it exist on this planet. But I cannot find it because I don't know where I put it. When we were working, we had a whole different filing systems in the house and, you know, in my job in Hawaii and our business, I kept track of everything, we had a giant file, and I kind of knew where everything was, for the most part I did. I mean, when you're working away every single day, it's fresh in your memory, you would know what to do exactly. But since moving here, I just don't know where anything is anymore. I don't have regular things to tend to, and I'm constantly, I cannot find things and it's so frustrating.” (P2)

“I mean, it [note-taking in lectures] kinda gives a shape or structure to my week, frankly. And I like that, I think there's some sense of security that that gives me. The sense that, you know, there are days when I simply have to be dressed and showered and look presentable and out of the house and going somewhere and interacting with people and yeah. Even if it's nothing more than getting in my car, driving to campus, finding a parking spot, walking to class, sitting and listening to the lecture. Like there's not a whole lot of social interaction that's happening there, but I think that helps keep my memory and helps keep my brain sharper.” (P6)

Social activities also helped participants build connections outside of the house, and they noted how scheduling these social interactions and managing goals were crucial exercises for retaining their memory:

“I think, especially for those who move from a different city, they have no contact with anyone, and then all of a sudden, they get like, ‘tell me about what you did last week, and that sort of a thing.’ So you gotta remember the things happening in your life. And I’m in charge of getting speakers for the Kiwanis group, and I’d say that’s the only thing that keeps my few brain cells turning over nowadays, it’s getting speakers. For instance, people who participated in that SLR group, I asked them if they would mind repeating it for the Kiwanis, and keeping track of that schedule, well, my calendar is just full of speakers and juggling them. So, they change and bounce around all over, so that’s what my primary activity mentally is.” (P1)

“If you’re isolated, physically and socially, then you have nobody to talk to, so your memory will be affected. Like your brain is always regrouping what it is you’re going to do, and when you’re gonna do it. So that helps you remember, or at least my computer does. You have to manage different schedules and make sure you remember what you talked about with others.” (P7)

5.4.2 ‘SI and memory’: SI affects memory by heightening social anxiety

Among the participants, those with a greater degree of SI or who had undergone prolonged periods of SI at some stage in their lives (regardless of their current SI status) spoke to how such prolonged isolation could induce social anxiety about leaving the house or interacting with people, subsequently leading to further SI and memory issues:

“The less you talk to a person, the harder it gets to talk to them. I mean, if we talk once a week and we were always up to date on everything going on in each other’s lives, that would be easier to maintain than when it’s like only here and there every couple of months. It’s like, I don’t know what to talk about, and it just gets harder and harder to stay connected or reconnect when you’ve been unconnected. And this is social anxiety.” (P2)

“I’ve noticed over the past years, it wasn’t so prevalent at the beginning of the pandemic, but it’s curious to me that over the past year, I’m finding it more difficult to leave the house and get in the car and go somewhere. I really think it through before I do it. And it really has 2 parts. One is the challenge of physically getting myself to go out or allowing myself to do that. And the other part is the challenge of when I get to where I’m going, what am I going to experience there, right? And I don’t know that my desire to be less lonely weighs more than these other things that are

happening in my mind. So, the longer you're isolated, the sort of anxiety about just being in social environment becomes more of an ordeal than it was before.” (P5)

“The other thing is, you know, like two years ago or three years ago, when I was shoveling the snow, I started thinking, I’m really not sure how much I can do that anymore. And again, the thing is, with my lack of being able to talk so much, sometimes I just can't say the words I want to, so I feel nervous about connecting and getting to meet new people, when I can't say what I want to say, and I can't say the word. So, I can't really ask for help with shoveling snow. That's where I'm at right now. In some way, I try to avoid social situations.” (P8)

Social anxiety created distractions for participants during their social interactions and made it challenging for them to concentrate on given tasks and remember information from their past conversations:

“My mind, there's so much distraction in my busy little brain, and it has to do with my social anxiety, and what's gonna happen, what's going on, how's this gonna work? My busy brain is distracting, and I think that's what the memory problem is. I mean, if I try to figure out why I didn't know what I needed when I walked in that other room, it's because my busy, big brain was thinking about something else. And it seems like it's happening more nowadays, and I feel like it's related to that distracted brain. It's the overstimulation of being out in the community, I mean just getting to the parking lot and getting in the store and then you go, 'shit, I forgot my list.' You might as well go home because you're not gonna, you know, are you gonna be able to put together now standing there in the store with all these people around and the noise and the music and the things that are driving, you know, they're overstimulating you. No, because it's not in my head anymore. It's gone. So, the social anxiety, it definitely has an effect on my memory. I know it does. I know that I am less focused when I get anxious.” (P2)

“I've noticed lately that I don't have the recall that I used to have. I know it's in there, it's just I can't get it to come out. I also have another self-diagnosed condition where my brain will think of five different words to answer a question, and I can't quickly decide which is the best word to use. So therefore, I'm so busy thinking about that, that I forget what I'm really talking about. I don't know if that's related to age or just my own condition or what it's coming from. But if you ask any of my friends lately, they'll say that my memory is probably fading a little bit, but I think it's more related to the distractions in my brain. It makes me lose my train of thought. And I think that when you spend a lot of time by yourself, you start talking to yourself, right? In your head. So then when you start talking out loud to other people, that's where my train of thought gets a little

jumbled, and I have to say to myself, 'oh yeah, you are talking to other people, pay attention.'"
(P5)

5.4.3 'LON and memory': LON has worse impact on memory than SI because it is harder to remedy, and individuals can still engage in mental stimulation while isolated but less so while feeling lonely

Aligning with the results from our quantitative study, participants believed that LON has worse impact on memory than SI. Participants remarked on how difficult it is to gain understanding from others about LON, as it is an internal feeling that must be resolved personally. In contrast, they explained that SI, although difficult, is somewhat more manageable because actionable steps can be taken to increase social engagement (e.g., reaching out to others, inviting company over, participating in community activities). Hence, they found that LON was more challenging to address than SI:

"I'm totally isolated but I'm calling to places to let them know I'm feeling really, you know, isolated. For me it was the SLR, the [nursing care organization], like people can reach out, so maybe social isolation is a little more fixable than loneliness. For the isolation thing, you can have people come over, you can reach out and make a new connection. And loneliness is like this feeling. It's a feeling that can overtake you, and maybe it isn't as easy to, fix or address. So, the loneliness has really been a problem for me. And it shouldn't be, you know, people tell me, you got it made. You shouldn't feel that way. I hate people's comments like that, you know, but I've been known to say that too. You shouldn't feel that way. You shouldn't feel that way. But you can't tell someone how to feel. They feel what they feel. You know, it's hard to even put your finger on it. And it's hard to get any understanding of it from other people. I feel really lonely. Okay, well, what can we do about that? I don't know. I'm the worst. You got any ideas? I'm out, fresh out of ideas. And you can maybe help that person get through those feelings, but you can't just give an immediate solution, so loneliness is just a much more difficult hurdle. And I felt it. I felt it a lot. Like, it's a feeling in your stomach, you know, it's just like a gut pain. So that's way worse because for isolation, usually there's a way around that, and if you have a partner, have somebody, just one important person in your life, they can rescue you on a daily basis from becoming completely isolated." (P2)

Other participants also reinforced this idea by pointing out that in an urban environment, there are ample opportunities for social engagement (e.g., volunteer opportunities, social clubs, religious/cultural groups) for those seeking to connect with others. Therefore, for those who are simply seeking to increase their social interaction, this can be addressed, as long as they are willing to ask for help. However, overcoming LON was portrayed as a much more complex process that requires more than just social

interaction to overcome, often necessitating deeper introspective reflection, emotional healing, and psychological work:

“I think social isolation is easier to fix than my internal emotions of feeling lonely. I think, moving away from social isolation is, to me, is pretty straightforward in an urban setting. You know, we're in [city name], there're lots of opportunities to socialize. I don't know what happens in rural communities or if you don't drive, you know, but you can, oh my goodness, there are so many groups and so many invitations and so much volunteer work and so much stuff this world needs. And honestly, there are some services out there for shut-ins too, although very imperfect. I used to deliver books to people who were shut-ins in the library system years and years ago. And they were often people who were immobilized and who were lonely for sure and who just wanted some kind of human connection but were unable for whatever reason. And so, if you are socially isolated and want to connect, it's honestly quite easy. But the loneliness, I don't know how people get over feeling lonely without doing the psychological and emotional work that it has taken me. I think I have a high level of concern about that in my own life, but if you feel lonely, you gotta do this psychic work or you're just gonna be stuck in that lonely stage.” (P3)

On the other hand, some participants acknowledged that SI could become persistent for those who do not perceive being isolated as a problem. However, SI was not regarded as adversely affecting memory in cases where individuals sought solitude and saw their socially isolated state as providing them with quality self-care time, where they could focus on their personal needs:

“I think social isolation by itself doesn't really affect my memory all that much. No, because when I'm wanting time to be alone, that doesn't affect my memory. It's sort of helping me to file all my stuff. It allows me that time to hit the reset button. Practice good self-care and yeah. And I mean, I could be tending to my vegetable garden. I could be doing some housework or some renovations, but every now and again, I just need a pajama day and a movie day and just completely decompress and have some kitty cuddles and then I'm good. So, for socially isolating, I do that more intentionally than when I have periods of loneliness. I isolate to recharge my battery.” (P9)

While practicing self-care during their isolation, many participants still engaged in solitary activities that occupied their physical and mental capacity, once again diminishing the association between SI and memory:

“We have another friend, who lives nearby who's 94 and he has terrible mobility issues, but he never seems to be lonely, and I'm always amazed at that. I mean, I don't even know what he eats

because he's thin as a rail, but whenever we have him over, he's very pleasant, he's full of conversation, he's been reading this and going, or not going anywhere, because all his activities are from his house. And I sort of think, wow, there's somebody who could have gone down a very lonely road. He's alone in this big house that he's living in because after his wife died, he decided to stay there, and his only son will inherit the property and eventually retire from the [university] to [city name]. Anyway, although he's isolated, I think he has a wide range of people he can connect to on an intellectual level, so he'll do projects for SLR, and he'll be reading and studying something in some kind of depth. Generally, the people I know who are apparently not lonely and who are socially isolated, they seem to occupy their minds with intellectual activity or artistic activity. And so, I don't see a memory decline in them. Yeah, I'm not sure that there is that direct connection between social isolation and memory loss as there is between loneliness.” (P3)

“I'm still doing things and using my brain when I'm isolated. I think I'm lucky that my hobbies are very much something you do isolated, right? If you're taking photographs or if you're creating art or even when I go to dance class, I'm with a group of people in dance class, but I am still in my mind, using my memory to remember the steps, to listen to the music, it's still a very individual thing.” (P5)

“I think that if I'm not working on some kind of an activity that engages my brain on a regular basis, on a daily basis, I'm not doing so well. And I think there are 2 types of socially isolated people. You have those that are still keeping themselves intellectually active in some way, and then the other type is when you're just not partaking in anything. That would be my observation. So, even if I have a week where I don't actually get together with any friends at all, but I go to the pool and swim a couple of times, I get out every day and walk the dog for an hour, I maybe go and see a movie by myself or you know, that sort of thing. Even if I'm not actually interacting with other people much, it's important for me to just be active.” (P6)

However, when socially isolated individuals were not engaging in any intellectual activities and even lacked the motivation to seek help, SI had a more serious negative impact on memory functions:

“I also think that people who are isolated need to stimulate themselves; however it is that you do it, it doesn't have to be explicitly social. My husband's sister is in a care home and she's only 73 and she's been in that care home for 5 or 6 years already. She's in her bed with nothing. She looks at the wall. She refuses to have a TV. She refuses to go out to look out the window. She doesn't want to ask us to take her for a ride in the hallways or anything. I think she's just existing. She's not even living. I don't think that's living, she's lost all motivation and she's given up on

her life. So, I think her dementia is her choice. They say she has dementia, but I don't really think she has dementia. I think she's just not thinking because she doesn't have the drive to live.” (P4)

“And since we moved here to [city name], I've really never connected with any people other than my partner I live with. So, having next to nobody here, I just haven't connected to anything here. All I do is watching TV, and sometimes, I play games on my computer so that's all I can talk about. It's a pretty lonesome, lonely situation, sort of the way it is. But it doesn't bother me very much. You know, I am alone, but it doesn't bother me all that much, that's just how I've always been. But my memory is getting really bad. I don't know how bad it is, but I'm nervous about it all, whether I'm already getting into dementia and all that kind of crap. So I'm somewhat in that situation.” (P8)

In fact, motivation was one of the key elements that participants mentioned as being crucial for maintaining their memory, and they discussed how LON severely dampened their motivation to do anything. For participants, LON was a debilitating, self-focused feeling that diminished their curiosity, optimism, and motivation to engage with external stimuli and learn new information:

“When you think about that sort of subjective state of loneliness, you can be locked in, so your mind, I mean, when that happened to me, my mind sort of went around and around and around in circles and it wasn't learning new thing. I wasn't learning much in the way of new things or curious about things. I think curiosity is a big thing. My husband is interestingly not at all curious. He learns things and he reads the newspaper and he's curious about certain things, but not about how something works or like taking apart the toaster oven or that sort of level. So, his interests or socially isolated and lonely person's interests and proclivities I think is a factor in affecting memory. Because if you take the toaster oven apart and you know how to do it, well you learned something, and you'll remember that for the next time something else needs to be taken apart, rather than just shutting down and not dealing with it. Yeah, and I think there's a connection between optimism and curiosity and then memory because you are out there feeling that it's a good day because something new is going to happen or you have an opportunity to do something, learn something, whatever. And so that kind of mindset, I've always been curious and an optimist. I mean, I love birthdays even now. I think, this is amazing what has happened in the year, what I have to look forward to. And that has allowed me possibly to open my mind.” (P3)

“There are times when I feel lonely, that I think I just feel old and kind of thrown on the junk heap of society kind of thing, you know, 'you're old, you can't do anything, your body doesn't work anymore.' You know, those kinds of defeatist thoughts when you're feeling depressed or lonely or

whatever. And then it's pretty easy to let yourself sink into feeling like just a useless old person. So, you're so self-focused, right? So, I'm less able to take in info and learn new things in that state. And really, being able to remember involves thinking outside yourself.” (P6)

Additionally, participants discussed how LON was so prevalent in their minds, constantly diverting mental resources to the emotional pain of feeling lonely, that it distracted their focus and attention and impaired their cognitive abilities to analyze and recall information about themselves and the surrounding situation:

“When I've been lonely and alone, and this is gonna sound silly, but I can be home alone, watching TV, feeling lonely. Well, I'm watching TV so I'm not totally bored, and the commercial will come on, but I cannot remember what TV show I'm watching. I have no clue. I actually have to put the remote on to see what I'm watching. And I think it's because, like there have been times when the feeling lonely is more prevalent in my mind than what I'm watching. So, when you're feeling lonely, your brain takes over any sort of logic in your head. And therefore, pulling memories is more challenging than if I'm just isolated.” (P5)

“When I was lonely and/or depressed, I'm sure it affected everything about my sort of mental faculty, right? My ability to even sort of critically analyze things, and I couldn't even read. I read all the time for my work, but even reading and sort of comprehension was negatively affected. I have to read something a couple of times before I sort of understand what it's saying, or it would take more effort, and so I connect that with memory.” (P10)

5.5 Memory decline in the combined isolated and lonely group

This theme is split into two subsections, each providing potential explanations for why experiencing both SI and LON together leads to worse memory outcomes than experiencing either factor alone.

5.5.1 Social isolation and loneliness can exacerbate each other in a feedback loop

Participants who identified as being both socially isolated and lonely noted the interconnectedness of SI and LON, explaining that SI and LON can exacerbate each other in a feedback loop. On one hand, SI limited the availability of social connections, making it challenging to find help, leading to greater depths of LON. On the other hand, when participants felt lonely, they perceived themselves as a burden or believed that others were too busy to help them, which further discouraged them from reaching out, reinforcing withdrawal and SI. Participants expressed that this vicious cycle between SI and LON made it harder to escape either condition:

“I think if you’re both isolated and lonely, it’s more severe than just feeling one way or the other. And I think your mind could start going in circles and then it could just get worse and worse, right? Because these people don’t have a lot of people around them and they’re also feeling lonely. So, they want to reach out, but there’s not a lot of people to go for help.” (P5)

“I think social isolation and loneliness can both persist consistently over time because they tend to both feed into each other, if you know what I mean? We isolate for various reasons such as weather, injury, fatigue, moods, overstimulation, etc. and that can lead into periods of loneliness. As well, when we feel lonely, it’s not easy reaching out to others to socialize. We have these perceptions that other people are too busy with their own stuff going on, be it family and grandchildren, snowboarding vacations and holidays, work, or other social activities that we don’t participate in. Plus, loneliness can be a bit of a drag on us, so we tend to avoid ‘burdening’ others with our problems and social interactions.” (P9)

Some participants also discussed how the combination of SI and LON can lead to more stress compared to facing either condition alone, producing deteriorations in both physical and mental health. They noted that the compounded impact of SI and LON on overall health can have a destructive effect on memory function:

“I think that people who are both lonely and socially isolated, it would affect their mental health. So, like the combination of both heightens my level of stress or mental health issues, because it kind of feeds into each other, and that level of stress grows more and more. And again, I saw that in my dad as well, right? So again, now that he is prone to depression because he’s bipolar, the combination of factors certainly negatively affected his health. His physical health as well, but I would say his mental health for sure. [...] It’s sort of hard to isolate the memory loss from the combination of factors because my dad’s memory was always really, really good, right? And I noticed definitely that especially short-term memory is like practically gone. At the same time, you know, my mother is not isolated and is active and that sort of thing. And I think her memory is a lot better. So, in terms of comparing those situations, I would say being isolated and lonely has impacted my dad.” (P10)

5.5.2 Those who are both socially isolated and lonely are more likely to engage in a self-destructive lifestyle

Several participants believed that various factors could layer on and interplay with SI and LON to affect memory. They observed that individuals who are both socially isolated and lonely are more likely to engage in self-destructive behaviors (e.g., having less physical activity, poor nutrition, increased

alcohol consumption, higher drug use, and a lack of participation in intellectual activities) than those who are only isolated yet not lonely, or those who are lonely yet remain socially active. They believed that compounding all these factors could exacerbate memory impairment more than if individuals were dealing with only the direct effects of either SI or LON alone:

“And alcohol is a factor, so lifestyle choices matter. Three years ago, up the street, there's a medical building and they began to give exercise classes. And so, I joined there along with small groups of 10 people in each of these classes, and it's remarkable how bright and articulate and healthy these people are who go out of their way to find physical activity to keep their memory going. We all talk about that, as well as all of the other factors. So, those people are sort of the opposite to your question about people who are both isolated and lonely. Those are people who are really working on keeping their memories. I know a woman, a friend of mine, who lost her husband just 3 weeks ago, but she was also suffering from other physical ailments like rheumatoid arthritis, breast cancer, and some other spine thing, and drinking too. And I think it's the same with depression, you know, it's just you get in this black hole and then look for other ways to cope, other self-destructive behaviors, I mean. That's where people, I'm not an alcoholic but I could understand because my brother is, and I can understand his sort of reason for retrieving into the bottle. But I mean, I'm doing these word games, these exercises, the diet I've got right now is a plant-based diet, and healthy foods, healthy activities, and I think they're helping with my memory.” (P3)

“I think a good, balanced, healthy nutrition is important to combat loneliness and isolation and memory loss. I am in the kitchen a lot, but taking the time to reflect, using all senses, reading a recipe, shopping for ingredients, and being satisfied at the end results are great to boost the mind. I also feel that by eating well rather than poorly, we have a brighter mind and a more energized body. Also, physical activity. So that also plays, I think, in memory. What I found or what I was told by the physio people, they said that my muscles had memory. I had muscle memory. So, I was able to do yoga, it was one of the first things that I was able to do after I was ill. I couldn't do what I could do before being ill for sure. I still can't, but I'm a lot better at it. And it helps with my balance. And when my balance is good, my brain is better. If my balance is off, then my brain is off. I know that it's true for me.” (P4)

“I know a few guys who are divorced, separated or whatever, and some of these friends of mine get into that habit of drinking more than they normally would, which would isolate them even more. Like I don't want to hang out with a guy who's totally drunk or a woman who's drunk, because they don't make any sense. And I don't want to fall into that rabbit hole where I just rely

on drinking away my problems. So, like alcohol, drugs, or whatever, the problem with that is, your problems are still there, like they're not going away. My wife died a year ago, and as her anniversary approached closer and closer, I walked around my house and had just a couple drinks in there by myself because it felt so lonely. But just a few drinks and I tried to think of the good times with her, I felt that was the honorary thing to do.” (P7)

5.6 Strategies for addressing challenges related to social isolation, loneliness, and memory changes

This theme consists of six subsections. The first four detail the common strategies participants used to address SI and LON, while the last two demonstrate how participants adapted to memory changes.

5.6.1 Taking proactive, intentional steps for social contact, being self-aware of one’s problems, and leveraging timely help from one’s social connections can combat social isolation and loneliness

Throughout the interview, participants repeatedly emphasized the importance of being proactive in seeking and maintaining social contacts to combat SI and LON. For example, participants made deliberate efforts to schedule daily social interactions, some involving deeper engagement with others, while some were more passive. Nonetheless, participants took the initiative to ensure constant engagement and connection with the world:

“So, another thing that interests me is the lengths to which people will go to connect with other people. You know, how do you get the impetus to make sure you do something every day or see other people. My single friends often say they've got something going every single day, either it's a group or like an SLR thing or a visit or, but it's not going shopping, it's something where they have to actually interact with another human.” (P3)

“It took some time for me to realize that I was going to have to initiate, you know, social interaction and take a really proactive approach so that I was not going to be consistently lonely. Yeah, so it took some time. I'm still working on it to tell you the truth. If I have a stretch of days where I'm just here in my apartment and I don't have anywhere that I have to go, or I don't have any social activities booked, and my daughter is busy with working, and her kids are busy with school, and you know that sort of thing, I don't handle those well. Yeah, I just need to be really proactive about making sure that I have something scheduled pretty much every day, even if it's only to go to the YMCA to swim, or take the dog for a walk, even if it's stuff that I'm still essentially doing by myself, I need to know that I have something that I'm required to do pretty much every day.” (P6)

Participants also described how acknowledging one's problems and actively seeking help and support from social connections could help reduce SI and LON. Here, participants emphasized how having open communication with one's social support systems (e.g., friends, family, health professionals) could foster opportunities for self-reflection, helping to recognize and understand the roots of their SI or LON. This self-awareness of one's mental and emotional state allowed for timely intervention and enabled participants to take active steps to address their SI and LON before they worsened:

“Really what therapy did for me, it was talk-therapy, was to enable me to understand some of the origins of my loneliness. So, I was the fourth child out of 5 and I always felt like I had to compete for attention, and I am also half deaf. So, understanding through therapy that I needed to reveal that to people, that it was a terrible disability for me but nobody else seemed to really care, they just accommodated. It enabled me to understand that I could be appreciated, even loved, even though I had this kind of disability. And once that door opened, over the years, I've sort of built on that realization and whenever I go back into the dark place, I think, now, just remember how this all worked and how I could work through that recurring sense of loneliness. So, I don't feel loneliness associated with the disability anymore, of being afraid that people would think less of me because of the hearing impairment, because now I can hear. So, it's a win-win. I think it's very important that you are talking about your problems and talking through it has led to a major shift in my feeling of loneliness. And maybe owning up too. Maybe acknowledging rather than hiding it, or rather than pretending that it's not there or being afraid to show it to people.” (P3)

“I've been, you know, like with my dad and his loneliness, I said, ‘you have friends, and sometimes, it's up to you to reach out.’ So, he's been doing more of that, which is good. I also have to be very self aware when it comes to isolating myself or being alone too often. And I push myself to get out of my house and you know, doing something. I've learned to recognize when isolation and loneliness start to become a problem for me, and try to take steps to get myself out of the house or make a point to connect with somebody close to me either by phone, Facetime, or going out for tea. I do things like make concrete plans to spend time with my friends and family, I call my best friend for a long winded, heart to heart phone chat, I have a solid support system that I connect with who understand that I live with a mood disorder and accept me as I am. In times such as these, I remind myself to be gentle and loving to myself, and I go out and do things solo, such as attend a movie, or a live music event, or a restaurant for a meal by myself. Inevitably, I end up running into people I know wherever I go, and that helps combat those feelings of loneliness. It also reminds me that I need to get out of my head more often, that there are people out there who enjoy spending time with me! However, if I've been socially isolated for

a long period and loneliness is consuming me, I recognize that I need professional support. Then, I connect with either my family doctor, my community mental health worker, or my closest family friend.” (P9)

5.6.2 Diverse social networks provide various types of functional social support

Following a discussion on seeking timely assistance from their social connections, several participants reflected on the importance of maintaining a diverse social network rather than one limited to specific types of connections (e.g., family-focused, friends-focused). They believed that by engaging in various social activities and nurturing relationships at different levels of intimacy, they could create a robust support system that mitigates SI and LON. For example, by diversifying their social interactions, if one type of social connection diminishes (e.g., casual acquaintances), participants still had other layers to rely on (e.g., lifelong friends):

“I can begin to see how important it is to have a kind of variety of social interactions as a child. And then when I retired, which was about 11 years ago, I began to join a few social activities. So, SLR and an art class and an exercise class. And those are more casual social relationships, but they're a nice framework. On top of that, I have maintained a relationship with the high school friends, so we've known each other for 60 years now and that's a deep friendship, and another one friend from university, and again, I've known her for 50 years, and so those are another kind of stratum of friendship. And then people whom I see once a week or more often and either walk with or do something with or just visit with, there are not many, but there are 3 or 4 right now who are crucial to my feeling of 'what a nice day it's gonna be, I get to see my friend' So, I think that my potential loneliness is in the future, but I think that in my case anyway, if I keep the social connections on these various layers going, and in balance, then the loneliness is something I can deal with because it definitely has been shrinking in importance in my life for all these years.” (P3)

Additionally, participants discussed how having multiple layers of social connections helped maintain their emotional balance. Each layer served a different purpose, from providing casual companionship (positive social interactions) to offering deeper emotional support. For example, participants mentioned how their casual friends and work colleagues provided companionship during times of need:

“There's a group of four of us that continue to see each other during the off-cycling season. I just went hiking with two of them the other day, and then the third one came over and had coffee with me last week. So, they are certainly providing the social interaction and companionship. I don't

know about in terms of emotional support because they're not like long-term, close friendships.”
(P6)

“My boss was sort of the catalyst in that [being hospitalized for anxiety and depression] all coming to a head because I had been actually documenting my experiences with him. And when this incident happened, one of my colleagues was my backup in it and he backed me up even beyond the call of duty. I mean, I didn't have like a full-on sob session with him like I did with my family, but he still took my side against my boss. And I thought that might backfire in my face, but it actually helped both of us because he just had had enough of watching this supervisor be basically abusive towards me. And once the staff sergeant heard what had happened and all that, he called me into his office and said, 'what's going on?' And I showed him all my documentation on the supervisor and all the things that he had done and said and the people that were present when it happened too so that he would have other people to confirm these stories with.” (P9)

On a more intimate level of social networks, participants discussed the critical role these connections played in providing emotional support. For example, participants shared how they depended on their family's presence during health crises, as they provided a sense of security and love:

“When I was ill for sure. I had the support. My husband was at the hospital every single day. One of my kids just had a brand new baby so they didn't come out as often but they came twice a week. The other guy was here at least every other day and every day for a certain amount of time and that really, really helped. I didn't feel tossed by the wayside. That kind of thing, right? I felt that I was important enough that people cared about me, and they wanted to see me better and to help me by however means that they could help me. I really felt that was really important for me. I'm not sure that things would be the way they are now if I had not had that stimulation.” (P4)

“After leaving the Mounties in 10 years, I had moved back home to take this job and things were... yeah, it was good to have my family here because in 2004, I had a complete breakdown and ended up being hospitalized for anxiety and depression and it was great to have my family here to help me. I don't know that I would have been able to go through it alone.” (P9)

Participants also discussed exchanging emotional support with their long-term close friend groups. The shared history with these enduring friendships created a strong emotional bond that was especially comforting during difficult times, such as grieving or personal loss. These friendships also offered stability and consistency in social interactions (even if infrequent) throughout life, making participants feel valued:

“I still maintain my close friendships with my, I have a group, we call ourselves the OBR, which stands for ‘old broads retreat’. And there are five of us and I’m sort of the central character in that group because one of them was my first-year university roommate at UofT back in 1967 believe it or not, and she lives in Guelph. Another one is my long-term friend on, up in northern Ontario. And she and I were friends and worked together for many, many years. A third one lives in Toronto. She lives in up north. She and I were neighbors when our kids were small and have just stayed in touch with each other, you know, based on that. And then the fourth one was my sister’s best friend who was really marvelous when my sister was dying and provided all kinds of emotional support for my sister and for me and I’ve maintained a friendship with her. So, I have them all come and stay with me in the place where I stay in up in northern Ontario. And that’s why we call ourselves the ‘old broads retreat’ because every summer, we spend three or four days together and do this retreat. Anyway, so it’s interesting because in terms of emotional support, that’s probably the group that I rely on the most. And it’s funny because I rarely only see them as a group once a year at our retreat. But I keep in close touch with them through social media. And the one friend who just lost her husband, that’s the friend who lives in Guelph, the one who was my university roommate, her husband just died this past year and so I spent really quite a lot of time providing emotional support for her. I drove back and forth to go on a weekly basis and that sort of thing, and kept in touch with her regularly by telephone. So, I’d say that’s the group that we provide emotional support to each other. Yeah, probably the most important emotional supports that I have outside of my family of course.” (P6)

Additionally, participants discussed the critical role their peer groups play in providing emotional support. These groups, built on common interests, shared experiences, and similar life stages provided a safe space for emotional expression without judgment, which participants found to be therapeutic. They noted that these groups offered mutual understanding, empathy, and validation that were difficult to find elsewhere. Therefore, participants recognized that peer relationships could be particularly effective in fostering a sense of community and belonging:

“[Nursing care organization] has a grief group, and these are all women that have lost their husbands mostly, so they’re all widows. And myself, I got, this grieving thing happened because of my mother-in-law dying. Because we moved here and it was going to be a big part of our life, but then for her to be out of the picture completely was really heartbreaking. And I’m grieving about my business and grieving my home and grieving a lot of things, so they said, ‘sure you can join our grief group, no problem.’ So, I’ve met some people through there, one is actually a pretty good friend now. We’ve taken a couple of trips together. There’re no men in the group, actually.

And it's all women that run the group. So, it's this supportive group of women where, you know, we don't talk about our grief when we meet every Thursday at 9 a.m. for an hour and a half on Zoom. We talk about all the stuff that goes on in our life now, everything. Nobody's dwelling on that they lost their husband four years ago still. There's lots of things to talk about. But I have felt very supported by those people, and they tell you, you know, the person that guides the group or leads the group, they're always saying, this is a safe space for you to say whatever you need to say. So anyway, that's a very good thing that I have that I felt very supported by, it's that group of women, you know, widows, really, they understand me well, they've heard a lot of my stories over the years, because I've been hanging out with them for a few years now. So, they've heard it all, but I think that having those people to at least listen to you and be there even if it's once a week to have a Zoom call, that's a huge deal. And if I'm not there, they reach out to me, 'Where were you? We missed you.'” (P2)

“There are three people whom I see at least once a week, and those are the people that I can talk much more deeply about emotional stuff. And we compare notes about things we learned and they're my age and they're grandparents as well, so we share a great deal in common including the ability and willingness to open up and share our emotional states and kind of feelings of shortcomings. I think building a social network that is meaningful and deep, so a few close friends and deep connections with them, certainly, improved the social isolation, but really improved the loneliness.” (P3)

“I've really noticed my dad's memory go down. So, I've got him going to Alzheimer's support groups now. At first, he was really resistant to going to this peer support group meetings and then he went to his first one and he couldn't stop talking about it. You feel like you're understood, and you care for them. And my friend, she's going through the same things I'm going through, dementia with her mom. So, we share that commonality and it's helpful to have that kind of support with somebody you've grown up with. And yeah, I also go to depression support group meetings and talking with people who have shared similar experiences, that just feels great.” (P9)

Lastly, participants discussed how their family members and friends were sources of instrumental support (e.g., aiding with technological devices for hearing impairment, offering financial assistance, and providing transportation) and informational/advice support (e.g., providing information about medical tests and the progression of health conditions):

“I no longer have the sense of loneliness because of that disability. I began to talk about it to people and my children knew, and now they're in their 40's and they began to look at hearing aids that would suit me, and so with the technology changing so quickly, the hearing aid system that I now have, that only really became available five or six years ago, is an aid that transmits sounds from my deaf side to my hearing side. So, that means I can walk with people on my left side, I can hear in restaurants, I can hear in parties, in crowded areas.” (P3)

“This past fall, I developed a pulmonary embolism. And it was quite unexpected, not that anybody ever expects one, I guess. But I had no family history of it or anything. So, I ended up doing a fair amount of, you know, medical stuff, various tests and so on. And my daughter who shares the house here with me was really, really supportive. She had also had the experience of a pulmonary embolism when she was just young as a result of an accident, and so she knew a fair amount about what that was like so she provided a lot of useful information. And she was really, really supportive and really interested in how I was doing and following closely with what the doctors were saying, and the tests were showing, and explaining the stuff I didn't understand and that sort of thing.” (P6)

“This morning, as one example, I was walking down the street to get on the bus, and my neighbour said, ‘Hey [P7's name], do you want a ride? Actually, I'm going downtown to this office. It's a long take anywhere.’ Anyway, so she did give me a ride, and I'm sure there are other friends who are talking amongst each other, ‘Oh, [P7] needs help here and there.’ That's what I think, they're talking amongst themselves, and I think that kind of stuff works like a snowball, and I get more and more support as time goes on. Anyways, well, this neighbour that picked me up from the street, we've been neighbours for like 25 years. She was a lawyer, and she retired a couple of years ago. So, I felt very confident in the relationship that my wife and I had with her and her husband that I could expose myself to this loneliness I was feeling and the stuff that's going on with my daughter, who's now 55 years old and lost her job just recently. And I wanted to help her out, but I wasn't sure how to talk to her about that. I didn't know how to say, ‘I gotta send you some money.’ So, how I got through this problem is, I asked my neighbor this morning, and we bounced back ideas and she said, ‘well why don't you do this?’ And that's what I did. I called my daughter, and we talked it out and we've gotten over that bridge. And she's going to go to the job bank, but until she finds a new job, she's gonna stress over not having money and go down that rabbit hole. So instead, I sent her some money.” (P7)

While the aforementioned functional social support is distinct from SI and LON, it does not just materialize from thin air; it comes from the people in one's social network. Therefore, being socially

isolated means that one naturally has less access to functional social support, and when one feels that they lack control over their social network or can't obtain functional social support as needed, this is linked to LON. Given that six out of ten participants highlighted functional social support in their interviews, it may be important to consider functional social support when discussing strategies to mitigate SI and LON.

5.6.3 Seeking reciprocity in social relationships

While participants acknowledged receiving a lot of support from their social network, they also emphasized the profound impact of being able to reciprocate help and feeling needed by others in fostering a sense of stability and purpose in their lives. For instance, P2 described her relationship with her husband, where both relied on each other for emotional regulation and stability, preventing either from feeling overwhelmed during tough times. This mutual dependence fostered a sense of purpose, as each partner felt needed and valued by the other:

“I have a great husband. He's awesome. He wants to take very good care of me, but he's a very stoic kind of person. You know, I love him for that. It means stability, right? It's great that I have him, if I didn't have him, I don't know. I probably would have ended my life seriously because he brings that, I mean, he needs me, I need him, and that makes that suicidal tendency kind of well, maybe not today, you know. And we used to joke around when we were in Hawaii and running our business, like only one of us can break out at a time. Today is my turn. Then next day, you know, he'd be the one going in and out the door slamming and upset about something going on with the business or some patient or some element of some tool he couldn't find or whatever. It's like 'okay, okay, let's trace your steps, we'll find the tool, it'll be okay, what can we do.' And I would calm him down, and then on the other side, he would help me through whatever was making me nuts. But we could only go nuts one at a time, that was the rule.” (P2)

Other participants also described how they found purpose and fulfillment in reciprocal relationships, seeking activities aimed at improving others' lives or assisting those in need. In return, they also received support when they were in need, and felt connected to their broader community. These dynamics helped enhance participants' sense of self-worth, perpetuated their engagement in social activities, and contributed to building long-term, strong ties among social network members, reducing both SI and LON.

“Well, it's kind of like participating in studies. I do that a lot also because I feel that I have a connection. I love doing what I'm doing. I really, really, really do. I could do this twice a week no problem, or three. And I like this sort of thing because it's something that I feel that I may be

useful for somebody, in some context. And I have a connection, and I'm good to go for the rest of the day. You know, it's my gratitude thing. And there's another group that I belong to that is a really great challenge. You may have heard about it, it's called '[name of a charity organization]'. And so, I participate in the monthly meetings and it's all on Zoom except once, we had a in person meeting in December. But those are really active kinds of commitments, about how you can make the world a better place, how you can make life happier, because if I make life easier for somebody else, my life is going to be easier for me, right? So, I do things like that, and I really enjoy it. I really do.” (P4)

“I guess, I've never been totally socially isolated. I don't know if I mentioned, but I have been very, very socially active, I go to lunches or dinners from place to place. And my wife, when she was around, she did all the cooking and all the shopping for food. Now I do all that. So, I'm able to reciprocate the things for people who take me out for dinner, like I'll invite them back to my place. I think it's because I want to help, like I always have in my head or in my heart that I want to help like everybody else. And if there's nobody that I can help either with a phone, or an email, or a text, I start getting lonely.” (P7)

5.6.4 Virtual social interactions, home visits, and pet therapy as a support to social connectedness for those who are both isolated and lonely

One of the most commonly discussed strategies participants found effective in alleviating their SI and LON was engaging in virtual social interactions. Eight out of 10 participants mentioned this approach, noting that they frequently interacted with others through platforms such as Facebook, WhatsApp, Skype, Zoom, emails, and telephone calls. Participants believed that these virtual platforms could be particularly beneficial in reducing SI and LON for individuals who are at risk of experiencing both (e.g., those living with disabilities or facing physical barriers to traditional social activities), emphasizing that these platforms could serve as a vital social outlet and connection to the outside world. For example, P3 highlighted the case of a friend who was confined to her home due to mobility issues and heavily relied on Facebook for social interactions to alleviate feelings of LON:

“I have a friend from high school who is by choice in her house most of the time. She's quite overweight and now has mobility issues but has lots of brain power. And her connection is in Facebook. So, there's a whole other element of social media, and how that fits into your study, because she can go down that rabbit hole and spend much happy time there. I personally don't see that as much of a meaningful, in-depth interaction, but I could be wrong. I'm quite prepared to be wrong about that, particularly for people who are physically isolated who are damaged in some way physically.” (P3)

Other participants discussed how virtual social interactions could bridge the physical gap in long-distance relationships. They used virtual platforms for daily communication, to share content (e.g., sending email links related to shared interests), and to organize or facilitate social events and community building across long distances:

“My mom was in her late eighties at that point and she said, ‘you know what, our lifeline is our Skype, right?’ So, we used Skype daily, we talked daily during COVID. I think that there's a lot of negative and bad things that are being said about technology because people are dependent and whatever, but I think that it's a big help. Oh, if you are technologically challenged, I think that's more of a negative for your social isolation and for your brain stimulation. I think that technology can help in both of these areas. And if you're deficient there, well, you know, I don't like the idea of saying I can't teach an old dog new trick. My mom was 91 when she died, and we talked on Skype every day. I could send her email. If I wanted to send her links to things, you know, like in religion, I would send her links to mass. I would send her articles about her former doctor who was doing really interesting things, so she would love to read about them so I would send her the articles she would read, and she was really happy. So, those are things that made life not so lonely.” (P4)

“Oh, I use all of those, Zoom, Facebook, telephone calls. My wife and I were in California for 15 years, and we always had Superbowl parties. So, I virtually sent out an invitation to my friends in Hawaii and Australia. So, they were having fun in Australia, and in Hawaii, and they were having fun here in [city name] watching the game. And I was emailing to send out the invitation.” (P7)

These virtual social interactions could encourage frequent and substantial conversations that were not solely superficial. They encompassed meaningful discussions about important life events and personal emotions, aiding in the maintenance of close bonds with family and friends:

“Just about half an hour before this call, I spent probably an hour on the phone with my friend who lives in northern Ontario because her husband now has cancer and so she's going through a fairly hard time as well. So yeah, we spend a lot of time on the phone with each other. All of us. I would say probably on a weekly basis, I talk to each of them at least once a week or every two weeks for sure. And at a pretty deep level too. I mean, it's not a let's get together for coffee kind of a group. It's really more like, you know, what's going on in your life kind of a group, you know? And then, my oldest daughter lives in Kenya, she's civil rights lawyer there, or human rights lawyer. And so, I get lonely for her. I miss her, and that's not an isolation thing, that really is just

because I miss my contact with her. So, you know, like thank God once again for virtual connections because she and I regularly talk over WhatsApp or telephone. So that's how I managed to keep in touch with her.” (P6)

In addition to virtual interactions, participants discussed home visits and pet therapy as two other effective interventions for individuals experiencing both SI and LON due to age, health issues, or other life circumstances. Regarding home visits, P8 described how they received visits from healthcare professionals, which not only offered personalized care (such as medical support and adjustments to their home environment tailored to their health and functional needs) but also introduced them to new support groups during subsequent visits. For someone with a limited social network, this external support could become a crucial lifeline:

“Earlier, I had some sort of a doctor thing. Last week I went to the emergency, and I talked to the doctor, and you know, then I could talk to other people there and answer to them. But I don't have any connection to hang out with people. Oh, but when I was in the emergency and after the sciatica and how bad and sick I was, the doctors decided that we really need to connect to things, like we have nobody here as far as family or anything. I got no family at all. I guess basically my wife's family is all gone too. So, we've just connected to all sorts of social, you know, some sort of groups of socials, it's through the doctors. One is called [name of a health centre]. So, doctors and other people are coming over and they're gonna see how we're doing, how physical we are, and try to help. And they'll look at our house, like where the stairs are, because we're old people, and they'll tell us whether we should have railings and stuff like that. And we're trying to find out more what's going to happen, you know, people are coming and visiting us and seeing how we're doing, which is a very good thing to do. Through all that, maybe there'll be some connections to work for me.” (P8)

In terms of pet therapy, participants discussed how their pets provided constant companionship and unconditional love, significantly reducing feelings of LON in the absence of in-person interactions. Pets provided opportunities for emotional healing and notably enhanced participants' mental well-being. Moreover, the responsibility and affection for a pet served as a strong incentive for participants to persevere through difficult times and imbued their lives with a sense of purpose:

“I think pets are, like for me, they're the be all and all. I've never not had a pet. Never. And if I did, it was for like a very short window of time. And I've had both dogs and cats. So right now, when I say I'm alone, like I'm still with my cats, so I'm never really ever alone. And I'm afraid to get older for that very reason because I would have to leave my pets, or like give that

responsibility to someone else to take care of them, which is a scary thing. And when I had depression, I had suicidal ideations at the time. And the only reason I didn't do anything was because nobody could love my dog and look after my dog like I had. The dog saved my life basically.” (P9)

“Yeah, so like moving here, I am lonely and I guess I’m somewhat isolated too. I moved here for work and so I have my colleagues, but I still work from home, right? I mean I go to the office every once in a while, but just, there’s not a lot of in-person social interaction. But then, I got a puppy and that has made a big difference too. So, like I’m alone but not completely alone. I have my dog who is constantly here. You know, it sounds funny, but she’s literally my best friend now, I talk to her about all my problems. Yeah, she’s very present, she talks back, and she catches my emotions well, so she knows when I’m sad. And I can tell that my memory is better. It’s really interesting because I noticed that. And well, I have to say in terms of my mental health and just the general feelings of well-being, I know that having my puppy has improved that aspect, 100%. So, I wouldn’t be surprised if she improved my memory too.” (P10)

5.6.5 Relying on spouses or cohabitants in memory retention

Among the five participants who were married, three discussed how their spouses or cohabitants played a critical role in memory retention, acting as external memory aids. For instance, P2 talked about relying on her husband for enhanced recall, outsourcing certain memory tasks relating to specific details to complement her memory gaps:

“My husband has so much more focus that he can remember things way better than I can. I always go to him, ‘Do you remember where we did that with that person and that thing happened?’ And he goes, ‘Oh yeah, that was this and that.’ He remembers the date and the time and who was there and what cloud blew by. So that helps me a lot. He’s my go to person.” (P2)

Participants also discussed that their spouses provided them with opportunities for storytelling and routine discussions that helped them reflect and re-assess information from their past:

“My husband and I, we always share stories, and he likes to tell stories, the same stories from his childhood. He’s very interested in his past and telling those stories. And so, I have sort of learned from him, if I look back on my own childhood which was not so happy, I can begin to retrieve those childhood memories and young adulthood memories and look at them from a different lens or from a different perspective.” (P3)

These interactions with their spouses also helped participants articulate information in detail, and such active rehearsal of memories helped them re-organize/brainstorm ideas and ensured that important information was verified:

“If this was before, my wife and I would talk about it and how we would approach our daughter. And she would question me about this and that and so on. I think, if nothing else, just being able to say all of that, sort of rehearse it, helps you remember it, right? I think that's something that I've known about myself for a long time, that if I actually have to tell somebody about something, and especially if I have to tell them in detail about it, it cements it more in my memory. But now, because I don't have my wife to bounce my ideas back and forth, I often get more stuck making decisions. And if my wife had an issue, she could bounce her ideas off of me. And I would tell her what I thought, but without her to bounce my ideas off, it's just a lot tougher and my memory is often slipping. My daughter's in trouble and these are problems you discuss with your mate. I don't know if you're married or in a relationship or not, but having that person you can open up to, it's important. And if you're living with a partner, like if you have a wife or a husband or whoever else. That would help them, I think. Yeah, they'll have you covered if you forget something. But if you're isolated, that's harder and there's also less commitments for you to remember.” (P7)

5.6.6 Language-based/creative activities, repetition, and planning can help manage memory changes

Several participants reported that engaging in language-based activities, particularly writing notes, helped them externalize and visualize memory tasks, making it easier to manage daily activities:

“People write notes to themselves, and I'm always writing things down. I've got more pieces of paper with writing on them. I mean, for the grocery list and things like that, you know, you just better write it down. You just better have it on the fridge. As soon as you see that we're running out of something, write it down because, I used to think, and I did, I don't remember being so dependent on lists as I am now. Like you could just say, yeah, we need this and this at the store. When I go to the store, which might be two days from now, I'll remember, and I did. And now that's not happening anymore, I don't go to the store without a list. Why even bother? If you forgot the list, turn around and go back and get it because you will forget everything. Or sometimes, when that happens, I just go back into the car and sit there, and get a piece of paper and a pen and maybe that list will come back to me. I can sort of visualize it on the fridge. I can visualize that there was a long word and then a short word and then a word that began with a B, and you know what I mean?” (P2)

Other participants highlighted their involvement in additional language-based activities, including word games, reading, and writing, alongside creative pursuits like artwork and solving math problems. They asserted that engaging in these activities enhanced their attention and problem-solving skills, which proved beneficial for memory:

“I have certainly found that the practice of both Wordle and Crosswords and keeping that up, and any of those word games has improved my attention span. I've gotten better at it over the last few years than I was and so that kind of memory is improving. And if my memory declines more, I think that we talked about this in my age cohort, and I think that I will be okay with memory aids, you know, thank God for Post-It notes and reminder calls and for friends to drop in and stuff like that.” (P3)

“My memory has changed a lot, and I attribute it to the aphasia. I do notice it. And I try to keep it stimulated for that reason. And to me, I play cards like I told you, but I also played word games on my phone. If I have five min, I'm just playing cards or word games and finding words and just keeping that wheel going. I also do reading, writing, adjusting to different situations, basic math, creative artwork, they're all activities that engage the mind and help with memory and I feel, combats loneliness and isolation too. So reading is a really, really big thing, even though it's hard. But now I can read, every night I read in French, I read maybe 30 pages a day and that's fine. So that's another big thing that my aphasia clues taught me, you know, when I went to the camps and whatever. Yeah, those are all things that are important.” (P4)

Some participants also talked about utilizing repetition to help reinforce their memory. Repetition could aid them in the encoding process by giving the brain multiple opportunities to process and store information. Each repetition strengthens the neural connections associated with a specific memory, facilitating consolidation. Through repetition, some participants engaged different sensory modalities by regurgitating information in various ways (e.g., saying things out loud and rereading materials). This provided multiple pathways to encode information, which could enhance memory retention more effectively than using a single modality:

“And then repetition as I said, I tend to, because I live alone, I can do this, I say things out loud, you know, things that I want to remember, I'll repeat them two or three times. So yeah, I guess those are the things that I use the most frequently to remember stuff. And another thing that I do is, you know, in terms of repetition, I reread things if I try to remember something that I know that I've read and I can't remember it, then I go back and reread it.”

Lastly, participants mentioned that they liked to integrate structured planning into their daily routines. Breaking down tasks into manageable steps, recording, and revisiting these plans served as a form of spaced repetition to enhance memory retention. Planning provided a clear roadmap of what to expect for the day, alleviating anxiety and stress associated with uncertainty and memory lapses:

“That's why we have to plan these things out and that really helps, right? That's our way of coping with it. It's by saying, “hey, we gotta get a good night's sleep tonight because we gotta get up and we gotta set an alarm for 9 a.m. so we can get out the door by 10:15 and get way down on the end of Adelaide.” It's more the social anxiety part of it that's making me feel like I have to have a plan, and that plan involves remembering everything about what's involved in getting this task accomplished, even if it's just going to get a few things or running some errands. You got to have your memory on straight to accomplish anything, and I mean, life is just really, there's so many distractions now.” (P2)

“I write down who I met with and what I did, and when I'm gonna meet with this person again. And then when I get home, I look at my notes, and then I'll put on my computer. So those 2 things in particular helps with my memory. Like I have a two-way system of organizing things and it helps me carry out what I committed to do. And then, my other strategy is, right before I go to bed, I turn on my computer and I look over what I'm gonna do tomorrow, like specific items. So, at 9'o clock, I'm gonna go to the dentist, at 1'o clock, I'm gonna talk to this person. So I go over my plan for the next day.” (P7)

Chapter 6

Discussion

In Chapter 6, I integrate the quantitative and qualitative results of the study, discussing how qualitative themes from Chapter 5 provide context and explanation for the quantitative findings concerning the association between the four combined groups of SI/LON and memory (shown in Table 8). The quantitative and qualitative results agree with one another, showing that while SI and LON each have negative impacts on memory, LON may have a stronger association with memory than SI, and that the combination of SI and LON is most detrimental to memory. This chapter also situates the present study's findings within the broader existing literature and concludes with a discussion of the strengths, limitations, and future directions of this research.

Table 8.

Joint display of quantitative and qualitative results

Domains	Quantitative	Qualitative	Mixed Methods interpretation
Effect of SI alone on memory	-0.69 (-1.09, -0.29) A unit increase in SI is significantly associated with an average decrease of 0.69 units in the combined memory score, after accounting for sociodemographic, functional ability, lifestyle, and health-related covariates.	<p><i>"I do note-taking for students who have disabilities, mostly hearing disabilities, hearing loss. So yeah, I've been doing that for six or seven years now and I like it because I get an opportunity to meet students and go to campus and attend lectures on courses that I otherwise wouldn't take. It really feeds me intellectually I would say. So, that hopefully keeps my brain a little sharper than it might otherwise be. I think just having to be there at 8:30 in the morning on campus and then having to focus on a lecture on a subject that I don't really know anything about and, you know, that sort of thing. I think it is having an effect on my memory, it's probably beneficial. I mean, I think of my ex-husband who stays in his apartment in that retirement living facility that he's in. And other than going downstairs to the dining room to have dinner once a day, I don't think he really interacts at all. And he spends most of his time watching television. I think that's basically how he spends most of his time, and I observe that his memory is not doing so well."</i></p> <p><i>"The less you talk to a person, the harder it gets to talk to them. I mean, if we talk once a week and we were always up to date on everything going on in each other's lives, that would be easier to maintain than when it's like only here and there every couple of months. It's like, I don't know what to talk about, and it just gets harder and harder to stay connected or reconnect when you've been unconnected. And this is social anxiety [...] It's the overstimulation of being out in the community, I mean just getting to the parking lot and getting in the store and then you go, 'shit, I forgot my list.' You might as well go home because you're not gonna, you know, are you gonna be able to put together now standing there in the store with all these people around and the noise and the music and the things that are driving, you know, they're</i></p>	<p>The quantitative results reveal a significant negative association between SI and memory. Qualitative findings suggest that engaging in social interactions can enhance memory by promoting opportunities for public speaking, continuous learning, establishing routines and goals, and building community connections. However, SI diminishes these social activities, which are essential for stimulating memory function.</p> <p>SI makes building social connections more difficult and is associated with social anxiety, which may prolong SI in a feedback loop. This anxiety can decrease one's focus and make recalling past information challenging.</p>

		<p><i>overstimulating you. No, because it's not in my head anymore. It's gone. So, the social anxiety, it definitely has an effect on my memory. I know it does. I know that I am less focused when I get anxious."</i></p> <p><i>"I think social isolation by itself doesn't really affect my memory all that much. No, because when I'm wanting time to be alone, that doesn't affect my memory. It's sort of helping me to file all my stuff. It allows me that time to hit the reset button. Practice good self-care and yeah. And I mean, I could be tending to my vegetable garden. I could be doing some housework or some renovations, but every now and again, I just need a pajama day and a movie day and just completely decompress and have some kitty cuddles and then I'm good. So, for socially isolating, I do that more intentionally than when I have periods of loneliness. I isolate to recharge my battery."</i></p>	<p>Short-term, periodic episodes of SI could be beneficial for some aging adults who prefer solitude to relax, attend to personal needs, and engage in intellectually stimulating solitary hobbies. For these socially isolated and not lonely individuals, SI may not significantly impact memory.</p>
Effect of LON alone on memory	<p>-0.73 (-1.13, -0.34)</p> <p>A unit increase in LON is significantly associated with an average decrease of 0.73 units in the combined memory score, after accounting for sociodemographic, functional ability, lifestyle, and health-related covariates.</p>	<p><i>"I think social isolation is easier to fix than my internal emotions of feeling lonely. I think, moving away from social isolation is, to me, is pretty straightforward in an urban setting. You know, we're in [city name], there're lots of opportunities to socialize. I don't know what happens in rural communities or if you don't drive, you know, but you can, oh my goodness, there are so many groups and so many invitations and so much volunteer work and so much stuff this world needs. And honestly, there are some services out there for shut-ins too, although very imperfect. I used to deliver books to people who were shut-ins in the library system years and years ago. And they were often people who were immobilized and who were lonely for sure and who just wanted some kind of human connection but were unable for whatever reason. And so, if you are socially isolated and want to connect, it's honestly quite easy. But the loneliness, I don't know how people get over feeling lonely without doing the psychological and emotional work that it has taken me. I think I have a high level of concern about that in my own life, but if you feel lonely, like you gotta do this psychic work or you're just gonna be stuck in that lonely stage."</i></p> <p><i>"When you think about that sort of subjective state of loneliness, you can be locked in, so your mind, I mean, when that happened to me, my mind sort of went around and around and around in circles and it wasn't learning new thing. I wasn't learning much in the way of new things or curious about things. I think curiosity is a big thing [...] I think there's a connection between optimism and curiosity and then memory because you are out there feeling that it's a good day because something new is going to happen or you have an opportunity to do something, learn something, whatever."</i></p>	<p>The quantitative results indicate that LON has a significant negative impact on memory, slightly stronger than that of SI. Qualitative findings suggest that LON can be more challenging to address than SI because it is a subjective emotion. Unlike SI, which can often be mitigated through external community resources and increased social activities, LON may not be resolved solely through external means and often requires personal introspection and psychological healing to be overcome.</p> <p>When feeling lonely, the associated emotional pain and stress can cause one to stay self-focused, reducing curiosity about the external world. This can diminish one's motivation and ability to learn new information, which is crucial for memory.</p>
Effect of combined SI and LON on memory	<p>-0.80 (-1.22, -0.39)</p> <p>A unit increase in the combination of SI and LON is significantly associated with an average decrease of 0.80 units in the</p>	<p><i>"The combination of both [SI and LON] heightens my level of stress or mental health issues, because it kind of feedbacks into each other, and that level of stress grows more and more. And again, I saw that in my dad as well, right? So again, now that he is prone to depression because he's bipolar, the combination of factors certainly negatively affected his health. His physical health as well, but I would say his mental health for sure. [...] It's sort of hard to isolate the memory loss from the</i></p>	<p>The quantitative results reveal that the combined effects of SI and LON on memory are more detrimental than the individual impacts of either SI or LON alone. Qualitative results show that SI and LON can</p>

	<p>combined memory score, after accounting for sociodemographic, functional ability, lifestyle, and health-related covariates.</p>	<p><i>combination of factors because my dad's memory was always really, really good, right? And I noticed definitely that especially short-term memory is like practically gone. So, to what degree that's related to his social isolation, and I'm sure lonely now, I know he's lonely. And to what degree it's related to other factors like general health and mental health, because he's bipolar, I can't say. But at the same time, you know, my mother is not isolated and is active and that sort of thing. And I think her memory is a lot better. So, in terms of comparing those situations, I would say being isolated and lonely has impacted my dad."</i></p> <p><i>"I know a woman, a friend of mine, who lost her husband just 3 weeks ago, but she was also suffering from other physical ailments like rheumatoid arthritis, breast cancer, and some other spine thing, and drinking too. And I think it's the same with depression, you know, it's just you get in this black hole and then look for other ways to cope, other self-destructive behaviors, I mean. That's where people, I'm not an alcoholic but I could understand because my brother is, and I can understand his sort of reason for retrieving into the bottle. But I mean, I'm doing these word games, these exercises, the diet I've got right now is a plant-based diet, and healthy foods, healthy activities, and I think they're helping with my memory."</i></p>	<p>exacerbate each other, making it difficult to escape either condition. The combined stress from both factors can exceed the stress of experiencing them individually, leading to poor physical and mental health. When these factors combine, their negative impact on memory may be more severe than just the sum of SI and LON alone.</p> <p>Individuals who are both socially isolated and lonely may be more prone to self-destructive behaviours that negatively impact memory (e.g., increased alcohol or drug consumption, physical inactivity, poor nutrition) than groups who are facing only SI or only LON.</p>
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Notes. Quantitative – Least squares means estimates are shown, with their 95% confidence intervals in brackets, for the multivariable, mixed effects regression analysis of the full model (Model 5). Qualitative – Semi-structured interview findings.

Abbreviations: SI = social isolation; LON = loneliness.

6.1 Phenomenology of social isolation and loneliness

In the quantitative section of this thesis, I differentiated between SI and LON based on the discrepancy theory of loneliness. SI was defined as the objective lack of structural social support, whereas LON was characterized by emotional distress resulting from a perceived deficiency in social relationships, regardless of actual social isolation [18]. Specifically, Menec et al.'s [17] metric was utilized to measure SI, examining five structural elements of social relationships: number/frequency of social network contacts, participation in social activities, marital or cohabiting status, living arrangement, and retirement status. Aligning with the definitions used in our quantitative study, participants in the qualitative interviews linked SI to objective aspects of social relationships, and the thematic analysis highlighted the same five structural indicators as foundational elements of SI, mirroring the quantitative SI measure. The most reported sources of SI in the qualitative study were social network contacts and participation in social activities, all of which align with the broader SI literature [33,34,36,37]. Participants described experiencing SI when their social network size decreased or the frequency of their social interactions diminished. This often coincided with major changes in their life circumstances, such as bereavement, relocation, or retirement. However, reductions in social network size did not always lead

to SI because some individuals deliberately reduced their social network sizes to avoid 'toxic' individuals and focus on close, meaningful connections.

Existing literature reports on similar experiences of reduction in social networks as people age, particularly at peripheral levels, but less so in close and familial relationships [170]. This phenomenon can be explained through socioemotional selectivity theory, which describes how social goals and relationships change throughout life due to shifts in one's perception of their lifespan [171]. During adolescence/young adulthood, when future time is perceived as unlimited, individuals prioritize information acquisition from diverse relationships and large social network sizes. In later adulthood, when time is perceived as limited, emotional regulation goals become more important, and people focus on close relationships (that are perceived as pleasant interactions) for emotional satisfaction. Therefore, the reduction in network size in older adulthood is often a deliberate choice rather than a passive consequence of network members' deaths [172,173]. In addition to socioemotional selectivity theory, Elder's [174] life-course approach highlights the dynamic nature of social relationships across different life stages [175]. As individuals age, they encounter various cultural, economic, political, and social environments, interact with changing demographics, and develop new interests, values, and preferences [175]. For instance, older adults often lack structured social settings (e.g., school or work environments) where regular social interactions occur naturally, making it difficult to form new connections and find peers to share hobbies. These factors influence the size and composition of social networks, the quality of social ties, and the resources accessible through these relationships [176].

The thematic analysis also revealed that changes in social network size and composition were often accompanied by reduced participation in social activities, further exacerbating SI. Many participants emphasized the necessity of being proactive in seeking new social activities, such as social clubs, volunteer work, exercise groups, and educational or cultural events. They also stressed the importance of relying on their social network members to help them connect with these new activities as replacements for their discontinued ones. This reliance on social networks for finding new social activities is well documented in other literature, such as the work of Kang et al. [53], underscoring the strong connection between social networks and social activity participation.

While social network contacts and participation in social activities were the most frequently mentioned factors, three out of five socially isolated participants from the qualitative phase also discussed other structural elements such as marital status, living arrangements, and retirement status as important influences on SI. Participants who had been widowed described the challenges of suddenly living alone, dealing with emotional pain, and losing a built-in support system. They mentioned inviting others over to maintain social connections, but experiencing a lack of interaction once their guests left. They also noted

the extra effort required to maintain relationships with existing friends and neighbors, as they lost the group-focused activities they once shared with their spouse. Retired participants also discussed experiencing reduced daily social interactions and disruptions to their established social routines, as well as the effort needed to replace former work-based relationships with new relationships. Notably, rarely did participants report only one indicator of SI when describing their experiences with isolation. This finding aligns with our quantitative study and the basis for Menec et al.'s [17] multi-modal approach to measuring SI, suggesting that SI should be understood as a combination of various deficiencies in social relationships, rather than the absence of a single component.

Regarding the basis of LON, our qualitative themes echoed the broader literature in defining LON as a subjective and negative emotion [177,178]. All participants uniformly indicated that the experience of LON was internal and personal, and it was this deeply personal nature that generated the most distress. Among the various emotions associated with LON, depression was the most frequently reported, followed by feelings of boredom. Similar findings were observed in our quantitative analysis. For instance, at baseline, 5.80% of participants who were neither isolated nor lonely reported moderate to severe depressive symptoms, compared to 32.54% of lonely, 7.97% of isolated, and 40.94% of those both isolated and lonely. Existing research also underscores a close relation between depression and loneliness: Steen et al. [178] demonstrated that a unit increase in LON led to a 56% increased odds of major depressive disorders (OR = 1.56, 95% CI = 1.47, 1.65), while Lee et al. [177] reported that 11–18% of depression cases in adults aged 50 years or over were attributable to LON in a 12-year follow-up study.

In terms of boredom, people's personality traits strongly influenced their approach to alleviating boredom. Extroverted individuals relied heavily on social activities outside the home, while more introverted individuals found satisfaction in any activity—social or solitary—to counteract boredom. This suggests introverts may find it easier to combat LON, even in periods of social isolation, if they can engage in solitary pursuits that occupy their time.

Other emotional experiences accompanying LON included feelings of resentment, jealousy, and remorse directed toward oneself, others, current circumstances, or past decisions. Although these emotions were less frequently mentioned than depression or boredom, navigating these negative affects often necessitated a reliable social support system, and participants noted that a perceived lack of supportive social ties, characterized by the perceived unavailability of functional support (e.g., emotional, informational, instrumental, etc.), worsened their feelings of LON. These qualitative themes therefore highlighted a discrepancy between perceived and received social support: when anticipated support did not materialize, it intensified feelings of LON. Existing research supports the notion that perceived support has a greater impact on an individual's well-being than the support actually received, and this

subjective evaluation of social relationship quality remains independent of the size of one's social network, the frequency of interactions, or physical proximity to others [19,28,179]. These findings underscore the distinction between SI and LON, reflecting the objective versus subjective aspects of social relationships, respectively. Individuals can be isolated without feeling lonely, feel lonely without being isolated, experience both, or experience neither, consistent with the discrepancy theory of loneliness.

6.2 Comparing associations of social isolation, loneliness, and their combination with memory

Overall, qualitative data corresponded with the quantitative results, which showed a hierarchical pattern of memory decline observed across the four combined SI/LON groups: the group with neither SI nor LON had the highest memory scores, followed by the only SI group, the only LON group, and the SI+LON group. This pattern is supported by participant quotes from the qualitative interviews, where participants agreed that while SI and LON can each have detrimental effects on memory function, LON has a more severe impact than SI. This is because alleviating SI was perceived as more immediately actionable than reducing LON, given the existence of numerous volunteer, religious, cultural, and other social engagement opportunities available for access that can alleviate SI. However, participants stressed that increasing social interactions did not automatically remedy their feelings of LON. Resolving LON was perceived as more challenging because it required participants to do additional psychological work, emotional healing, and self-reflection. When LON persisted, participants experienced a lack of optimism and diminished motivation. They observed that this preoccupation with the pain of LON substantially impaired their mental capacity and distracted them from recalling memories.

In line with this finding, Cacioppo's Evolutionary Theory of Loneliness [180] examined the phenomenon of LON reducing neuroplasticity. The theory posits that LON initiates a highly conserved biological stress response that is adaptive in the short term, but maladaptive in the long term, both physically and psychologically [180]. Social species, including humans, have evolved to perceive LON as a threat to their survival, prosperity, and reproduction, making the brain hypersensitive to social cues (e.g., body language, vocal tones, changes in communication patterns or social environments) in an effort to restore social connections [180,181]. This consumes cognitive resources needed for other functions, such as memory [180,181].

This response to LON can create a vicious cycle where lonely individuals are more likely to interpret ambiguous social information (e.g., avoiding eye contact, vague replies like 'we'll see') negatively, leading to behaviors and thoughts that undermine social connections and increase feelings of

LON [181,182]. Behavioral studies show that lonely individuals pay increased attention to images of social rejection and threats as measured by eye tracking [183,184]; are more likely to mislabel emotional expressions as negative [185]; and are quicker to identify negative emotional faces (e.g., anger, sadness, and fear) [186,187]. Additionally, LON is associated with poorer sleep quality [188,189], increases in depression and negative affects [190,191], increased levels of pro-inflammatory cytokines and inflammatory compounds (e.g., interleukin-6, C-reactive protein, and fibrinogen) [192,193], and heightened activation of the hypothalamus-pituitary-adrenal (HPA) axis, which plays a role in the body's response to stress through increased release of glucocorticoids (e.g., cortisol) [194]. Inflammation can impair critical areas of the brain involved in memory processing (e.g., hippocampus, prefrontal cortex, and amygdala), and thereby is a crucial mechanism linking the disrupted affective processes associated with LON to decreased memory and neuroplasticity [181].

Regarding the effects of SI on memory, our study discusses some positive aspects of introversion. Introverted participants often found solace in solitude, using it for self-care and personal focus. They engaged in non-social, but intellectually stimulating activities, which buffered SI's impact on their memory and made its effect less direct/severe than the effect of LON. This is consistent with our quantitative findings, as there were no statistically significant memory differences between the 'neither' and 'SI-only' groups (difference = -0.05 [BH-corrected p-value = 0.08]). However, memory differences were statistically significant between the 'neither' and 'LON-only' groups (difference = -0.15 [BH-corrected p-value = 0.00]) and between the 'SI-only' and 'LON-only' groups (difference = 0.10 [BH-corrected p-value = 0.02]). In the literature, information on aging adults' preference for introversion is sparse, with notable exceptions [32]. In fact, much of the literature supports the benefits of social activities on the psychosocial well-being of middle-aged and older adults [195–197], without fully considering the possibility that introverted persons may be psychosocially content with solitary activities. Existing research may prefer narratives that align with external constructs of successful aging (extroversion, social activity, independence, and productivity), overshadowing positive introversion experiences [198,199].

Nonetheless, our findings still agree with the existing literature in affirming that SI negatively impacts memory by reducing social engagement, which is crucial for memory-stimulating opportunities such as continuous learning, community connections, and establishing regular routines/structure and a sense of purpose/direction in life [200]. While short-term SI may not severely impair memory function, prolonged SI can be more detrimental because it may induce social anxiety, making social interactions stressful. In turn, individuals with social anxiety may withdraw further from social situations to reduce their stress, which over time can extend periods of isolation. Therefore, SI and social anxiety work in a

bidirectional cycle, as supported by Teo et al.'s [201] systematic review, which showed that individuals with social anxiety disorder were 73% more likely to live alone than those who did not have social anxiety disorder (pooled OR = 1.73, 95% CI = 1.34–2.24), and those living alone were 70% more likely to have social anxiety disorder than those living with cohabitants (pooled OR = 1.70, 95% CI = 1.38–2.10). Additionally, the odds of not being married were 65% higher in those with social anxiety disorder (pooled OR = 1.65, 95% CI 1.43–1.91), and the odds of having social anxiety disorder were 93% greater in unmarried individuals (pooled OR = 1.93, 95% CI = 1.58–2.37).

Lastly, the qualitative data supports our quantitative finding that experiencing both SI and LON together has a more detrimental impact on memory function compared to experiencing either factor alone. Specifically, our quantitative analysis revealed that the memory LSMEANS estimates were -0.80 (95% CI = -1.22, -0.39) for the 'both' group, -0.73 (95% CI = -1.13, -0.34) for the 'LON-only' group, and -0.69 (95% CI = -1.09, -0.29) for the 'SI-only' group, after adjusting for all included covariates. Qualitative themes revealed that SI and LON exacerbate one another, particularly during major life transitions. For instance, qualitative data for this thesis were collected immediately after the COVID-19 pandemic, a unique period when social interactions were restricted, travel was limited, and social venues and activities were curtailed. These restrictions increased the time people spent in solitude, exacerbating both SI and LON. Several participants also experienced widowhood/bereavement, retirement, or relocation, leading to changes in their social network size and composition, daily routines, patterns of social interaction, and community environment, all of which contributed to increased SI. The lack of social connections also made it challenging to find help when needed, coinciding with poorly perceived social support, a low sense of belonging, and changes in social roles and identity, leading to LON.

In addition to COVID-19, widowhood, and relocation, participants identified old age, poor mental/physical health, and caregiver responsibilities as other risk factors that contributed to both SI and LON. Existing literature supports these findings, showing that people experiencing both SI and LON are more likely to be widowed, older, dealing with health comorbidities, have higher medical costs, more frequent visits to emergency rooms, lower incomes, and are more likely to be female compared to those who are only socially isolated or only lonely [17,18,202]. Similarly, our quantitative results for the effects of covariates on the association between SI/LON and memory revealed that health comorbidities and sociodemographic factors (e.g., age, sex, income, education) partially explain why the 'only LON' and 'both isolated and lonely' groups had worse memory than the 'only SI' group. In the qualitative interviews, participants revealed that health issues contributed to their feelings of LON due to fears of being judged or misunderstood because of societal stigma surrounding their conditions. This led to lowered self-esteem and feelings of being a burden, which resulted in reduced participation in certain activities or groups.

Additionally, participants mentioned that their health conditions or caregiver responsibilities often left them without the time, energy, or motivation to connect with others, resulting in SI. Some participants also noted that the medications they took for their health conditions produced side effects that impacted their memory. Thus, health conditions contributed to memory decline both directly and by exacerbating SI and LON.

Poor health status was also linked to mobility issues, causing functional impairments in basic and instrumental activities of daily living such as walking, using public transportation, shopping, doing house chores, and taking medications. These functional impairments limited community mobility, which is crucial for mitigating SI and LON by enabling individuals to stay connected to their social networks and engage in meaningful activities like work, volunteering, leisure activities, outings with family and friends, medical appointments, shopping, and community sports [32]. This qualitative finding aligns with the quantitative analyses, which showed that functional impairments amplified the individual and combined negative effects of SI and LON on memory.

Overall, our qualitative interviews demonstrate that while SI and LON are distinct concepts, they are often experienced together, particularly when certain risk factors create a feedback loop that perpetuates both conditions. Being trapped in this cycle of SI and LON can substantially increase stress levels beyond what one might experience from being either only isolated or only lonely. High stress levels associated with simultaneously experiencing both SI and LON can lead to a cognitive overload, making it more difficult for individuals to process and retain information [113,130].

Some participants theorized that memory loss can occur because of attempts to suppress stressful memories from the past (i.e., dissociation). Conversely, they noticed that a supportive environment and reduced stress enhanced their memory function, recognizing the importance of emotional well-being and social support in maintaining cognitive health. Numerous studies on post-traumatic stress disorder (PTSD) support this hypothesis: trauma can impair the brain's ability to cope with and process memories, leading to memory loss, distortion, or suppression of traumatic events, and difficulties remembering everyday aspects of life [203–205]. Memory loss is often classified as an avoidance or numbing symptom of PTSD, theoretically acting as a defense mechanism of the brain [206]. Another explanation is the brain's failure to integrate sensory memories (sight, hearing, taste, touch, smell) with the emotional fear associated with a specific traumatic event [207]. In addition, our participants and existing research on self-defeating behaviours [208,209] demonstrated that high stress levels increase the tendency to engage in self-destructive behaviors, such as smoking, drinking, physical inactivity, and poor nutrition. Therefore, the effects of being isolated and lonely are not merely additive, but exponential, as both

conditions perpetuate one other and intertwine with other health and lifestyle factors to worsen the memory function and overall cognition.

6.3 Strengths and limitations

To our knowledge, this is the first sequential explanatory mixed-methods study to investigate the combined impact of SI and LON on memory. Previous memory research related to SI/LON has predominantly used quantitative methods, but introducing a qualitative approach can add significant value by providing contextual insights and deeper explanations for quantitative findings. Moreover, this study explored both the individual and combined effects of SI and LON on memory, diverging from most previous studies that focused only on their separate impacts.

6.3.1 Quantitative phase

The quantitative phase of this study employed a four-level exposure group for SI/LON, allowing for a systematic identification of significant differences in memory across various combinations of SI and LON. Unlike most SI studies, our research used a multi-modal measure of SI, providing a more accurate depiction of the relationship between SI and memory. Additionally, we utilized longitudinal data to track changes in memory scores over a six-year period, offering more comprehensive observations than cross-sectional or shorter longitudinal studies. This extended follow-up period also provided insights into how memory scores evolve as individuals transition into more vulnerable SI and LON groups. In contrast to the work reported in this thesis, among the 12 studies reviewed by Kang and Oremus [78], eight were either cross-sectional [33,34,43,44] or had follow-up periods shorter than six years [12,26,35,54]. Another strength of this study was the inclusion of both middle-aged and older adults, expanding the focus beyond the older populations typically enrolled in memory studies. This broader sample allowed us to examine the association between SI, LON, and memory across different age groups, where we found that severe cases of SI and LON were more common in older-aged groups than in the middle-aged group. However, more middle-aged individuals reported moderate levels of SI and LON compared to older age groups, some of whom did not feel socially isolated nor lonely. Thus, SI and LON generally increased with age, but some older adults deviated from this trend, having adapted to their older-age stage by finding ways to reconnect socially and manage LON. Understanding these differences in SI and LON between age groups is crucial, as today's middle-aged people will become tomorrow's older adults, and these differences could impact future social support systems and mental health services.

Our study also accounted for a more comprehensive set of covariates than past research, reducing the potential for residual confounding. On average, previous studies considered seven covariates, with

age, sex, education, and depressive symptoms being the most frequently adjusted variables, as seen in 8 out of 12 earlier memory publications [78].

However, the present study also had some limitations. First, the participants may not represent an unbiased sample of the target population. At baseline, CLSA participants were generally healthier, wealthier, and more educated than the average Canadian aged 45 to 85 years [210]. Additionally, older participants with depression, greater functional limitations, higher levels of SI/LON, and lower memory performance were more likely to drop out of the CLSA over time. These factors resulted in an analytical sample that was cognitively healthier and less affected by SI/LON, potentially underestimating the true associations under investigation. Consequently, our findings are only applicable to individuals with similar characteristics to our analytical sample.

Another limitation was the use of a single-item measure for assessing LON (in the quantitative phase), which can be prone to recency and response biases [42,49]. However, other researchers [26,35,36,54] have used single-item measures of LON and found results comparable to those obtained from validated, multi-item instruments like the De Jong-Gierveld Loneliness Scale [50] and the UCLA Loneliness Scale [51]. Mund et al. [211] explained that single-item direct and indirect measures (such as asking about the availability of confiding relationships instead of directly about LON) show convergent validity, especially at extreme levels of LON.

Most single-item measures of LON typically assess the frequency of feeling lonely within a 7-day timeframe, usually with four response choices [18,49,54], similar to the CES-D question [52] used in the CLSA baseline data. Among these single-item measures, the CES-D has been a popular and reliable choice in many studies involving middle-aged and older populations from diverse ethnic backgrounds [18,49,54]. In Kang and Oremus's [78] review, 11 of 12 studies assessed LON using either the De Jong-Gierveld Loneliness Scale, UCLA Loneliness Scale, or CES-D Scale.

6.3.2 Qualitative phase and its integration with quantitative data

A notable strength of the qualitative phase of this study was the diversity among our participants. We recruited individuals from two distinct organizations (SLR and Brandon University) to achieve maximum variation in our sample. Participants reported varying levels of SI and LON, social activity participation, ages, marital statuses, numbers of cohabitants, and socio-economic statuses. Given the context-driven nature of the qualitative findings, this diversity enabled a more comprehensive and nuanced understanding of how aging adults experience SI and LON, and how they perceive these factors as contributing to memory impairment.

However, a limitation of this study phase was that we drew upon different samples for the quantitative and qualitative phases. However, the CLSA participants' contact information is confidential, thereby necessitating the employment of a parallel sample in the qualitative phase. Parallel sampling in mixed methods research is a process whereby researchers recruit qualitative participants who possess sociodemographic characteristics similar to those in the quantitative study [212]. Several sequential explanatory mixed methods studies in healthcare-focused research have employed parallel samples and yielded validated results [80,159,165,166]. To ensure similarity between the two samples, I screened for age, sex, and education during the recruitment stage. While this effort resulted in generally comparable demographics between the quantitative and qualitative samples, the qualitative sample was slightly older and were more educated than its quantitative counterpart.

6.4 Future implications and conclusions

The findings of this research highlight the critical need for targeted interventions, especially for adults facing a combination of SI and LON, who are at the highest risk of memory impairment. Although this group constitutes a smaller proportion of the population, their high prevalence of health issues and low income suggests they face substantial structural barriers to social engagement that would justify the development of targeted prevention policies. In the qualitative phase, participants mentioned the benefits of virtual social interactions, home visits, and pet therapy for the combined SI and LON group. These ideas can serve as the basis for policy development.

Virtual platforms serve as crucial social outlets and connections to the world for persons confined to their homes due to mobility issues or other disabilities. Aging individuals may also live apart from family and friends, lack connections to their local community, and have insufficient time or funds to travel. Virtual social platforms can help overcome these barriers and sustain long-distance relationships by mitigating the effects of low income and prevalent health problems on social connectedness in this isolated and lonely group. Holt-Lunstad [213] highlighted that virtual interventions (e.g., online social networking, video conferencing, messaging apps, and virtual companions like robotic pets) present some of the most promising evidence for effectively reducing SI and LON, particularly among older adults and individuals with mental health challenges.

In addition, home visits may provide personalized care, including medical support and home environment adjustments, and foster opportunities for new social connections. Existing literature indicates that structural barriers, such as limited awareness of available resources (due to a lack of communication between service providers and service users) and geographical challenges (e.g., the need to travel long distances to access services), often prevent individuals from accessing community services and programs

[32,214]. For those who are isolated and lonely, but unaware of where to seek social support, home visits can break this cycle by bringing relevant information about social services directly to their homes and creating new avenues for social connections. In addition to home visits, Goldman et al. [215] provided further intervention examples to address the above-mentioned structural barriers. These included creating flexible housing solutions to support life transitions, such as adaptable homes that could change in size or function to meet the resident's evolving needs. They also recommended enhancing accessible transportation options within residential areas, including local subsidies for public transit, and promoting mindful urban planning that prioritizes pedestrian-friendly spaces (e.g., designated walking paths/trails with safe crossings, benches, and exercise stations designed to encourage organized walking groups). Moreover, they recommended transforming underutilized community spaces into venues for social events, community gardens, or pop-up markets, thereby creating hubs where residents could gather, interact, and participate in community life.

Regarding pet therapy, qualitative participants explained that their desire for human interactions and social support was partially fulfilled through bonding with their pets, as taking care of pets allowed them to take on a nurturing role, and spending time with pets resembled interactions with friends. Similarly, Banks et al. [216] and Krause-Parello [217] demonstrated that animal-assisted therapy in long-term care facilities and pet ownership significantly improved older adults' perceptions of general attachment and substituted for human interaction.

The 'only LON' group emerges as the next priority. Despite potentially having large social networks, individuals in this category struggle with unmet social needs. Therefore, traditional interventions focused solely on increasing the frequency of social interactions may not be optimal for this group. In fact, Courtin and Knapp [117] reported that befriending programs and group activities effectively increased the number of new friendships, improved physical health, and enhanced overall well-being among older adults, but did not significantly reduce LON. In contrast, social support programs fostering peer companionship and social cognitive training (e.g., interventions enhancing social skills, empathy, and emotion recognition) were identified as promising interventions for reducing LON [213,215]. However, Goldman et al. [215] noted that effective LON interventions must be tailored to the specific type of LON experienced by an individual, as a one-size-fits-all approach is unlikely to succeed. Therefore, LON interventions should focus on conducting needs assessments (i.e., collaborating with social workers or other professionals to identify individual goals, needs, and challenges) and providing counseling to navigate existing relationships, such as a strained marital relationship [218,219]. Addressing the negative perceptions individuals may hold about their social relationships (e.g., how

others perceive them, the level of support they receive, or their fit within social circles) could be crucial for the 'only LON' group.

In the qualitative phase, participants highlighted the importance of a solid spousal/cohabitant relationship for alleviating LON and maintaining memory retention, as they relied on their spouses for memory help, and they outsourced certain memory tasks to their spouses to alleviate memory gaps. Given that individuals generally spend substantial time, and share intimate/personal experiences, with their spouses, being married provides someone who is readily available to help recall forgotten information. Existing literature indicates that people prefer to rely on their spouses over others (e.g., friends, children, or siblings) for help with basic daily tasks [220]. They feel less guilty asking their spouses for help and find it easier to coordinate schedules with them compared to other members of their social network [220].

The underlying premise of this dynamic shows that aging adults do not want to be seen as burdensome or dependent to people outside their most intimate circles. Our participants actively sought reciprocity in their social relationships and emphasized how this reciprocity improved their self-esteem, fostered fulfillment/purpose in their lives, helped maintain a healthy, long-lasting relationship, and connected them to the broader community. Therefore, programs targeted at alleviating LON should consider introducing opportunities for people to give back to their community and engage in activities that help others. This approach may improve the quality of existing relationships for people who are not isolated yet still feel lonely. Given that this reciprocal dynamic is particularly strong in spousal relationships, where mutual support is both expected and readily given, fostering environments where couples can participate in volunteer work or community projects together may strengthen their bond while simultaneously contributing to the broader community. These couple-focused activities can incorporate memory elements in various ways. Couples could engage in community storytelling projects, sharing personal or historical stories to stimulate their memory and strengthen community ties. They might also organize memory-themed events, such as trivia nights, to involve the broader community and raise awareness about cognitive health.

Our findings show that SI may not significantly or directly impact the memory of individuals who are briefly isolated or who choose isolation; however, SI can be more detrimental and pronounced for those experiencing prolonged isolation. For this group, effective interventions might include practical strategies for managing memory changes and educating them on the cognitive health risks associated with social isolation [18]. For instance, our qualitative participants mentioned engaging in (memory-enhancing) language-based or creative activities, such as writing memory notes, reading, playing word games, creating artwork, solving math problems, and pursuing hobbies. They also employed techniques

like repetition (rereading materials, verbally repeating information) and planning (creating detailed daily schedules, specifying who to meet and what to do at certain times) to manage memory changes.

Finally, it is crucial to recognize that socially isolated individuals are more likely to experience LON as they age and face the possibility of functional limitations, chronic conditions, or income decline, which can lead them to perceive a gap between existing and needed levels of social support to cope with these challenges [18]. Therefore, monitoring transitions into different SI/LON categories is essential for maintaining memory function. SI is directly linked to the availability and receipt of social support: to receive necessary social support, one must remain connected to their social network. Our qualitative participants emphasized the need for a diverse social network, comprising multiple layers of connections (e.g., family, close friends, and casual acquaintances). Casual acquaintances, such as coworkers and neighbors, can provide companionship through positive social interactions, while more intimate connections, like family and long-time friends, offer a more comprehensive range of support, including emotional, informational, and instrumental aid, in addition to companionship. Our participants also noted that characteristics shared with peers, such as gender, age, or disability, fostered better understanding and empathy because they could receive support without needing to explain themselves or directly request help. This finding was echoed in related studies [221–223]. Therefore, interventions focused on alleviating SI may particularly benefit from increasing peer-group activities.

In conclusion, this research emphasized the importance of SI and LON in understanding memory outcomes in middle-aged and older adults over a six-year period. The study found that LON had a more pronounced impact on memory than SI. Furthermore, experiencing both SI and LON together had a more severe impact on memory than experiencing SI or LON alone. These associations remained after adjusting for covariates, including sociodemographic factors, functional limitations, lifestyle variables, and health comorbidities. The qualitative interviews added valuable context to these quantitative findings and explained the mechanisms through which SI alone, LON alone, and experiencing both can affect memory differently. The qualitative interviews also suggested tailored approaches to foster social connections and emotional well-being, revealing specific policies and interventions for reducing SI and LON, thereby enhancing cognitive health.

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APPENDIX I: Literature Review of the Evidence for the Association between Social Isolation, Loneliness, and Memory

Table S1.1.

Review Search Strategy Used in All Databases

Step	Terms
PubMed	(Social isolation OR social connection OR Social Network OR family OR friend OR peer OR informal social network OR social participation OR social engagement) AND (loneliness OR lonely) AND (memory OR memory loss OR recall memory OR immediate recall OR delayed recall OR memory function)
Scopus	(TITLE-ABS-KEY (“Social isolation” OR “social connection*” OR “Social Network*” OR family OR friend OR peer OR peers OR “social participation” OR “social engagement”) AND TITLE-ABS-KEY (loneliness OR lonely) AND TITLE-ABS-KEY (memory OR “immediate recall” OR “Delayed recall”))
PsychInfo	Any Field: “Social isolation” OR Any Field: “social connection*” OR Any Field: “Social Network*” OR Any Field: family OR Any Field: friend OR Any Field: peer OR Any Field: peers OR Any Field: “social participation” OR Any Field: “social engagement” AND Any Field: loneliness OR Any Field: lonely AND Any Field: memory OR Any Field: “immediate recall” OR Any Field: “delayed recall”

Figure S1. Article Screening Process and Eligibility Criteria

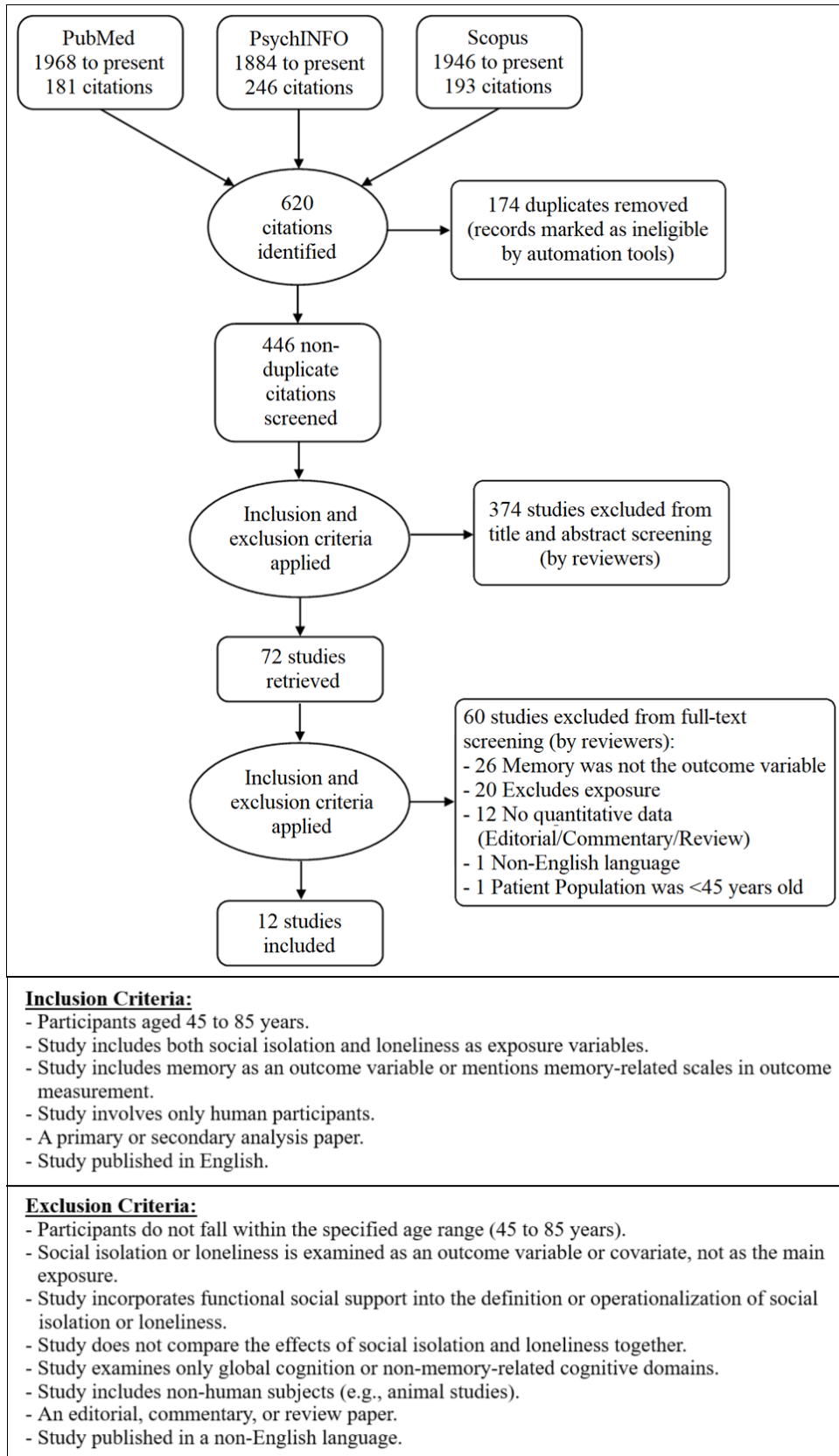


Table S1.2.

Data Extraction for Studies Included in Review

Author (year); study design; setting; sources of funding	Sample size; age range/ mean age; %female	Social isolation and loneliness (exposure) measure	Memory (outcome) measure	Covariates	Summary findings
Estrella et al. (2021); cross-sectional; USA – study used baseline data (2008-2011) from HCHS/SOL; no funding received	2,818; 45-75 years; 56.40%	Continuous scores for loneliness and social isolation respectively measured by the Revised UCLA Loneliness Scale and the SNE Subscale of SNI (assesses presence of social relations across domains of family, friends, church/temple, school, work, volunteering, neighbors, and other groups)	Continuous score for verbal episodic memory (delayed recall) measured by B-SEVLT	age, sex, education, Hispanic/Latino background, income, language, and depressive symptoms	SNE was significantly positively associated ($\beta = 0.35$ [95% CI = 0.09 to 0.60]), and loneliness was significantly negatively associated ($\beta = -0.48$ [95% CI = -0.65 to -0.32]) with memory (independent of age, sex, and education). However, only loneliness (and not SNE) remained significantly associated with memory after further adjustment of Hispanic/Latino background, annual household income, language preference, and depressive symptoms (SNE: $\beta = 0.13$ [95% CI = -0.13 to 0.38]; loneliness: $\beta = -0.20$ [-0.37 to -0.03]).
Fung et al. (2019); cross-sectional; study was conducted between 2012 – 2013 in Hong Kong; received funding from Lui Che Woo Institute of Innovative Medicine	497; ≥ 60 years; 54.90%	Continuous score for loneliness measured by Chinese 6-items version of DJGLS. Dichotomous score for social isolation assessed through size of confiding and non-confiding networks (isolated = network size of ≤ 6 ; non-isolated = ≥ 7). Loneliness and network sizes were mean-centered.	Continuous score for verbal episodic memory (10-minute delayed recall) measured by ADAS-Cog	age, education, sex, living arrangement, family history of dementia, marital status, life satisfaction, neuroticism, CIRS-based physical health status, and CIS-R-based mental illness diagnoses	There was a significant interaction effect between loneliness and non-confiding networks size ($\beta = 0.092$ [p = 0.036]), but loneliness had no significant interaction with total network size ($\beta = 0.083$ [p = 0.062]) nor with confiding network size ($\beta = -0.010$ [p = 0.869]) for memory performance. Within non-confiding networks, loneliness had significant interaction with number of family members (but not friends) for memory (Loneliness x NFamily: $\beta = -0.119$ [p = 0.006]; Loneliness x NFriend: $\beta = -0.078$ [p = 0.074]). Overall, social network size was significantly positively associated with memory ($\beta = 0.126$ [p = 0.005]), while loneliness was negatively associated with memory ($\beta = -0.165$ [p = 0.002]) and social network size.

Gilmour (2011); cross-sectional; Canada – study used 2008 – 2009 data from CCHS - Healthy Aging Cognition Module; received funding from the CLSA	13,176; ≥65 years; NR	Dichotomous score for loneliness measured by asking participants how often they lacked companionship, felt left out, or felt isolated (lonely = answering ‘some of the time’ or “often” on each of three questions; not lonely = answering ‘hardly ever’). Social isolation assessed through living arrangements (nominal: living alone/living with a partner/other arrangements) and frequency of social participation (dichotomous: ‘yes/no’ to having at least weekly participation in at least one community-related social activity).	Dichotomous score for verbal episodic memory (immediate and 5-minute delayed recall) measured by 15-item word list recall test (scores dichotomized as ‘low’ vs ‘moderate/high’)	Age, sex, education	Participants with low scores on both immediate and delayed recalls were significantly more likely to live alone than those with moderate/high immediate and delayed recalls ($low_{immediate}$: 33.1 [$p < 0.05$]; moderate/high $_{immediate}$: 29.6 [$p > 0.05$]; $low_{delayed}$: 32.8 [$p < 0.05$]; moderate/high $_{delayed}$: 29.4 [$p > 0.05$]). Those with low scores on only the immediate recall (but not delayed recall) were significantly less likely to participate in social activities ($low_{immediate}$: 74.1 [$p < 0.01$]; moderate/high $_{immediate}$: 78.4 [$p > 0.05$]), and more likely to be lonely ($low_{immediate}$: 13.9 [$p < 0.01$]; moderate/high $_{immediate}$: 10.4 [$p > 0.05$]).
Goldberg et al. (2021); cohort; USA – study used 6-year follow-up data from the Northern Manhattan Aging Project; received funding from the Stroud Foundation	855; ≥65 years/ mean age of 74; 68.70%	CARE survey of QOL used to measure social isolation and loneliness. Social isolation measured by 24 items relating to: participation in social activities, contacts with friends, and going unnoticed for 24h when ill (continuous score). Loneliness measured through 6 items, including often feels lonely, does not feel close to anyone, no one to talk to about problems (continuous score).	Dichotomous score for verbal episodic memory (immediate recall) measured by the 12-item, 6-trial, VSRT (dichotomized as ‘low’ vs ‘high’ scores using median split)	Time, age, sex, education	Social isolation was significantly positively associated with loneliness ($r = 0.07$ [$p < 0.05$]) and significantly negatively associated with memory ($\beta = -2.66$ [95% CI = -3.72 to -1.59]). Loneliness had no significant association with memory ($p = 0.913$).
Gow et al. (2013); cross-sectional; Scotland – study used the Lothian Birth Cohort 1936 data (completed a SMS-1947 mental ability test at mean age of 11 years); received funding from the Economic and Social Research Council	1,091; mean age of 70; NR	Social isolation assessed through living arrangements (dichotomous: living alone/with others), marital status (nominal: married or cohabiting/unmarried /divorced/widowed or single), and social contact (continuous: summed score for 7 ‘yes/no’ items adapted from Starr et al. (2003) study). Continuous score for loneliness measured by asking participants whether they feel lonely at the present moment, scored on a five-point scale	Continuous score for memory measured by the principal components analysis performed on the battery test, taken from WAIS-III UK and WMS-III UK.	age, sex, social class, age-11 IQ, depression	Loneliness was significantly negatively associated with the number of social contacts ($\rho = -0.25$ [$p < 0.001$]) and memory. The association between loneliness and memory remained significant after controlling for age, sex, and age-11 IQ ($\eta^2 = 0.009$ [$p = 0.003$]), but not after further adjustment for social class ($\eta^2 = 0.001$ [$p = 0.434$]) and depressive symptoms ($p = 0.74$). Social contacts ($\eta^2 = 0.004$ [$p = 0.056$]), marital status ($\eta^2 = 0.000$ [$p = 0.735$]), and living alone ($\eta^2 = 0.001$ [$p = 0.396$]) were not significantly associated with memory.

Hulur (2022) and Hulur et al. (2022); cohort; USA – study used 8-year follow-up data from the Health and Retirement Study; received funding from the NIA and the University of Michigan	19,297; 50 – 104 years; 58.00%	Social isolation assessed through marital status (dichotomous: yes/no), number of children/relatives/friends (continuous: scored on a 5-point scale), and interaction frequency (continuous: defined as how often participants meet up in-person, speak on the phone, and email/write to children, relatives, friends, respectively). Continuous score for loneliness measured by the 3-item UCLA Loneliness scale.	Continuous score for verbal episodic memory (immediate and 5-minute delayed recall) measured by 10-item word list recall test	age, gender, education, functional health limitations, depressive symptoms	Participants had significantly higher memory performance when they were married ($\beta = 0.77$ [$p < 0.01$]), had more close friends ($\beta = 0.08$ [$p < 0.01$]), interacted more frequently ($\beta = 0.79$ [$p < 0.01$]), and had lower level of loneliness ($\beta = -0.69$ [$p < 0.01$]). However, participants with larger numbers of children ($\beta = -0.19$ [$p < 0.01$]) and relatives ($\beta = -0.06$ [$p < 0.01$]) had significantly lower memory performance than those with smaller children/relatives network size. These effects remained significant after including all covariates, except for the effect of number of children.
Kuiper et al. (2020); cohort; Netherland – study used 2-year follow-up data from NESDO; received funding through the Brain and Behaviour Research Fund, Leiden University Medical Center, and University Medical Center Groningen	378; mean age of 70.7; 66.10%	Continuous score on loneliness measured by the DJGLS. Social isolation assessed through the following Close Person Inventory question: ‘How many family members, friends, and acquaintances, over the age of 18, do you have regular and important contact with, disregarding roommates?’ (ordinal: 0-1; 2-5; 6-10; 11-15; 16-20; 20+ contacts)	Verbal episodic memory (immediate and delayed recall) was measured by modified RAVLT (continuous score). Working memory was measured by forward and backward digit span from WAIS (continuous score)	age, sex, years of education, alcohol use, physical activity, depressive symptom severity (at baseline and after 2 years of follow-up)	Loneliness and social network size were both not significantly associated with baseline measures of both verbal and working memory (all $p > 0.05$). Loneliness was significantly associated with 2-year decline in working memory ($\beta = -0.08$ [$p = 0.049$]), but not with verbal memory ($\beta = -0.03$ [$p > 0.05$]). Social isolation was not significantly associated with 2-year decline in both working and verbal memory. The association between loneliness and working memory was also not significant after adjusting for all covariates. The backward elimination procedure retaining all independent variables with $p < 0.05$ retained education level ($\beta = 0.09$ [$p = 0.035$]), suggesting that a low education level confounded the association between loneliness and 2-year decline in working memory.
Lara et al. (2019); cohort; Spain – study used 3-year follow-up data from ‘Edad con Salud’; received funding from the European Union European Regional Development	1,691; mean age of 64.5/ ≥ 50 years; 52.80%	Continuous score for social isolation was measured by Shankar et al.’s (2011) Social Isolation Index, which scores participants on a 5-point scale based on their marital status, participation in organizations/religious groups/sports clubs/committees, and having less than monthly contact with friends/children/other immediate family. Loneliness	Verbal episodic memory (immediate and 5-minute delayed recall) was measured by CERAD (continuous score). Working memory was measured by forward and backward digit span from WAIS (continuous score). Semantic memory was assessed with animal	Age, sex, education, level of physical activity, alcohol consumption, disability, stroke, diabetes, depression	Loneliness was significantly negatively associated with immediate recall ($\beta = -0.83$ [95% CI = -1.29 to -0.36]), delayed recall ($\beta = -0.25$ [95% CI = -0.46 to -0.03]), and backward digit span ($\beta = -0.14$ [95% CI = -0.24 to -0.04]). Lonelier participants also reported more rapid declines in backward digit span from baseline to follow-up ($p < 0.04$). Social isolation was significantly negatively associated with forward digit span ($\beta = -0.06$ [95% CI = -0.11 to -0.02]),

Fund: “A Way to Build Europe.”		measured by the 3-item UCLA Loneliness scale ((i) continuous: total loneliness score converted to percentile scale; and (ii) dichotomous: scores dichotomized based on a cutoff score of 6.38)	naming task (continuous score)		but higher social isolation was not associated with faster rate of decline in forward digit span.
Pugh et al. (2021); cohort; USA – study used data from MARS; received funding from the NIA	617; mean age of 73.31/57 – 97 years; 77.00%	Continuous score for loneliness measured by 5-items version of DJGLS. Continuous score for social isolation was assessed through the frequency of participation in social activities in the past year (measured on a 5-point scale) and the number of children/family members/friends seen at least once a month.	Verbal episodic memory was measured with Word List Memory, Word List Recall, Word List Recognition, and immediate/delayed recall of EBMT and Revised WMS (continuous). Working memory was measured with forward and backward digit span from Revised WMS and Digit Ordering (continuous). Semantic memory was measured by BNT, Category Fluency from CERAD, 15-item WRAT reading test (continuous).	Age, education, vascular risk, sex, marital status, time (number of years since enrollment), depressive symptoms	Social activity was significantly positively associated with semantic ($\beta = 0.096$ [$p < 0.001$]) and working memory ($\beta = 0.055$ [$p = 0.041$]). Social activity also demonstrated an interaction with time such that higher social activity was associated with improvement in episodic memory over time ($\beta = 0.015$ [$p < 0.001$]). Loneliness was significantly negatively associated with semantic memory ($\beta = -0.109$ [$p = 0.018$]), but not episodic ($\beta = -0.089$ [$p = 0.059$]) or working memory ($\beta = -0.086$ [$p = 0.081$]). However, over time, higher loneliness was associated with improvement in semantic memory performance ($\beta = 0.009$ [$p = 0.037$]). Social network size was not significantly associated with episodic ($\beta = 0.000$), semantic ($\beta = -0.001$), nor working memory ($\beta = 0.001$) (all $p > 0.05$).
Shankar et al. (2013); cohort; England – study used 4-year follow-up data from ELSA; received funding from the NIA and United Kingdom Office for National Statistics	8,630; mean age of 65.6; 54.70%	Continuous score for social isolation was measured by Social Isolation Index, which scores participants on a 5-point scale based on their marital status, participation in organizations/religious groups/sports clubs/committees, and having less than monthly contact with friends/children/other immediate family. Continuous score for loneliness measured by the 3-item UCLA Loneliness scale.	Continuous score for verbal episodic memory (immediate and delayed recall) measured by 10-item word list recall test	Age, sex, socioeconomic status, smoking, employment status, depression, physical activity	Social isolation was significantly positively associated with loneliness ($\beta = 0.24$ [$p < 0.001$]). At baseline, social isolation and loneliness were both significantly negatively associated with immediate recall (both loneliness and social isolation: $\beta = -0.05$ [$p < 0.001$]) and delayed recall [loneliness: $\beta = -0.03$ [$p < 0.05$]; social isolation: $\beta = -0.04$ [$p < 0.001$]]. These effects remained significant after including all covariates. There was a significant interaction effect between loneliness and social isolation for immediate ($\beta = -0.03$ [$p < 0.01$]) and delayed recall ($\beta = -0.03$ [$p < 0.05$]) such that recall declined over time with increases in loneliness for individuals who are more isolated.

Yu et al. (2021); cohort; China – study used 4-year follow-up data from CHARLS; received funding from the National Social Science Foundation	7,761; mean age of 60.97; 49.20%	Loneliness was measured by single-item question from the CESD-10 depression scale that asks, "In the last week, how often did you feel lonely?" (dichotomous: lonely = answering 'rarely' or 'none of the time'; not lonely = answering 'some of the time', 'occasionally', or 'often'). Social isolation was assessed through marital status, monthly participation in social activities, and weekly contact (by phone, in-person, or by email) with children (continuous: scored on a 3-point scale)	Continuous score for verbal episodic memory (immediate and delayed recall) measured by 10-item Chinese word list recall test	Age, sex, education, heart disease, diabetes, hypertension, depressive symptoms, drinking/smoking status, functional limitations (required assistance with 6 ADLs and 5 IADLs), area of residence (rural/urban)	Social isolation and loneliness were both significantly negatively associated with episodic memory (social isolation: $\beta = -0.05$ [$p < 0.001$]; loneliness: $\beta = -0.03$ [$p = 0.002$]). However, only social isolation (but not loneliness) remained significantly associated with episodic memory after fully adjusting for all covariates.
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Notes. ADAS-Cog = Alzheimer's Disease Assessment Scale-Cognitive Subscale; ADL = activity of daily living; BNT = Boston Naming Test; B-SEVLT = Brief Spanish-English Verbal Learning Test; CARE = Comprehensive Assessment and Referral Evaluation; CCHS = Canadian Community Health Survey; CERAD = Consortium to Establish a Registry for Alzheimer's Disease; CHARLS = China Health and Retirement Longitudinal Study; CLSA = Canadian Longitudinal Study on Aging; CIRS = Chronic Illness Rating Scale; CIS-R = Revised Clinical Interview Schedule; DJGLS = De Jong Gierverg's loneliness scale; EBMT = East Boston Memory Test; ELSA = English Longitudinal Study of Ageing; HCHS/SOL = Hispanic Community Health Study/Study of Latinos; IADL = instrumental activity of daily living; MARS = Minority Aging Research Study; NESDO = Netherlands Study of Depression in Older Persons; NFamily = number of family members in non-confiding network; NFriend = number of friends in non-confiding network; NIA = National Institute on Aging; η^2 = partial eta squared; NR = not reported; QOL = quality of life; RAVLT = Rey Auditory Verbal Learning Test; SMS-1947 = Scottish Mental Survey of 1947; SNE = Social Network Embeddedness; SNI = Social Network Index; UCLA = University of California, Los Angeles; USA = United States of America; VSRT = Verbal Selective Reminding Test; WAIS = Wechsler Adult Intelligence Scale; WMS = Wechsler Memory Scale; WRAT = Wide Range Achievement Test

APPENDIX II: Quantitative Research Ethics Approval

UNIVERSITY OF WATERLOO

Notification of Ethics Clearance to Conduct Research with Human Participants

Principal Investigator: Mark Oremus (School of Public Health Sciences)

Student investigator: Ji Won Kang (School of Public Health Sciences)

File #: 43985

Title: Examining the Combined Effects of Social Isolation and Loneliness on Memory

The Human Research Ethics Board is pleased to inform you this study has been reviewed and given ethics clearance.

Initial Approval Date: 02/11/22 (m/d/y)

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

This study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Expiry Date: 02/12/23 (m/d/y)

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Board



Joanna Eidse, Research Ethics Officer, jeidse@uwaterloo.ca, 519-888-4567, ext. 37163

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Documents reviewed and received ethics clearance for use in the study and/or received for information:

file: CLSA Data Access Application.docx

file: CLSA Data Access Application_Version1_20220210.docx

file: CLSA VARIABLES LIST_Version1_20220210.docx

file: CLSA QUESTIONS_Version1_20220210.docx

Approved Protocol Version 2 in Research Ethics System

This is an official document. Retain for your files.

You are responsible for obtaining any additional institutional approvals that might be required to complete this study.

Appendix III: Qualitative Research Ethics Approval

UNIVERSITY OF WATERLOO

Notification of Ethics Clearance to Conduct Research with Human Participants

Principal Investigator: Mark Oremus

Student investigator: Ji Won Kang

Co-Investigator: Suzanne Tyas

Co-Investigator: Charity Oga-Omenka

Co-Investigator: Joel Dubin

Collaborator: Nancy Newall (Brandon University)

File #: 45670

Title: Combined Effects of Social Isolation and Loneliness on Memory: A Qualitative Study

The Human Research Ethics Board is pleased to inform you this study has been reviewed and given ethics clearance.

Initial Approval Date: 12/21/23 (m/d/y)

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS2 2022), the Ontario Personal Health Information Protection Act (PHIPA), and all laws and regulations of the province of Ontario (as applicable). Additionally, CREB operates in a manner consistent with the International Conference for Harmonization of Technical Requirements for Pharmaceuticals for Human Use (ICH) Guidance E6(R2): Good Clinical Practice, the International Organization for Standardization of Good Clinical Practices (GCP) as set out by ISO 14155 - Clinical investigation of medical devices for human subjects, Part C, Division 5 of the Food and Drug Regulations, Part 4 of the Natural Health Products Regulations, Part 3 of the Medical Devices Regulations. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

Expiry Date: 12/22/24 (m/d/y)

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Board



Joanna Eidse, Research Ethics Officer, jeidse@uwaterloo.ca, 519-888-4567, ext. 47163

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Documents reviewed and received ethics clearance for use in the study and/or received for information:

file: Community Mental Health Resources_Version1_20230820.pdf

file: tcps2_core_certificate_2022_Newall.pdf

file: Screening Questionnaire_Version2_20231211.docx

file: Demographic Questionnaire_Version1_20230820.pdf

file: Interview Questions_Version1_20231109.pdf

file: Letter of Information_Version3_20231220.docx

file: CONSENT FORM_Version2_20231211.docx

file: Oral Consent Log_Version1_20231211.docx

file: Written Appreciation_Version2_20231211.docx

file: Recruitment Flyer and Poster Information_Version2_20231211.docx

file: Email Script_Version2_20231211.docx

file: Telephone and Verbal Script_Version2_20231211.docx

file: Email Newsletter Post_Version2_20231211.docx

Approved Protocol Version 3 in Research Ethics System

This is an official document. Retain for your files.

You are responsible for obtaining any additional institutional approvals that might be required to complete this study.

APPENDIX IV: Recruitment Poster Information



PARTICIPANTS NEEDED FOR A RESEARCH STUDY ABOUT SOCIAL ISOLATION, LONELINESS, AND MEMORY

Who: Adults aged 45 - 85 years.

What: We are looking for volunteers to participate in a study to understand how social isolation and loneliness are related to memory in middle-aged and older adults.

When: You will be asked to participate in one interview, which will last for 60 – 90 minutes. The interview will take place on a date and time that is convenient for you.

Where: The interview will be held by telephone or virtually (i.e., video conference), depending on your preference.

Participation is completely voluntary. Your identity will remain confidential. This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board.

If you are interested in participating in this study or if you would like more information, please contact:

Principle Investigator

Mark Oremus, Professor, PhD

[Redacted contact information for Principle Investigator]

Student Investigator

Ji Won Kang, PhD candidate, MSc

[Redacted contact information for Student Investigator]

Manitoba Site Collaborator

Nancy Newall, Professor, PhD

[Redacted contact information for Manitoba Site Collaborator]

APPENDIX V: Email Newsletter Post



The Combined Effects of Social Isolation and Loneliness on Memory: A Qualitative Study

Researchers: Ji Won Kang, Dr. Mark Oremus, Dr. Nancy Newall, Dr. Suzanne Tyas, Dr. Joel Dubin, Dr. Charity Oga-Omenka

The purpose of this interview research is to hear from middle-aged and older adults about their experiences and thoughts related to social isolation and/or loneliness, and how they believe these experiences affect memory. The goal is to better understand the connection between social isolation, loneliness, and memory, and to provide a platform for middle-aged and older adults to offer advice on developing programs/policies to reduce social isolation, loneliness, and memory impairment.

Participation in the study will consist of a single interview session lasting for 60 – 90 minutes. The interview will be held by telephone or video conference (depending on your preference). Interviews will be audio- or video-recorded by default, but if you prefer not to be recorded, handwritten notes will be taken instead. The questions will start off quite general and become progressively more specific based on your responses to previous questions. Some sample questions may include: “Reflecting on the past six years, have you noticed any changes in your memory?”; “Do you think loneliness or social isolation played a role in these changes?” You can answer these questions in any way you prefer, as there are no right or wrong answers. At the end of the interview, you will be asked to provide some demographic information about yourself. There are no known risks to participation, but it is possible to feel discomfort when discussing health issues. The benefit of participation is that you have the opportunity to share your experiences, and your views may shape policies/programs for addressing social isolation, loneliness, and memory issues. However, there are no incentives for you personally to participate in this research.

Participation in this study is voluntary. We are looking for middle-aged and older adults who meet the following criteria:

- Must be 45 – 85 years of age.
- Must be comfortable participating in interview in English.

If you are interested and meet the above criteria, please contact Ji Won Kang at 226-289-8039 or by this email: jw3kang@uwaterloo.ca. She will email/mail you an information letter containing more details about this study, as well as the written consent form for you to sign. Alternatively, you may opt to provide verbal consent. Once an informed consent has been obtained, Ms. Kang will reach out to you to schedule an interview session.

This study is being conducted by researchers across Canada: PhD student Ji Won Kang (University of Waterloo), Professors at the University of Waterloo (Dr. Mark Oremus, Dr. Suzanne Tyas, Dr. Joel Dubin, and Dr. Charity Oga-Omenka), and Manitoba research affiliate Dr. Nancy Newall (Brandon University). This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board.

APPENDIX VI: Email Script

Research Project Title: The Combined Effects of Social Isolation and Loneliness on Memory: A Qualitative Study

This script will only be used when interested participants contact the research team to learn more information about the study. They will have heard about the study through a recruitment flyer, poster, or email.

This email script will be used by the student-investigator, Ji Won Kang, when a participant emails to inquire about participating in the research study.

Hello,

My name is Ji Won Kang, and I am a PhD student in the School of Public Health Sciences at the University of Waterloo. Thank you for your interest in the research study that I am running in collaboration with Brandon University.

In order to participate in this study, you must be: 1) 45 to 85 years of age; 2) be able to communicate in English; and 3) not have any cognitive (e.g., Alzheimer's disease, other dementia) or sensory (e.g., visual, hearing) impairments.

We are also planning to recruit an approximately even mix of men and women, as well as participants from various age cohorts with different educational attainment. In an effort to recruit a diverse, representative sample of participants, we kindly request that you provide information about your biological sex, exact age, and highest level of education, if you wish to participate in this study.

This study will examine how social isolation and loneliness are related to memory in middle-aged and older adults. To participate in this study, all you need to do is engage in one interview, which will last for 60 – 90 minutes. The interview will be held by telephone or video conference.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board.

A letter of information about this study has been attached to this email. If you are willing to participate in this study, or have more questions, please contact the researcher at the contact information provided below.

Principle Investigator

Mark Oremus, Professor, PhD

[Redacted contact information for Principle Investigator]

Student Investigator

Ji Won Kang, PhD candidate, MSc

[Redacted contact information for Student Investigator]

Manitoba Site Collaborator

Nancy Newall, Professor, PhD

[Redacted contact information for Manitoba Site Collaborator]

APPENDIX VII: Telephone Script

Research Project Title: The Combined Effects of Social Isolation and Loneliness on Memory: A Qualitative Study

This script will only be used when interested participants contact the research team to learn more information about the study. They will have heard about the study through a recruitment flyer, poster, or email.

This telephone script will be used by the student investigator, Ji Won Kang, when a participant calls the researcher to inquire about participating in the study.

Hello, this is Ji Won Kang speaking, how may I help you?

**If participant expresses interest in participating in the study*

Thank you for your interest in this study. Before we move on to discussing details regarding the study, I would like to ask you a few questions to confirm your eligibility to participate. You can answer with a yes/no response.

1. Are you 45 to 85 years of age? If yes, what is your age?
2. Do you have any cognitive (e.g., Alzheimer's disease, other dementia) or sensory (e.g., visual, hearing) impairments?
3. Are you comfortable participating in interviews in English?

**If participant answers 'yes' to questions 1 and 3, and 'no' to question 2, will continue with sharing details regarding the study*

**If not, I am sorry, you do not meet the eligibility criteria to participate in this study, thank you for your time and good-bye*

We also want to make sure that we have a diverse, representative group of participants, so the next two questions are being asked to ensure that we have an approximately even mix of men and women, as well as participants with different educational attainment.

4. What is your biological sex?
5. What is your highest education level?

**Thank the participant for responding and move on to provide details about the study. If they do not answer, thank and dismiss.*

I am running this study as a PhD student in the School of Public Health Sciences at the University of Waterloo, in collaboration with Brandon University. I am looking at how social isolation and loneliness are related to memory in middle-aged and older adults. To participate in this study, all you need to do is engage in one interview which will last for 60 – 90 minutes. The interview will be held by telephone or video conference. Would you be interested in hearing more about this study?

If no, thank you for your time, good-bye.

If yes,

The following brief summary of the letter of information (LOI) will be read clearly to the participants over the phone and participants will receive a copy of the full/original LOI via email/mail for their reference.

Study Purpose:

The purpose of this study is to understand how being lonely, socially isolated, or both, influences the memory of middle-aged and older adults. This study will not involve a clinical evaluation of participants' memory capabilities.

Procedure:

You will participate in a 60 – 90 minute interview over video conference or phone. All sessions will be video-recorded or audio-recorded and transcribed, unless you explicitly express to not be recorded. In that case, we will offer to take handwritten notes during the interview. The questions will start off quite general, and you can answer them in any way you prefer, as there are no right or wrong answers. Some sample questions may include: “Reflecting on the past six years, have you noticed any changes in your memory?”; “Do you think loneliness or social isolation played a role in these changes?” While you speak, I’ll be taking some observational notes and might ask more specific questions based on your responses. At the end of the interview, you will be asked to provide some demographic information about yourself.

Potential Risks: There are no known risks, but it is possible to feel discomfort when discussing health issues. However, all questions are optional to answer, and you may stop the interview at any time.

Benefits of Participation: There is a short-term benefit of having the opportunity to talk about your experiences. In the long-term, your views may shape policies and programs for addressing social isolation, loneliness, and memory issues. However, there are no incentives for you personally to participate in this research.

Confidentiality:

Your data will be stored in a password-protected server at the University of Waterloo, accessible only to a pre-approved research team. Your data will be identified by a number only, and any personal details like names of people and places will be replaced with pseudonyms.

Participant Withdrawal:

Your participation is completely voluntary, meaning that you may refuse to answer questions and withdraw from the study without penalty. However, we may ask your permission to keep the information you shared prior to the point of withdrawal to inform our study analyses. If you do not consent to this request, we will promptly remove your data upon withdrawal. Signing the consent form does not waive any legal rights.

Research Ethics:

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board.

Do you have any questions?

[Any questions they may have will be answered at this time]

Do you agree to participate in this study?

**If no, thank you for your time and good-bye. *If yes, with your permission, I would like to email/mail you the information letter containing all these details, as well as the written consent form for you to sign and return to me. Alternatively, you may opt to provide verbal consent [get email or mailing address from potential participant].*

Great, thank you so much for your time. Once again, if you have any questions, feel free to contact me at [redacted] or by this email: [redacted]

APPENDIX VIII: Letter of Information and Consent



LETTER OF INFORMATION

DATE: _____

Project Title: The Combined Effects of Social Isolation and Loneliness on Memory: A Qualitative Study

Principle Investigator

Mark Oremus, Professor, PhD

[Redacted]

Student Investigator

Ji Won Kang, PhD candidate, MSc

[Redacted]

Co-Investigator

Suzanne Tyas, Associate Professor, PhD

[Redacted]

Co-Investigator

Joel Dubin, Associate Professor, PhD

[Redacted]

Co-Investigator

Charity Oga-Omenka, Assistant Professor, PhD

[Redacted]

Manitoba Site Collaborator

Nancy Newall, Associate Professor, PhD

[Redacted]

You are being invited to voluntarily participate in a study conducted by the University of Waterloo. Please read the following study description carefully to understand what participation in this study will mean for you. Should you decide to participate, please sign the consent form below. Please feel free to contact the student researcher using the details provided on the cover page if you have any questions regarding the study. Thank you for reading this letter.

1. Study purpose

This project will study the link between social isolation (SI), loneliness (LON), and memory (MEM). SI and LON are related but different concepts. SI occurs when one has small social network and low social activity participation. It also relates to living alone, being retired, and not being married. Simply put, it is the objective lack of social connections. In contrast, LON relates to subjective perceptions. It refers to feelings of not belonging and unmet social needs. MEM is the ability to store/retrieve past knowledge. Decline in MEM can cause major cognitive disorders.

2. Study procedure

You will participate in one semi-structured interview (60 to 90 minutes). This will take place over video conference (Zoom, Microsoft Teams) or phone, depending on your preference. We will choose a date/time that is convenient for you. With your permission, the interview will be video-recorded and live-transcribed as we speak (video conference) or audio-recorded and typed (phone). All written, video-, and audio-records of the interview will be stored in a password-protected computer file at the University of Waterloo. In the case where videos are collected, audio will be retained for transcriptions (and then deleted five years after the project end date) and video data will be destroyed immediately following collection. To allow us to use your interview for the research, we need your consent to transcribe or record the interview.

During the interview, you will be asked a set of questions about how being socially isolated or lonely might affect one's MEM. These questions do not have right or wrong answers. Instead, we want your opinion on the subject. The researcher will jot down observation notes as you speak. This may include non-verbal cues such as body language, tone of voice, and hesitation in speech, as well as specific wording/phrases you frequently use throughout the interview. She may also ask further questions about your responses. At the end of the interview, you will be asked to provide details about yourself (such as age, sex, education).

3. Potential risks

No known risks come with participating in this research. Rarely, some people may be uncomfortable when talking about health issues or personal experiences related to social isolation and loneliness, but you can freely choose not to answer any question. You may stop the interview at any time if you feel uncomfortable or tired. The research team will be aware of mental health resources available in Ontario, and could provide them on a case-by-case bases if/when necessary.

4. Benefits of participation

You may not directly benefit from joining this study. However, your views may help influence public policies and programs designed to reduce SI, LON, and MEM impairment.

5. Confidentiality

Your data (interview recording, transcript) will only be accessible by the members of the research team. We will not share your data without your consent or as required by law. All personal information from your interview (such as names of people, places, telephone numbers) will be replaced by pseudonyms. Your interview will be identified by a number only. A list linking this number with your name will be kept in a

secure place, separate from your data. All data will be password protected and be erased after seven years. Additionally, we will seek your permission before publishing any of your anonymized quotations.

6. Can participants withdraw from the study?

Participation in this study is voluntary. You may refuse to answer any questions without penalty. You are also free to withdraw from the study before we submit our results for publication – a process we estimate will take 6 – 8 months. Please be aware that once results are publicly shared, it is not possible to remove your data.

When you withdraw from the study, we may ask for your permission to retain the information collected from you before withdrawal to inform our study analyses. Rest assured, even if we retain your data, none of your quotes will be formally reproduced anywhere. If you do not consent to this request, we will promptly remove your data upon withdrawal. You do not waive any legal right by signing this consent form.

7. Whom do participants contact for questions?

If you have any questions or want additional information about the study, you may contact Ji Won Kang at jw3kang@uwaterloo.ca or at this Fongo mobile number: (226) 289-8039.

If you have concerns or questions about your rights as a research participant or the conduct of this study, please contact University of Waterloo, Office of Research Ethics by telephone at 519-888-4567 ext. 47163.

This letter is yours to keep for future reference.

CONSENT FORM

I confirm that I have read the Letter of Information and have had all questions answered to my satisfaction.

YES NO

I understand that participation is voluntary, and I can withdraw from the study at any time (before results are submitted for publication).

YES NO

I have been given a copy of the Letter of Information.

YES NO

I agree to participate in this research.

YES NO

I agree to be video-recorded and live-transcribed as we speak (for video conference) or audio-recorded and typed (for phone interview).

YES NO

I consent to the use of unidentified quotes obtained during the study in the dissemination of this research.

YES NO

I wish to be informed of any publication that arise out of this study. *[If yes, we will retain your email on record after the study concludes, to update you about publication progress.]*

YES NO

Signing this consent form does not waive any legal rights.

Print Name of Participant

Participant's Signature

Date (DD-MM-YYYY)

APPENDIX IX : Interview Questions

1. How do you personally define social isolation and loneliness? Can you describe a specific time when you felt isolated or lonely, or both? Can you please walk me through that experience, including the circumstances, emotions, and thoughts associated with it?
2. How have your social connections changed over time? Can you share any experiences that led to a decrease or increase in how many people you meet or how frequently you interact with your social network?
3. Imagine a time when you were socially isolated but not lonely. Can you describe how your day-to-day memory was affected during this time, if at all?
4. Similarly, imagine a time when you were lonely but not socially isolated. Can you describe how your day-to-day memory was affected during this time, if at all?
5. Reflecting on the past six years, have you noticed any changes in your memory? Do you think loneliness or social isolation played a role in these changes? Please explain.
6. In our previous study, some participants described that being both socially isolated and lonely has a worse impact on memory than experiencing either factor alone. Have you personally experienced something similar to this?
 - If yes, could you please describe how or why you had such an experience?
 - If no, are you aware of anyone who has experienced this? Or can you think of any situation where this finding might occur?
7. What do you think about the finding that, at first, socially isolated people had worse memory than those neither isolated nor lonely, but after 6 years, both groups had similar memory declines?
 - Can you relate this discovery – that social isolation seems to matter less for memory over time – to how your own memory might have been affected by your social connections over time?
8. When comparing social isolation vs. loneliness, which one do you think tends to persist more consistently over time? Can you elaborate on why you think that is the case?
9. What do you think about the finding that feeling lonely has a worse impact on memory than being socially isolated? Can you relate it to any personal experiences?
10. Can you tell me about a time when you experienced challenges because you were socially isolated, lonely, or both?
 - Are any of the challenges related to changes in your memory? Please explain.
 - What are some strategies you may use to manage these challenges? Are there any activities you do differently or is there anyone you ask for help?
11. Do you think there are specific needs or challenges associated with experiencing social isolation compared to dealing with loneliness (or vice versa)? Please explain.
12. Do you think there are specific needs/challenges that are unique to being both isolated and lonely? Please explain.
13. Can you recall a time when you felt particularly supported or unsupported while dealing with social isolation, loneliness, or changes in your memory?

APPENDIX X: Demographic Questionnaire

1. What is your biological sex?
 Male
 Female
2. What is your age? _____
3. What is your highest completed degree of education?
 Less than high school
 High school diploma
 None-university certificate or diploma (e.g. community college, vocational school)
 Some university
 Completed university degree
 Post-university degree
4. Which ethnicity do you identify as (multiple responses allowed)?
 Arab/West Asian (e.g. Moroccan, Egyptian, Armenian, Lebanese, Iranian)
 Aboriginal (e.g. Inuit, North American Indian, Métis)
 African (e.g. Jamaican, Haitian, Somali)
 East Asian (e.g. Chinese, Korean, Japanese)
 South Asian (e.g. Pakistani, East Indian, Si Lankan)
 South East Asian (e.g. Cambodian, Malaysian, Vietnamese, Laotian)
 Caucasian
 Caribbean
 Latin American/Hispanic
 Filipino
 Other (please specify) _____
5. What is your annual household income?
 < \$25,000
 \$25,000 - \$50,000
 \$50,000 - \$100,000
 > \$100,000
6. Please specify your marital status
 Married

- Common-law partnership
- Single
- Widowed
- Separated
- Divorced
- Never married

7. Are you living alone (Y or N)? If no, how many cohabitants are living with you? _____

8. Please specify your retirement status

- Not retired
- Partly retired
- Completely retired

9. Please check-off all activities that you participated in at least once a month, within the last 12 months.

- Religious activities
- Sports/physical activities
- Educational or cultural activities (e.g. going to courses, concerts, museums)
- Clubs/fraternal organization activities (Kiwanis Club, Foresters, Royal Canadian Legion)
- Community/professional association activities
- Volunteer or charity work
- Other recreational activities (e.g. hobbies, gardening, Bridge card games)
- Activities with family/friends outside of household

10. In the past six months, did you have at least monthly visit with any of the following social network groups, who live outside of your household (Y or N)? If yes, please specify all network groups you hang out with.

[(1) Children; (2) Siblings; (3) Other relatives (e.g. parents, grandparents, grandchildren, nieces, nephews, cousins, aunts, uncles); (4) Neighbours; (5) Friends]

11. In the last week, how often did you feel lonely?

- All the time (5 – 7 days)
- Occasionally (3 – 4 days)
- Some of the time (1 – 2 days)
- rarely or never (less than 1 day)