Exploring the Sensory-Psychosocial-Cognitive Relationship in Older Adults with (or at Risk for) Alzheimer's Disease

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Abstract

Exploring the Sensory-Psychosocial-Cognitive Relationship in Older Adults with (or at Risk for) Alzheimer's Disease

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Both sensory and psychosocial deficits are associated with cognitive decline and Alzheimer's disease (AD). This dissertation explores interactions between sensory, psychosocial, and cognitive functioning in cognitively healthy controls and individuals with mild cognitive impairment (MCI) and AD using cross-sectional data from the COMPASS-ND study of the Canadian Consortium of Neurodegeneration in Aging.

Study 1 examined associations between psychosocial (depressive and anxiety symptoms, social support, and social engagement) and cognitive measures (memory, executive function, processing speed, working memory, verbal fluency) in individuals with MCI. Regression analyses showed that low social participation was associated with poorer verbal fluency and slower processing speed compared to normal or high participation, suggesting that social participation may offer cognitively stimulating opportunities that support these abilities in at-risk individuals.

Study 2 characterized sensory (speech-reception thresholds, contrast sensitivity) and psychosocial (depression, anxiety, quality of life, social support, isolation) function in controls and individuals with MCI and AD, and evaluated whether psychosocial function and diagnostic group modified sensory-cognitive associations. Participants with MCI and AD demonstrated poorer sensory and psychosocial functioning than controls. Poor psychosocial function strengthened sensory-cognitive associations in MCI and AD, suggesting that individuals with cognitive impairment and poor psychosocial functioning may be particularly vulnerable to sensory effects on cognition.

Together, these studies enhance understanding of the sensory-psychosocial-cognitive relationship in individuals with cognitive impairment and suggest that psychosocial function plays an important role in shaping sensory-cognitive associations. This work explores potential mechanisms underlying these observations and highlight implications for preventative strategies and interventions targeting sensory and psychosocial functioning.

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Contribution of Authors

Two original manuscripts are included in the present thesis. Both studies used cross-sectional data from the COMPASS-ND dataset of the Canadian Consortium of Neurodegeneration in Aging (CCNA), which were collected at various clinical and research sites across Canada. Citations for these manuscripts and a description of each co-author's contributions are listed below.

Manuscript I (Study 1)

Rehan, S., & Phillips, N.A. (2025). Psychosocial function in mild cognitive impairment: Social participation is associated with cognitive performance in multiple domains. *Journal of Applied Gerontology, 44*(10): 1629-1640. doi:10.1177/0733464824131166

For this manuscript, SR and NP collaboratively developed the research question, study conceptualization, and design. Data cleaning and statistical analyses were conducted by SR, with feedback from NP. SR wrote and revised the manuscript, with supervision and feedback from NP. Both SR and NP reviewed, edited, and approved the final manuscript published in the *Journal of Applied Gerontology.*

Manuscript II (Study 2)

Rehan, S., Mehrabi, F., Mick, P., Pichora-Fuller, M.K., Wittich, W., & Phillips, N.A. (2026). Bridging the gap: Psychosocial function moderates the link between sensory and cognitive performance differently across normal cognition, mild cognitive impairment, and Alzheimer's disease. *Manuscript submitted for publication in the Journal of Aging and Health.*

The study conceptualization and design were developed by SR and NP, with feedback from FM and PM. Data cleaning and statistical analyses were conducted by SR, with feedback from NP and FM. Data were interpreted with input from NP, FM, PM, MKPF, and WW. SR wrote and revised the manuscript, with supervision and feedback from NP. FM, PM, MKPF, and WW all provided valuable revisions and edits to the manuscript. All co-authors reviewed, edited, and approved the final manuscript submitted to *the Journal of Aging and Health.*

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Chapter 1: General Introduction

Aging is accompanied by sensory, psychosocial, and cognitive changes, which can shape one's health and quality of life. Sensory decline, particularly in hearing and vision abilities, reduces the capacity of older adults to interact and engage with their environment. This can in turn hinder effective communication with others, limit social engagement and the maintenance of social connections, and negatively affect psychological well-being. Beyond sensory changes, the size and level of engagement with one's social networks often decrease with age due to other factors such as migration of family and friends, life transitions, as well as individual factors (e.g., limitations due to physical health). Cognitive abilities also undergo age-related changes, including declines in memory, attention, language, visuoperceptual and visuospatial skills, and executive functions. While many older adults experience typical, non-pathological changes in cognitive function, the prevalence of dementia increases significantly with advancing age. Cognitive health in older adults can also be influenced by a broad range of modifiable risk and protective factors (e.g., poor diet, limited physical activity, poor cognitive stimulation; Fratiglioni et al., 2004; Livingston et al., 2024). In a recent *Lancet Commission on Dementia Prevention, Intervention, and Care* report, hearing and vision impairments, social isolation, and depression were identified as several potentially modifiable risk factors (along with lifestyle-related diseases, physical and leisure activities) that can hypothetically prevent or delay up to 45% of dementias (Livingston et al., 2024). Supporting this, poor sensory and psychosocial function are independently associated with cognitive function and contribute to risk for cognitive decline and Alzheimer's disease (**AD)**.

The interrelationships between sensory, psychosocial, and cognitive factors form a complex nexus within gerontology and dementia research. To date, research investigating

sensory-psychosocial-cognitive relationships has measured singular components of psychosocial, sensory, and cognitive function, or has measured bivariate relationships between two factors only (sensory-cognition, social-cognition, or sensory-social). However, most of this work has been conducted with cognitively healthy older adults, and there remains limited research in clinical groups with (or at risk for) developing AD. To address this gap, Study 1 (Chapter 3) will examine associations between psychosocial and cognitive function in individuals with mild cognitive impairment **(MCI),** a prodromal form of AD that remains understudied in the literature. Study 2 (Chapter 4) will characterize sensory, psychosocial, and cognitive function in both cognitively healthy older adults and older adults with (or at risk for) AD. Building on this, the study will examine whether psychosocial factors moderate the link between sensory and cognitive performance, and whether these effects differ across diagnostic groups. Overall, this thesis aims to advance understanding of sensory-psychosocial-cognitive interactions and how they are differentially manifested across cognitively healthy older adults and clinical groups with cognitive impairment.

Chapter 2: Literature Review

Cognitive Decline and Alzheimer's Disease

AD is the most common age-related neurodegenerative condition leading to cognitive impairment. The number of older adults living with AD is high and expected to rise sharply over the next decade. The World Health Organization (WHO) estimates that the total number of people with dementia and severe cognitive impairment globally is projected to reach 78 million by 2030, with nearly 10 million new cases each year (World Health Organization, 2025). In Canada alone, there were approximately 772 000 people living with dementia in 2022, a figure anticipated to approach nearly a million people in by 2030 and 1.7 million people by 2050 (Alzheimer Society of Canada, 2022). Moreover, the economic impact is equally striking – the combined healthcare and caregiver costs for AD are expected to rise from $10.4 billion in 2016 to $16.6 billion by 2031 (Alzheimer Society of Canada, 2022). Given the staggering personal, societal, and economic costs of AD, identifying and understanding modifiable risk factors has become an urgent public health priority to prevent or delay the onset of dementia.

The clinical and pathological features of AD were first described by Dr. Alois Alzheimer in 1911, who described symptoms such as neuritic plaques, neurofibrillary tangles, and amyloid angiopathy in a 51-year-old patient (Möller & Graeber, 1998). The first research-specific diagnostic criteria for AD were established in 1984 by the National Institute of Aging (NIA; McKhann et al., 1984). Clinical diagnostic criteria include significant cognitive impairment accompanied by deterioration in daily functioning and independence (McKhann et al., 2011). Although impairment in episodic memory (i.e., the ability to learn and remember new information) is observed as the most common cognitive presentation, there can also be changes in reasoning, language, and visuospatial abilities (McKhann et al., 2011). Neuropathologically,

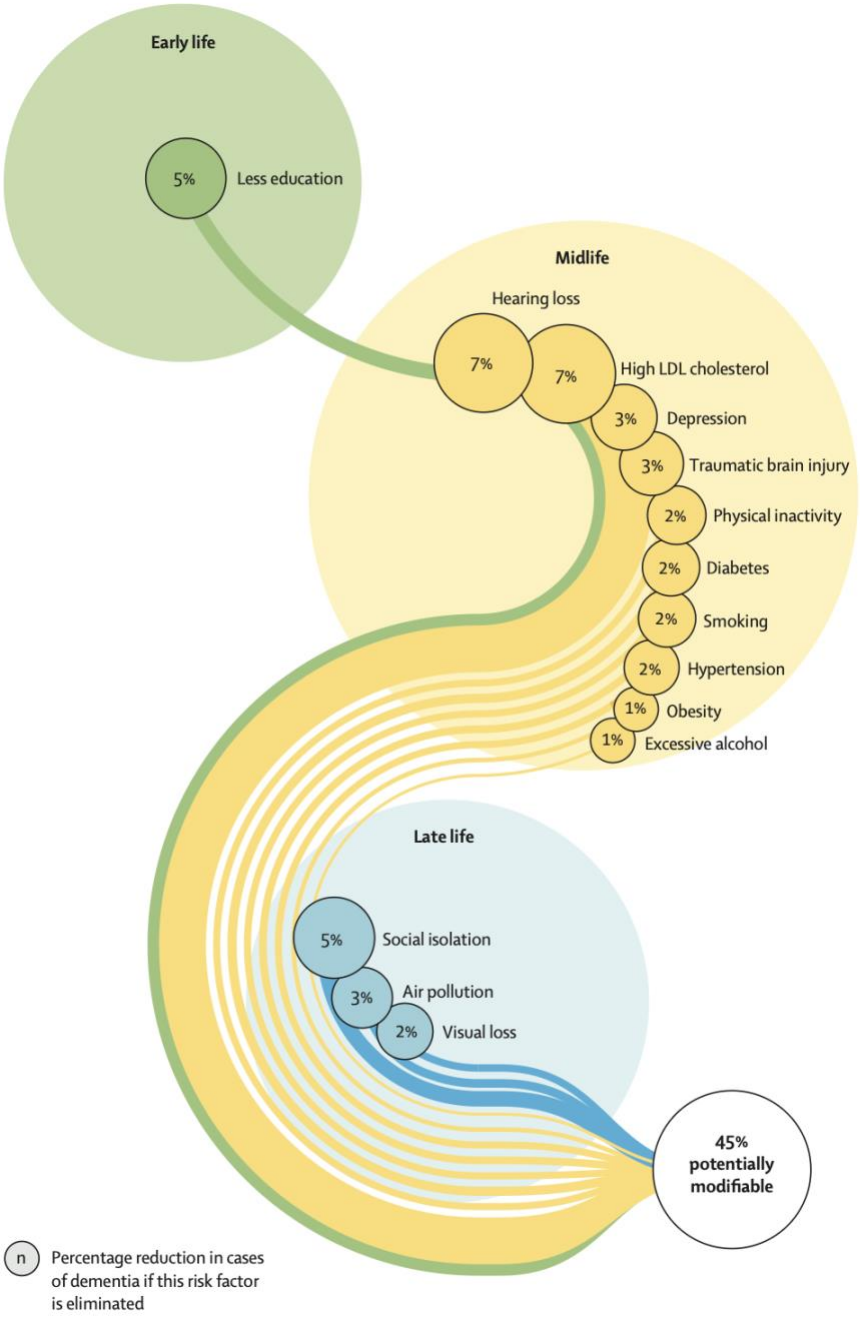
AD is characterized by the accumulation of amyloid-β plaques and tau-related neurofibrillary tangles, which serve as critical biomarkers that can precede the onset of clinical symptoms (Jack Jr. et al., 2024). Consistent with these advances, recent guidelines in defining and diagnosing AD propose moving towards integrating clinical manifestations with biologically based models of AD (Jack Jr. et al., 2024).

Since pathological changes associated with AD can emerge decades before the onset of clinical symptoms, identification of at-risk or intermediate states in the progression of disease pathology is crucial for prevention (Albert et al., 2011; McKhann et al., 2011). Early stages of dementia include subjective and/or objective declines in cognition that exceed normal age-related changes, although these conditions do not always progress to dementia. Mild cognitive impairment (MCI) is widely recognized as a prodromal state of cognitive impairment prior to AD onset, with prevalence estimates increasing with age and ranging between 15-20% among adults 60 years and older (Petersen, 2016). Core clinical criteria for MCI include concern regarding a change in cognition, objective impairment in one or more cognitive domains, and, critically, preservation of independence in functional abilities (Albert et al., 2011; Petersen, 2011). Individuals diagnosed with MCI most commonly report decline in episodic memory, though cognitive deficits may also be observed across many cognitive functions (including executive function, attention, language, and visuospatial abilities). Although not all MCI individuals progress to dementia, the general rate for progression is 10-15% per year in high-risk clinical populations, with outcomes influenced by factors such as age, cognitive function at baseline, genetic predisposition, and neuroimaging biomarkers (Petersen, 2011). For example, medial temporal lobe atrophy, amyloid-β accumulation, and the presence of the apolipoprotein E4 (APOE4) genotype, are all associated with rapid progression of cognitive decline (Petersen,

2016), and clinical factors like multidomain cognitive impairment and late-onset neuropsychiatric symptoms are also associated with progression to dementia (Angevaare et al., 2022; McGirr et al., 2022).

As there are limited disease-modifying treatments available for AD, there is substantial research focused on investigating modifiable risk factors for dementia to inform prevention and intervention strategies. The *Lancet Commission on Dementia Prevention, Intervention, and Care* has published several landmark reports highlighting potentially modifiable risk factors for dementia across the lifespan, which together could theoretically prevent or delay up to 45% of dementias (Livingston et al., 2024; see Figure 1). These include vascular-risk factors and diseases (e.g., high cholesterol, smoking, hypertension, obesity, diabetes) and lifestyle-related factors (e.g., physical inactivity, social isolation, excessive alcohol use) or conditions (e.g., depression, traumatic brain injury, hearing and vision loss). Notably, hearing loss in midlife has been identified as the largest potentially modifiable risk factor for dementia in the *Lancet* report, accounting for 7% of the population attributable risk for dementia. In comparison, late life visual loss accounted for only 2% of the population risk. Psychosocial variables, such as depression in midlife and social isolation in late life, have also been identified as potentially modifiable risk factors, accounting for 5% and 2% of the population attributable risk for dementia, respectively. Importantly, these findings demonstrate that interventions or lifestyle changes at any point across the life (e.g., treating hearing loss, reducing social isolation) can potentially alter the risk of dementia; and as such, it is critical to deepen our understanding of how potentially modifiable risk factors contribute to cognitive decline.

Figure 1. *A life-course model of the potentially modifiable risk factors for dementia and associated population attributable fractions. Taken from (Livingston et al., 2024).*[1]



[1] Permission to re-use figure was obtained from RightsLink via Science Direct, Elsevier.

Sensory Loss and Cognitive Function

Early studies demonstrated that sensory functioning is a strong predictor of individual differences in cognitive functioning in late life (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994). In the Berlin Aging Study, auditory and visual function predicted 93% of age-related variance in performance on cognitive tests among older adults (Lindenberger & Baltes, 1994). Other seminal papers also established that sensory impairment was associated with an elevated risk for cognitive impairment and dementia (e.g., Uhlmann et al., 1989, 1991). Since then, research examining the link between age-related sensory decline and cognitive decline has extensively grown over the past few decades (Albers et al., 2015). Longitudinal evidence consistently indicates that decline in hearing (Gates et al., 2011; F. R. Lin, Metter, et al., 2011) and vision (Ehrlich et al., 2021; Z. Zhu et al., 2022) abilities increase the risk of cognitive impairment leading to dementia. Moreover, sensory deficits (e.g., hearing and vision loss) are prevalent in MCI and AD patients (see Albers et al., 2015 for a review).

Hearing

Hearing Impairment and Prevalence

Hearing loss (presbycusis) is a gradually progressive and highly prevalent condition associated with a range of adverse health and cognitive outcomes. It increases in prevalence after 50 years of age and affects over 65% of adults above 60 years of age (GBD 2019 Hearing Loss Collaborators, 2021). Other estimates suggest that approximately 30% of individuals aged 65-74 years and more than 40% of individuals aged 75 years and older experience hearing loss (F. R. Lin, Niparko, et al., 2011). Hearing loss currently affects an estimated 20% of the global population and is projected to impact nearly 2.5 billion people by 2050 (World Health Organization, 2021). The economic impact is considerable, with the annual global cost of

unaddressed hearing loss estimated to be greater than $980 billion annually across healthcare, educational, and societal domains, creating a profound burden for families and societies. In Canada, data from the Canadian Longitudinal Study on Aging (nearly 30 000 Canadians aged 45-85 years) showed that mild, moderate, and severe hearing loss (measured by audiometry) was prevalent among 13.4%, 3.7%, and 0.4% of males, and 23.9%, 2.3%, and 0.2% of females, respectively (Mick et al., 2020).

Functional Burden of Hearing Impairment

Age-related hearing loss is the third leading cause of years lived with disability worldwide and the primary cause among adults older than 70 years of age (GBD 2019 Hearing Loss Collaborators, 2021). Unaddressed hearing loss can negatively impact multiple aspects of an individual's life, including interpersonal communication, social integration, independence, quality of life, and wellbeing. Auditory deprivation creates challenges for maintaining communication with others, especially when listening to speech and engaging in conversations, especially in noisy settings. These difficulties often contribute to broader psychosocial consequences such as social isolation, loneliness, depression, and anxiety (Jayakody et al., 2022; Lawrence et al., 2020; Mick et al., 2014; Heffernan et al., 2022; Pronk et al., 2014; Shukla et al., 2020), which will be discussed in greater detail in the sensory-psychosocial literature review.

Measurement of Hearing

Age-related hearing loss (presbycusis) is commonly categorized by either peripheral or central deficits in the hearing-cognition literature (Gates & Mills, 2005). The peripheral apparati of hearing include the outer ear, middle ear, cochlea, and the auditory nerve, which are responsible for detecting sound and converting acoustic stimuli into neural signals for subsequent processing (Musiek & Baran, 2018). Peripheral hearing loss is typically characterized by reduced

audibility, such that individuals may have trouble perceiving soft sounds or describe them as being muffled, even in quiet listening conditions. Peripheral hearing is typically assessed through audiometric evaluations that measure detection thresholds across various frequencies and intensities (e.g., pure-tone or speech audiometry), which do not rely on higher-order cortical processing (Musiek & Chermak, 2015).

By contrast, the central hearing system encompasses the cochlear nucleus, auditory cortex, and higher-level cortical regions that process, interpret, understand, and integrate auditory information with additional cognitive processing (Musiek & Baran, 2018). Deficits in central hearing loss are often reflected in difficulty recognizing speech in noisy environments, impaired dichotic listening (i.e., processing different inputs in each ear), and diminished temporal resolution (i.e., tracking rapid changes in sound; Gates, 2012). Measurement of central auditory function requires higher-order auditory processing, which is evaluated through the presentation of speech among background noise (i.e., speech-in-noise testing) or specialized tasks involving listening to degraded or temporally modified speech (e.g., dichotic digits; Gates, 2012; Musiek & Chermak, 2015). Importantly, both peripheral and central auditory dysfunction have been linked to cognitive function and decline (Gates et al., 2011; F. R. Lin, Metter, et al., 2011).

Prevalence of Hearing Impairment in Populations with MCI and AD

There is substantive evidence that individuals with MCI and AD commonly experience deficits in peripheral hearing and/or central auditory processing compared to cognitively healthy controls (Edwards et al., 2017; Tarawneh et al., 2022; Uhlmann et al., 1989). In clinical settings, individuals with MCI and AD presenting at memory clinics show a high prevalence of mild peripheral hearing loss (Nirmalasari et al., 2017), as well as poor speech perception that worsens with disease progression (Idrizbegovic et al., 2011). These findings are reinforced by various

studies and meta-analyses examining the prevalence rates of peripheral and central hearing difficulties in MCI and AD. In a meta-analysis encompassing 34 studies of cross-sectional and longitudinal designs, Lau et al. (2022) observed a significant association between hearing loss and early dementia or cognitive impairment. They found that peripheral hearing loss was highly prevalent among patients with mild cognitive impairment (risk ratio = 1.40). In addition, significantly more people with peripheral hearing loss had mild cognitive impairment compared to those without hearing loss across several cohort studies. Central auditory processing challenges are also implicated in those with cognitive impairment. For example, individuals with MCI and AD perform significantly worse than cognitively healthy controls on several central auditory processing tests, including Dichotic Digits, Dichotic Sentence Identification (DSI), and Synthetic Sentence Identification-Ipsilateral Competing Message, indicating poor binaural processing and degraded speech perception (Tarawneh et al., 2022). Collectively, these findings provide strong evidence that peripheral and central hearing loss are both highly prevalent in individuals with MCI and AD.

Hearing Loss, Cognitive Decline, and Dementia

Prior cross-sectional and longitudinal research has demonstrated a consistent link between age-related hearing loss and poor cognitive performance across multiple domains, including global cognitive function (Gao et al., 2020; F. R. Lin et al., 2013; Moradi et al., 2024), executive function, processing speed, attention, and verbal learning and memory (Bonmassar et al., 2023; Brewster et al., 2021; Gates et al., 2010; F. R. Lin, Ferrucci, et al., 2011; F. R. Lin et al., 2013; Phillips et al., 2022). For example, in the Baltimore Longitudinal Study of Aging, hearing loss (as measured by pure-tone audiometry) in cognitively healthy participants (>55 years) was independently associated with decline in non-verbal (visual) and verbal (auditory)

measures of cognition (learning, memory, and executive function) over five years (F. R. Lin, Ferrucci, et al., 2011). In another cohort study of 1162 individuals followed over six years (mean age = 77.4 years), Lin et al. (2013) observed that a greater severity of pure-tone hearing loss at baseline was associated with an increased risk for cognitive impairment on a global cognitive function test that relies on auditory processing (Modified Mini-Mental State Examination) and a visually-presented test of executive function and processing speed (Digit Symbol Substitution Test) at follow-up. Importantly, hearing loss remains linked with poor cognitive performance even when excluding tests that involve or rely on the auditory modality (Deal et al., 2015; Phillips et al., 2022). For instance, older adults with hearing loss recalled fewer visually presented words on the MoCA than those with normal hearing (Dupuis et al., 2015). Longitudinally, Deal et al. (2015) found that older adults (mean age = 77 years) with moderate to severe hearing impairment (as measured by audiometric thresholds) experienced accelerated decline in memory (e.g., learning and recall of words and stories and visually-presented digits and symbols) and global cognitive function over 20 years compared to participants without hearing loss, even when auditory-based tests were excluded. Taken together, this evidence demonstrates that hearing loss is consistently associated with poor cognitive function cross-sectionally and with decline in cognitive performance over time, irrespective of the sensory modality of cognitive tests.

In addition to the associations between hearing and cognitive performance, hearing loss has been established as an important risk factor for dementia. As noted earlier in this chapter, hearing loss has been identified as one of the largest potentially modifiable risk factors for dementia in the *Lancet* report, accounting for 7% of the population attributable risk for dementia (Livingston et al., 2024). Consistently, a recent population-based study with U.S. community-

dwelling older adults found that nearly 17% of dementia cases were attributable to moderate or greater audiometric hearing loss, with hearing loss contributing to over 40% of dementia cases among men (Smith et al., 2023).

The association between hearing loss and dementia was first demonstrated in a seminal study by Uhlmann et al. (1989), who reported increased odds of dementia among older adults with hearing impairment compared to those with normal hearing. Since then, a substantial body of evidence, including meta-analyses and reviews of population- and cohort-based studies, has consistently shown that peripheral hearing loss (typically measured using behavioural audiometry) is associated with increased risk for dementia over time (Lau et al., 2022; Lin, Metter, et al., 2011; Yu et al., 2024; and see Brewster et al., 2022; Powell et al., 2021). For instance, a meta-analysis reviewing nine longitudinal cohort studies (mean follow-up time = 10.4 years) presented that pure-tone hearing loss was associated with an accelerated cognitive decline across multiple domains, with the odds of cognitive impairment and dementia in those with age-related hearing loss 1.22 and 1.28 times higher, respectively, than those with normal hearing (Loughrey et al., 2018). Longitudinal cohort studies demonstrate that deficits in peripheral hearing at baseline are associated with cognitive decline and dementia 9-10 years later (Deal et al., 2017; F. R. Lin, Metter, et al., 2011), and in some studies even two decades later (Myrstad et al., 2023), though findings are not entirely consistent (e.g., Marinelli et al., 2022). Results from the Baltimore Longitudinal Study of Aging following adults 55 years or older (N = 639) who were cognitively healthy at baseline show that individuals with mild and moderate hearing loss (as measured by pure-tone audiometry) had 1.89 and 3.00 times the risk of developing dementia over 12 years, respectively (F. R. Lin, Metter, et al., 2011). Likewise, in a cohort study with 1889 individuals followed over 9 years (mean age = 76 years), moderate and severe peripheral hearing

loss was associated with a greater risk of developing dementia (hazard ratio = 1.55; Deal et al., 2017). Moreover, an increasing degree of pure-tone hearing loss was associated with an increased risk of dementia (hazard ratio per 10-decibel hearing loss increase in pure-tone audiometry = 1.14). Across multiple cohorts, dementia risk increases proportionally with the severity of hearing loss (Deal et al., 2017; Myrstad et al., 2023; Yu et al., 2024), with a recent meta-analysis concluding that a 10-decibel decrease in hearing ability is associated with a 16% increase in dementia risk (Yu et al., 2024).

In addition to peripheral hearing loss, central auditory processing is linked to incident dementia (Gates et al., 2002, 2011; Stevenson et al., 2022). In a hallmark paper (N = 274), poor performance on three central auditory tests (Dichotic Sentence Identification, Dichotic Digits, Synthetic Sentence Identification) was associated with incident dementia over 4 years (Gates et al., 2011); however, their sample size was small with a small number of AD cases. In a larger study with UK Biobank participants (N = 82 039), older adults with poor speech-in-noise hearing at baseline (measured by the Digit Triplets Test) had an increased risk of developing dementia over 11 years compared to individuals with normal speech-in-noise performance, and this association remained strong at shorter follow-up intervals (Stevenson et al., 2022).

Taken together, these findings indicate that pure-tone hearing loss and central auditory deficits are associated with an increased risk for dementia, with a dose-response relationship for pure-tone hearing loss whereby greater severity of hearing loss confers progressively higher dementia risk; however, the strength of this association may vary across populations and study designs. Importantly, variability in methodology (e.g., sample size, follow-up intervals) and measures of hearing and cognition have placed challenging demands on synthesis of results (e.g., definition and categorization of hearing loss, using global screening tools instead of rigorous

neuropsychological evaluations (Powell et al., 2021). Despite these limitations, there is a compelling amount of evidence supporting the link between hearing loss and cognitive decline or cognitive impairment, which compels further research of underlying pathophysiological mechanisms to understand and mitigate risk.

Vision

Visual Impairment and Prevalence

Rapid population aging is associated with increased prevalence rates for visual impairment globally. In 2019, the World Health Organization (WHO) estimated that 2.2 billion people worldwide were living with some form of visual impairment. Individuals 50 years or older had the highest burden of vision impairment, representing 86% of blind individuals, 80% of individuals with moderate to severe vision impairment, and 74% of individuals with mild vision impairment on a global scale (Bourne et al., 2017). Much of the burden is driven by the prevalence of major age-related eye diseases, including cataracts, age-related macular degeneration (AMD), diabetic retinopathy, and glaucoma (GBD 2019 Blindness and Vision Impairment Collaborators, 2021). In Canada, approximately 1.2 million Canadians are currently living with vision loss or blindness in 2019, generating over $32 billion in annual healthcare costs (Gordon, 2021). These rates are projected to rise substantially over the next 25 years, affecting an estimated 2 million people with vision loss by 2050. In a recent study using data from the Canadian Longitudinal Study on Aging, which assessed data from approximately 30 000 Canadians 45-85 years of age, mild and moderate vision loss (in terms of acuity) was prevalent among 19.8% and 2.4% of males and 23.9% and 2.6% of females, respectively, with vision loss increasing steadily with age (Mick et al., 2020).

Functional Burden of Visual Impairment

Visual impairment has a profound impact on the preservation of daily functioning and independence. It can reduce quality of life in multiple ways, including difficulties in reading, increased risk for falls (Harwood, 2001; Kulmala et al., 2009), mortality (McCarty, 2001), and frailty (Swenor, Lee, Tian, et al., 2020), as well as four times the risk for serious hip fractures and early admission to nursing homes (H. T. V. Vu, 2005). Moreover, individuals with age-related maculopathy or glaucoma frequently experience mobility difficulties, especially with driving and balance (Popescu et al., 2011; Scilley et al., 2002). Consequently, visual impairment can result in reduced communication and engagement in social and pleasurable activities (e.g., participation in regular leisure activities; Han et al., 2019; Hassell, 2006). Regardless of the degree of vision loss, individuals with vision complaints report poor quality of life with concern about worsening eyesight and coping with everyday life (Hassell, 2006). Moreover, limited mobility and household activity due to poor vision can negatively impact emotional well-being (Xiang et al., 2020). Together, these studies demonstrate the impact of poor vision on daily functioning and overall quality of life.

Measuring Visual Impairment

In the vision–cognition literature, measures of visual function vary across studies but most commonly include tests of visual acuity (e.g., Snellen chart or logMAR units) and contrast sensitivity (e.g., logCS units), which capture distinct low-level aspects of visual perception (Swenor et al., 2019; Uhlmann et al., 1991; Ward et al., 2018; Zheng et al., 2018). Visual acuity reflects the ability to resolve fine spatial detail (e.g., letters on a chart), whereas contrast sensitivity assesses the ability to distinguish objects from their background under varying levels of contrast, the latter which is critical for recognizing faces and navigating environments

(Cormack et al., 1999). Both measures are shown to be sensitive to age-related vision changes and cognitive function; although standard visual acuity tests are commonly used to assess visual impairment, contrast sensitivity is considered to be a more sensitive indicator of subtle visual changes and predictive of interference in daily functioning (e.g., driving, mobility) and cognitive performance in AD in early papers (Bertone et al., 2007; Cormack et al., 1999; Cronin-Golomb et al., 1995). In addition to objective measures, other studies in the literature rely on self-reported vision status (as measured by an interview or a questionnaire, e.g., Davies-Kershaw et al., 2018; Rogers & Langa, 2010), which provides insight into perceived functional impairment but is less precise than objective testing. Finally, other research incorporates clinical diagnoses of age-related eye diseases such as macular degeneration, cataracts, or glaucoma, either as indicators of visual impairment (e.g., Clemons et al., 2006; Varin et al., 2020), exclusion criteria, or as covariates (e.g., Ward et al., 2018).

Prevalence of Visual Impairment in Populations with MCI and AD

The prevalence of visual impairment is high in individuals with MCI and AD. For example, visual impairment (distance visual acuity lower than 6/12 in the better seeing eye) was reported in 50 (37.3%) of 150 residents with a diagnosis of dementia residing in a long-term care facility (Chriqui et al., 2017). Similarly, the prevalence of visual impairment (measured by visual acuity worse than 6/12) was 32.5% in 708 patients with dementia aged 60-89 years (Bowen et al., 2016). In one cross-sectional study examining rates of cognitive impairment in outpatients at an eye clinic (followed for poor visual acuity), Raji et al. (2005) found that 65 (out of 100) community-dwelling older adults (aged 55 years and older) screened positive for cognitive impairments (46 with MCI, 19 with severe impairment) on the St. Louis University Mental Status Examination (SLUMS) scale, though two of 11 items on this test relied on visuoperceptual

and visuospatial processing (i.e., clock copying). In addition to prevalence studies, many cross-sectional findings have demonstrated that individuals with AD have poorer performance on visual measures compared to cognitively healthy older adults, including visual acuity (Uhlmann et al., 1991), contrast sensitivity (Cronin-Golomb et al., 1995; Hutton et al., 1993; Nissen, 1985; Rizzo, 2000), spatial orientation (Henderson et al., 1989), colour vision/discrimination, stereopsis (Cronin-Golomb et al., 1991; Pache, 2003; Salamone et al., 2009), and motion and depth perception (Mendez et al., 1996; Rizzo, 1998). In studies comparing across several diagnostic groups on the spectrum of cognitive impairment, both MCI and AD groups demonstrated greater contrast sensitivity deficits compared to individuals with cognitive complaints or healthy controls (Risacher et al., 2013); though we previously found no differences in visual function between MCI and individuals with cognitive complaints (SCD) in the COMPASS-ND sample (Rehan et al., 2021). These studies support the vision-cognition relationship in demonstrating that visual deficits are highly prevalent in MCI and AD; moreover, individuals with AD are likely to perform worse on various visual measures compared to preclinical groups with less cognitive impairment and cognitively healthy controls.

Visual Impairment, Cognitive Decline, and Dementia

Poor visual function at baseline has been associated with cognitive decline at follow-up (M. Y. Lin et al., 2004; Reyes-Ortiz et al., 2005; Swenor et al., 2019; Zheng et al., 2018). For example, Reyes-Ortiz et al. (2005) found that near vision impairment at baseline was associated with cognitive decline (i.e., a lower Mini-Mental State Exam (MMSE) score) at a two-year follow-up among Mexican Americans aged 65 years and older. These findings have been supported by other studies that assessed visual function (e.g., visual acuity, contrast sensitivity, stereo acuity) and cognitive decline as a function of change in global cognition scores using the

MMSE (M. Y. Lin et al., 2004; Swenor et al., 2019; Zheng et al., 2018). For example, Swenor et al. (2019) found that individuals with poor visual acuity, contrast sensitivity, and stereo acuity at baseline presented greater decline on cognitive scores (MMSE) over 9 years compared to participants with normal vision, with the risk for incident cognitive impairment being the highest for those with poor visual acuity and contrast sensitivity at baseline. Similarly, in a prospective study following 2520 community-dwelling US adults (aged 65 to 84 years) over eight years, worse baseline visual acuity (measured using Early Treatment Diabetic Retinopathy Study charts) was associated with worse baseline MMSE scores cross-sectionally, with the rate of worsening visual acuity being associated with the rate of declining MMSE performance across multiple follow-ups (Zheng et al., 2018). On other cognitive measures, Anstey et al. (2001) found that performance decline in visual acuity was associated with visual memory decline (but not with processing speed or verbal ability) over two years in the Longitudinal Study of Aging. Notably, Valentijn et al. (2005) found that a change in visual acuity was associated not only with changes in processing speed and executive function, but also auditory-based tests measuring verbal memory. These findings highlight the link between visual function and cognitive performance across multiple domains (commonly on global cognition or visually presented measures), indicating that worse vision in older adults may be negatively associated with cognitive function over time.

In the recent 2024 *Lancet* report, visual impairment is considered a potentially modifiable risk factor for AD, with an estimated population attributable fraction of 2% (Livingston et al., 2024). Ehrlich et al. (2022) reported a comparable population attributable fraction (1.8%) of vision impairment in a population-based study of 16 690 U.S. adults aged 50 years and older. The link between visual impairment (measured using self-report or objective measures such as

visual acuity and contrast sensitivity) and risk for dementia has been established in longitudinal research (Davies-Kershaw et al., 2018; Fischer et al., 2016; Hajek et al., 2016; A. T. C. Lee et al., 2020; Naël et al., 2019; Ward et al., 2018; Z. Zhu et al., 2022). For example, Zhu et al. (2022) followed 117 187 cognitively healthy adults (aged 40-69 years) over a median of six years. Their analyses demonstrated that the presence of visual impairment at baseline (visual acuity worse than 0.3 logMAR units in the better-seeing eye) was associated with increased risk of dementia, with risk rising progressively as acuity worsened. In a different prospective study with older women (mean age = 77.7 years), Ward et al. (2018) demonstrated that poor contrast sensitivity at baseline not only predicted reduced performance across several cognitive domains (e.g., digit span, memory, verbal fluency, executive function, global cognitive function), but also development of MCI or dementia over a decade later. Importantly, these associations persisted even after exclusion of baseline age-related eye diseases (e.g., age-related macular degeneration, glaucoma). Likewise, Davies-Kershaw et al. (2018) found that healthy individuals aged 50-69 who had moderate and severe visual impairment (as measured by self-report) at baseline were 2 and 4 times as likely, respectively, to have dementia after 10 years compared to those who reported normal vision at baseline (although this risk was lowered when age-related eye diseases were accounted for). Evidence from pooled analyses further highlights this relationship (Kuźma et al., 2021; Shang et al., 2021). A comprehensive meta-analysis conducted by Shang et al. (2021) across many prospective studies showed a robust relationship between visual impairment and incident cognitive impairment and dementia, regardless of method of vision assessment, length of follow-up, and study quality. Across 14 prospective cohort studies (follow-up time ranging between 3.7 and 14.5 years), visual impairment was associated with an increased risk and incident dementia (risk ratio = 1.47). Collectively, these findings provide strong evidence

that poor visual function (across various measures) at baseline can predict development of cognitive decline and dementia over time.

Sensory-Cognitive Mechanisms

Several non-mutually exclusive hypotheses have been proposed to explain the pathways between hearing and cognitive decline, which often overlap (see Figure 2 for a visual overview of these pathways, and see previous reviews: Brewster et al., 2022; Powell et al., 2021; Uchida et al., 2019). For example, the common-cause hypothesis suggests that a common age-related pathological factor (e.g., inflammation or vascular factors) contributes to both cognitive and sensory outcomes (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994). According to this hypothesis, a common neurodegenerative process in the aging brain contributes to both hearing loss and cognitive impairment. For instance, inflammatory and vascular risk factors (e.g., cardiovascular disease, smoking, diabetes, stress) can have both a negative impact on both hearing and cognition (e.g., Gates et al., 1993; Gopinath et al., 2009; Lourenco et al., 2018; Mick et al., 2023; Uchida et al., 2005, 2010). As an example, Mick et al. (2023) found that obesity, smoking, diabetes, and cardiovascular risk were cross-sectionally associated with worse hearing in both males and females (average age = 59) in the Canadian Longitudinal Study on Aging (CLSA); furthermore, hypertension and higher cardiovascular risk were associated with a greater loss of hearing after 3 years for both sexes.

Other hypotheses suggest that sensory loss worsens cognitive function as result of increased cognitive demands and changes in brain structure and connectivity. According to the information degradation hypothesis, degraded sensory input (i.e., auditory signals) requires effortful perceptual processing and listening. This additional effort dedicated to perceptual processing strains resources for higher-level cognitive processes and places greater demands on

neural systems, thereby depleting cognitive reserve (Lindenberger & Baltes, 1994; Pichora-Fuller, 2003; Tun et al., 2009; Wingfield et al., 2005). For example, hearing impairment may contribute directly to cognitive decline through the degradation of auditory signals or information required for perceptual processing, which in turn reduces resources for cognitive processing and places greater demands on neural networks and brain structures for compensation. Whereas this view may consider cognitive changes to be potentially reversible, the alternative sensory deprivation hypothesis builds upon this framework and emphasizes that prolonged sensory deprivation contributes to gradual and permanent cognitive decline through changes in brain structure and connectivity (Humes et al., 2013; F. R. Lin et al., 2014; Wingfield & Peelle, 2015). In simpler words, chronic reallocation of cognitive resources may produce permanent changes in cognitive performance over time. In support, previous studies on the relationship between peripheral hearing loss and gray matter density in primary auditory areas demonstrate that deteriorating sensory input may lead to cortical reorganization over time (F. R. Lin et al., 2014; Peelle et al., 2011).

Alternatively, psychosocial factors may explain the relationship between sensory and cognitive decline. The social isolation hypothesis posits that prolonged sensory deprivation reduces opportunities for social engagement and communication, leading to cognitive decline due to reduced stimulation and disruption of neural networks (Fratiglioni et al., 2004; F. R. Lin et al., 2013; F. R. Lin, Metter, et al., 2011; Marsiske et al., 1997; Strawbridge et al., 2000; Weinstein & Ventry, 1982). For example, difficulties in processing auditory information may cause older adults to avoid or withdraw from cognitively demanding or effortful environments, thereby limiting stimulation and accelerating cognitive decline. In support of this hypothesis, a growing body of evidence indicates that social isolation and other psychosocial factors (e.g.,

depression, loneliness, poor social support and network engagement) can increase the risk of cognitive decline and dementia (Cao et al., 2023; Fratiglioni et al., 2004; W. Huang et al., 2022; H.-X. Wang, 2002; Yorgason et al., 2022).

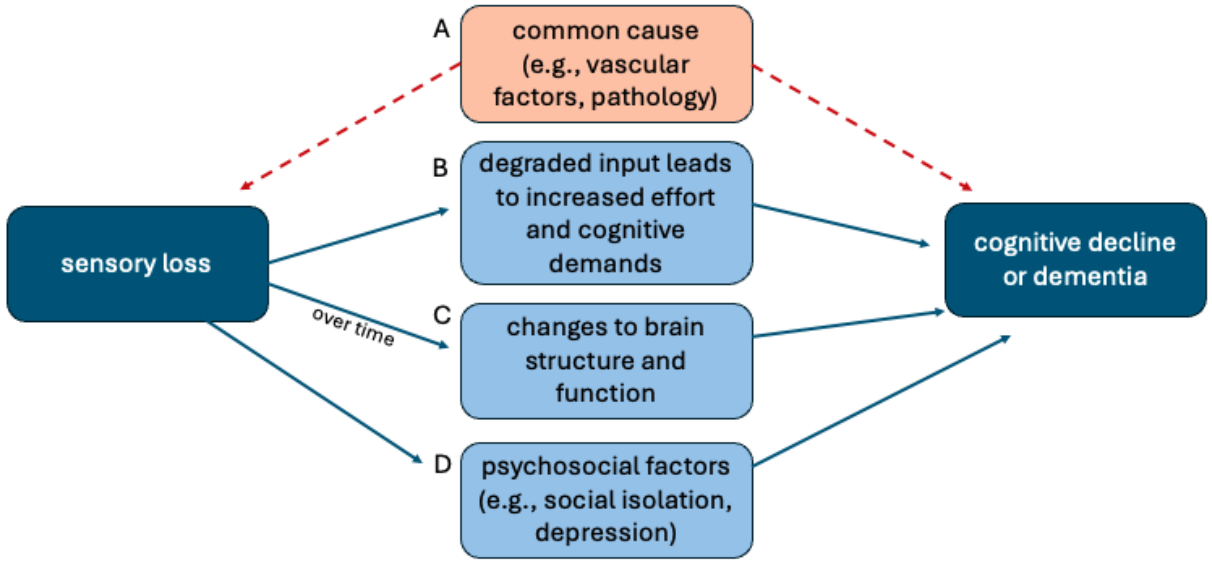


Figure 2. *Proposed mechanistic relationships between sensory loss and cognitive decline or dementia.* ***A: Common-Cause Hypothesis -*** *A shared factor may lead to both hearing and vision loss and dementia* ***B: Information Degradation Hypothesis -*** *Sensory loss leads to degraded input and increased listening effort, increasing cognitive demands.* ***C: Sensory Deprivation Hypothesis -*** *Prolonged sensory decline over time leads to structural and functional changes* ***D. Other Potential Mediators*** *– other factors may mediate the association between sensory and cognitive decline. Adapted from (Powell et al., 2021).*

Although the underlying mechanisms are less clear between visual impairment and the risk for dementia, similar pathways are proposed. Others have hypothesized that poor visual acuity can similarly result in degraded visual input, adding strain and impacting the neuronal networks that support cognitive processes (Anstey et al., 2001; Lee et al., 2020; Lindenberger & Baltes, 1994; Monge & Madden, 2016; Uhlmann et al., 1991). Over time, this added cognitive

load may impact brain structures and connectivity, accelerating cognitive decline. Supporting the sensory deprivation hypothesis, neuroimaging studies have documented both functional and structural alterations in visual-processing regions of the brain in older adults with profound visual deficits (e.g., glaucoma, age-related macular degeneration, central vision loss, visual field deficits, and blindness) compared to healthy controls (Boucard et al., 2009; Burge et al., 2016; Chen et al., 2013; Plank et al., 2011; Prins et al., 2017). Another explanation emphasizes psychosocial pathways: individuals with vision decline may reduce social engagement and participate less frequently in cognitively stimulating activities (especially in activities outside of the home; Heyl et al., 2005), which in turn may increase dementia risk.

Finally, in support of the common-cause hypothesis, there are shared risk factors between vision impairment and cognitive decline (e.g., smoking, hypertension, diabetes, inflammation; Swenor, Lee, Varadaraj, et al., 2020). For example, older adults with visual impairment show high comorbidity with other health conditions, such as hypertension, stroke, arthritis, and diabetes (Crews et al., 2017). Additionally, many age-related eye diseases associated with visual impairment have been linked to dementia, with individuals with AD often presenting concomitant diagnoses of age-related eye conditions. As such, it is proposed that visual impairment (including age-related macular degeneration and glaucoma) and dementia share overlapping neuropathological processes (tau proteins, amyloid beta plaques, neurofibrillary tangles, oxidative stress; Albers et al., 2015; Ikram et al., 2012; Lee et al., 2019). Importantly, these shared pathological features are evident in the retina and at various levels of the visual system/pathway and related structures, extending from subcortical areas (e.g., the lateral geniculate nucleus) to cortical regions responsible for visual processing (e.g., primary and associative visual cortices; Albers et al., 2015; Ikram et al., 2012). For instance, amyloid proteins

have been implicated in inflammatory cascades leading to drusen formation and retinal atrophy, which are hallmark features observed in both AD and age-related macular degeneration (Johnson et al., 2001; Ohno-Matsui, 2011). Similarly, AD and glaucoma share similar retinal features, including thinning of the retinal nerve fiber layer, degeneration of retinal ganglion cells, and optic nerve degeneration (Bambo et al., 2014; Hinton et al., 1986; Lu et al., 2010; Valenti, 2010). Importantly, a recent meta-analysis found that the association between visual and cognitive decline became stronger with increasing age, suggestive of shared underlying pathophysiological processes (e.g., accumulation of amyloid protein, increased prevalence of vascular disease; Vu et al., 2021) between the two conditions.

Despite several proposed mechanisms, it remains unresolved which of these hypotheses best supports the relationship between sensory loss and cognitive decline. Current evidence points towards an additive model, whereby shared neuropathological factors interact with sensory deficits to contribute to cognitive decline. As such, further exploration of sensory-cognitive interactions is warranted to clarify underlying mechanisms and advance understanding of dementia risk.

Sensory Function and Psychosocial Factors

As briefly outlined elsewhere in this literature review, decline in hearing and vision can contribute to reduced social engagement and psychological well-being. Indeed, older adults with sensory deficits frequently experience psychosocial difficulties (particularly reduced social engagement) due to challenges with communication, well-being, quality of life, and functional independence (Heffernan et al., 2022; Heine & Browning, 2004; Resnick et al., 1997). As a result, psychosocial factors such as social isolation, loneliness, and depression are hypothesized as potential mechanisms through which hearing or vision loss may be associated with cognitive

and health outcomes (Fratiglioni et al., 2004; Marsiske et al., 1997; Resnick et al., 1997; Rutherford et al., 2018; Strawbridge et al., 2000; Weinstein & Ventry, 1982).

Given that hearing loss can obstruct a person's ability to interact and engage with their environment, it is hypothesized that individuals with auditory deficits withdraw from situations in which they have difficulty processing, understanding, and communicating, eventually contributing to poor mental health and the development of social isolation, loneliness, and depression (Heffernan et al., 2022; Mick et al., 2014; Pronk et al., 2014; Shukla et al., 2020). Older adults with hearing loss may also encounter frustration or embarrassment (i.e., perhaps due to stigmatization) when their communication is strained or limited (Pichora-Fuller et al., 2015). At a neural level, others have hypothesized that chronic hearing loss and consequent changes in brain activation contribute to dysfunctional auditory-limbic connectivity (e.g., in the anterior cingulate cortex) that may impair emotional reactivity and regulation and cause atrophy in frontal areas (Husain et al., 2014; Rutherford et al., 2018), thereby increasing risk for depression.

Compared to individuals with normal hearing, those experiencing age-related hearing loss participate less in social activities (Wells et al., 2020), and have limited social networks (Ogawa et al., 2019), and are socially isolated (Shukla et al., 2020). For instance, Mick et al. (2014) reported that hearing loss (as measured by pure-tone average of speech frequency thresholds in the better hearing ear) was associated with a greater odds ratio of social isolation in women aged 60-69 years but not in men or older individuals (odds ratio = 2.48 per 25-dB of hearing loss), while another study found that each 10-dB increase in pure-tone average was associated with a 1.52 higher odds ratio of social isolation (Mick & Pichora-Fuller, 2016). Similarly, older adults who report hearing problems participate less frequently in group activities and tend to meet their friends less frequently compared to older adults with no reported hearing

difficulties (Mikkola et al., 2015). Moreover, Ogawa et al. (2019) demonstrated a smaller network size in those with pure-tone hearing loss (compared to normal hearing) in Japanese community-dwelling participants (N =1176 Japanese participants aged 60 years or older; mean age = 71 years). In addition to changes in social function, older adults with hearing loss (measured both subjectively and objectively) report more depressive and anxiety symptoms (Brewster et al., 2018; Contrera et al., 2017) and endorse more loneliness (Jayakody et al., 2022; Pronk et al., 2014; Shukla et al., 2020) compared to those with normal hearing. Notably, endorsing greater hearing handicap (e.g., on the Hearing Handicap for Elderly scale) can predict the incidence of depressive symptoms three years later (Saito et al., 2010). Lawrence et al. (2020) conducted a large meta-analysis of both cross-sectional and cohort designs and found that hearing loss (objective or subjective) was associated with greater odds of depression in both cross-sectional studies (odds ratio = 1.54) and cohort studies (OR = 1.39). Jayakody et al. (2018) also conducted a cross-sectional study investigating the association between the severity of speech and high-frequency hearing loss and symptoms of depression, anxiety, and stress (as measured by the Depression, Anxiety and Stress Scale) in community-dwelling older adults (mean age = 64.4 years). Participants with moderately severe to profound hearing loss had greater odds of clinically significant depression, anxiety, and stress symptoms compared to participants with normal hearing across both speech and high frequency thresholds. Moreover, they observed a graded association, with the severity of mental health symptoms increasing with the severity of hearing impairment. Collectively, this body of literature establishes that social and psychological changes associated with hearing impairment can have an important, adverse bearing on psychosocial functioning.

With increasing visual impairment, older adults experience more activity restrictions and mobility limitations (e.g., recognizing faces, reading, driving), making it challenging for them to leave their homes and enter more complex spaces (Shah et al., 2020; Tejeria et al., 2002). Consequently, a reduction in activity can lead to reduced social participation and more isolation (Shah et al., 2020; Xiang et al., 2020).

Several meta-analyses demonstrate associations between visual impairment and decreased social engagement (Shah et al., 2020; Varadaraj, Munoz, Simonsick, et al., 2021) and social isolation (Dunlop et al., 2025). In a systematic review of mostly cross-sectional studies measuring the relationship between visual impairment (objective measurement and self-report) and social participation (measured quantitatively), 18 of 19 studies reported that visual impairment was associated with reduced social participation, though there was significant variation in measurement and methodology (Shah et al., 2020). Similarly, Dunlop and colleagues (2025) reviewed many prevalence, cohort, cross-sectional, and qualitative studies and reported a strong prevalence of social isolation among those with visual impairment. Other studies have reported conflicting results on the longitudinal relationship between visual impairment and social participation. In a cohort study with 924 participants (mean age = 75.2 years), impaired contrast sensitivity and stereo acuity was cross-sectionally associated with participation in fewer cognitive activities, though the decline of participation over time was similar between those with and without visual impairment (Varadaraj, Munoz, Simonsick, et al., 2021). Along with poor social engagement, individuals with visual loss experience loneliness, depression, anxiety, decline in well-being, and poor quality of life (Bonsaksen et al., 2025; Han et al., 2019; Heesterbeek et al., 2017; van der Aa et al., 2015; Verstraten et al., 2005; Virgili et al., 2022; Xiang et al., 2020). For instance, older adults with low vision (visual acuity less than 6/18) are

two times as likely to develop depression compared to those with normal vision (Noran et al., 2009; van der Aa et al., 2015). Additionally, there is a high incidence of depression and anxiety in older adults with diagnoses of glaucoma and macular degeneration (Heesterbeek et al., 2017). Overall, sensory-psychosocial evidence thus far indicates that visual impairment is associated with poor social and psychological outcomes, though the strength of these associations may vary depending on how vision loss and psychosocial function are measured.

Psychosocial Factors and Cognitive Function

The recent *Lancet* review (Livingston et al., 2024) identified late-life social isolation and mid-life depression as other modifiable risk factors for dementia (population attributable fraction of 5% and 3%, respectively), supported by decades of research on the protective role of social functioning on health and cognitive outcomes (Berkman et al., 2000). In fact, social engagement has been consistently linked to a reduced risk of depression, coronary heart disease, functional decline, and all-cause mortality (Holt-Lunstad et al., 2010). Contributing to this research, a growing body of prospective and meta-analytic evidence presents that social factors (e.g., social isolation, participation in activities, social support, loneliness) and psychological factors (e.g., depression, anxiety) are strongly associated with cognitive function and predict cognitive decline and dementia (Dafsari & Jessen, 2020; Kwak et al., 2017; Lara et al., 2019; Ly et al., 2021; Shankar et al., 2013; Shen et al., 2022; Sutin et al., 2020; Wilson et al., 2007).

Social-Cognitive Mechanisms

A socially active lifestyle appears to protect against cognitive decline and dementia through multiple mechanisms (Berkman et al., 2014; Sommerlad et al., 2023). Early theories proposed that social engagement promotes cognitive stimulation and builds cognitive reserve by strengthening neural pathways and enabling compensatory strategies to offset neuropathology

(Fratiglioni et al., 2004; Scarmeas & Stern, 2003; Stern, 2002). For instance, an autopsy study of 89 older adults from the Rush Memory and Aging Project found that the amount of social contact prior to death moderated the relationship between neuropathology and cognition (Bennett et al., 2006). Specifically, greater neurofibrillary tangle density was less strongly associated with cognitive performance (episodic memory, semantic memory, and working memory) among individuals who had more frequent engagement with their social networks (as compared to those with less engagement), suggesting that social contact may provide some type of reserve that reduces the impact of AD pathology on cognitive function in late life. In a recent cross-sectional cohort study, social network size and density moderated the association between amygdalar atrophy and global cognitive function (as measured by the MoCA), further highlighting the influence of strong social ties on cognitive and brain reserve (Perry, Roth, et al., 2022).

Reviews of social-cognitive research also emphasize a reciprocal relationship, whereby social engagement promotes cognitive health and reserve, and in turn, preserved cognitive function enables an active and engaged lifestyle (Kelly et al., 2017; Sommerlad et al., 2023). Another theory, the stress-buffering hypothesis (Cohen & Wills, 1985), suggests that social relationships provide resources (e.g., emotional and tangible support) that promote adaptive and neurophysiological responses to stressors; thereby, social resources buffer the negative impact of stress on health and cognitive decline (Berkman et al., 2000). Indeed, large social networks and frequent social engagement promote psychological well-being and adaptive healthy lifestyle behaviours, providing opportunities for people to engage in behaviours that reduce dementia risk (e.g., social participation, exercise; Berkman et al., 2000; Fratiglioni et al., 2000, 2004; Seeman et al., 2001).

Measuring and Defining Social Function

As explained by Berkman et al. (2014), social relationships are shaped by contextual factors such as socioeconomic resources and network characteristics. These factors foster engagement with one's networks, provide social support, and promote psychological well-being (e.g., improved self-esteem and self-efficacy) and physiological and behavioural health (e.g., more exercise, lower stress). Social relationships can be further divided into structural and functional aspects of social function (Berkman et al., 2000, 2014). Structural factors describe characteristics about social networks (e.g., size of social networks, the number of family and friends an individual can rely on, frequency of contact with network members) and social activities (e.g., amount of participation and engagement with others, attending family and community activities), which provide an index regarding the quantity of one's social connectedness and network ties. Functional measures assess the role and support that is fulfilled by the social network (e.g., perceived social support, loneliness). For example, loneliness is described as a negative emotional state resulting from the perception of unfulfilled personal and social needs.

Prevalence of Psychosocial Deficits in Populations with MCI and AD

Prevalence studies demonstrate elevated rates of psychosocial difficulties in groups with cognitive impairment (Ismail et al., 2017; Leung et al., 2021; Richard et al., 2013). For example, individuals with MCI are likely to show significantly higher levels of perceived loneliness compared to age-, sex-, and education-matched counterparts, even after accounting for depression levels (Yu et al., 2016). Similarly, those with AD tend to participate in fewer social activities (Amano et al., 2021) and engage with fewer friends as dementia severity increases (Balouch et al., 2019). In addition, meta-analytic evidence suggests that the overall prevalence of

depression and anxiety in patients with MCI reaches 32% and 21%, respectively, with greater psychological burden in clinic-based samples than in community samples (Ismail et al., 2017; Chen et al., 2018). In comparison to those with MCI, slightly higher prevalence rates for depression (ranging from 13% to 37%) and anxiety (37%) have been found in individuals with mild – severe AD (Leung et al., 2021).

Social Factors, Cognitive Decline, and Dementia

Many cross-sectional and longitudinal studies, along with meta-analyses (Kelly et al., 2017; Kuiper et al., 2016), demonstrate that social factors play a significant role in cognitive performance among cognitively healthy older adults. Structural social variables, such as social isolation, social networks and ties, participation in social activities (Fratiglioni et al., 2004; Brown et al., 2012; Evans et al., 2019; Kelly et al., 2017; Yoo, 2022), and functional social variables, such as loneliness and social support (Boss et al., 2015; Kelly et al., 2017; Sutin et al., 2020) are all associated with cognitive decline and dementia risk.

Meta-analytic evidence suggests that compared to other social variables, structural social factors (e.g., activity, networks) are most closely related to cognitive performance cross-sectionally and over time (Kelly et al., 2017; Krueger et al., 2009; Stoykova et al., 2011; Yoo, 2022). Kelly and colleagues' (2017) meta-analysis of 39 studies examined the relationship between various social factors (e.g., social network size, social support, participation in social activities) and cognitive performance in multiple domains in cognitively healthy older adults. They found that social activity (compared to other social factors) was most consistently associated with better cognitive performance, notably in global cognitive function, working memory, executive function, visuospatial abilities, and processing speed. Similarly, another meta-analysis reported that social network size and complexity of one's network were more

strongly associated with changes in episodic memory, working memory, and processing speed compared to subjective social measures like relationship satisfaction (Yoo, 2022).

Longitudinal and meta-analytic evidence demonstrates that structural social factors, like social network size and number of social ties, are associated with increased dementia risk in late life over and above socioeconomic circumstances, health behaviours, and physical health. Early research demonstrates that those with a low number of social ties had an increased risk for incident cognitive decline over 3-12 years, compared to those with more ties (Bassuk et al., 1999; Fratiglioni et al., 2000, 2004). Other longitudinal studies demonstrate that social network size and fewer ties in late life can predict dementia onset and severity (Dyer et al., 2021; Fratiglioni et al., 2000; Saito et al., 2018). In a study assessing links between social networks and cognitive trajectories in patients with mild-to-moderate AD, Dyer et al. (2021) found that those with smaller social networks at baseline (as measured by number of friendship and family ties) had a greater dementia severity after 18 months, with further dementia progression influencing consequent decline in social engagement. In one study comparing living arrangements in those with mild cognitive impairment (i.e., a pre-clinical state to AD), living alone increased by 50% the risk of developing dementia (Grande et al., 2018).

Reduced participation in social activities and low social engagement are also associated with dementia (Kotwal et al., 2016; Kuiper et al., 2015; Piolatto et al., 2022; Wang et al., 2023). According to a meta-analysis of 19 longitudinal studies, older adults with limited social participation (RR = 1.41) and social contact with others (RR = 1.57) were at higher risk for incident dementia (Kuiper et al., 2015). Notably, in a prospective study with older adults with MCI (mean age = 78 years), lower risk of progression from mild to severe cognitive impairment was associated with a greater level of frequency of engagement in social activities and a slower

rate of decline in the variety of activities after three years (OR = 0.72; Hughes et al., 2013). In the UK Biobank Study with 155 070 participants (mean age = 64.1 years), socially isolated individuals (defined by meeting at least two of three criteria of living alone, seeing family or friends less than once per month, and no participation in weekly group activities) at baseline had a higher dementia risk compared to those who were not socially isolated over 8.8 years (Elovainio et al., 2022). Furthermore, socially isolated individuals in the same cohort (UK Biobank Study) had reduced gray matter volume in temporal, hippocampal, and frontal regions compared to those who were not socially isolated, supporting a link between social isolation and cortical atrophy (Shen et al., 2022).

In addition to structural social variables, aspects of perceived social function (e.g., social support, loneliness) in older adults are associated with cognitive decline and dementia over time (Boss et al., 2015; Donovan et al., 2017; Lara et al., 2019; Murata et al., 2019; Shankar et al., 2013), though the evidence is inconsistent for social support (e.g., Wang et al., 2023). In 8382 older adults aged 65 and over, subjective feelings of loneliness (perceived evaluation of unfulfilled social needs, measured by a one-item question on the CES-D) at baseline predicted a 20% faster accelerated rate of cognitive decline over 12 years (Donovan et al., 2017). In another longitudinal study following participants (ages 50 years and above) from the Health and Retirement Study (N = 12 030), loneliness (measured by the 3-item UCLA Loneliness Scale) was associated with a 40% increased risk of dementia after ten years, controlling for age, education, social isolation, as well as clinical, behavioral, and genetic risk factors (Sutin et al., 2020). Sutin and colleagues (2020) also noted that the association between loneliness and dementia risk was slightly stronger among relatively younger than older participants. Collectively, these studies demonstrate that many different aspects of social function (both

structural and functional) are consistently associated with cognitive decline and risk for dementia over time.

However, it is important to note that heterogeneity in the definitions and measurements of social relationships have prevented consensus on understanding the role of social factors in cognitive decline. For example, terminology on measures of social function (e.g., social participation, social engagement, social network) is applied inconsistently, and structural and functional aspects of social functioning are not always clearly distinguished (Gow et al., 2013; Kelly et al., 2017). Inconclusive findings in systematic reviews can be further influenced by other methodological differences, like the duration of follow-up and the identification and adjustment of confounding variables (e.g., living circumstances, depression; Kuiper et al., 2016; Piolatto et al., 2022). Additionally, the lack of supportive evidence from randomized controlled trials limits the ability to evaluate causal effects of social interventions on cognitive outcomes (Kelly et al., 2017). Finally, reverse causation must also be considered in the context of social-cognitive relationships, particularly in the context of short follow-up durations. It is proposed that there is likely a bidirectional relationship between psychosocial function and dementia, such that low participation contributes to cognitive decline, which may further reduce levels of social engagement or psychosocial well-being (Sommerlad et al., 2023).

Psychological Function, Cognitive Decline and Dementia

Psychological variables, such as depression and anxiety, are also consistently linked with poor cognitive performance across multiple domains. Cross-sectional studies demonstrate that compared to non-depressed participants, cognitively healthy older adults with depressive symptoms (previous diagnosis or elevated scores on the Geriatric Depression Scale) perform worse on many cognitive tests (e.g., measuring working memory, story memory, executive

function, global cognitive function, processing speed) compared to non-depressed controls in various populations (Hamilton et al., 2014; Shimada et al., 2014), whereas longitudinal studies show that individuals with late-life depression experienced more rapid decline in language and memory abilities compared to those who were not depressed or had early-onset depression at baseline (Ly et al., 2021).

Similar to depressive symptoms, cognitively healthy older adults endorsing elevated anxiety symptoms (measured by anxiety questionnaires) showed poorer cognitive performance cross-sectionally in multiple cognitive domains compared to those with less anxiety, such as global cognitive function, episodic and visual memory, working memory, processing speed, and verbal fluency (Beaudreau & O'Hara, 2009; Potvin et al., 2013). In a noteworthy prospective study measuring cognitive function in amyloid-positive participants with high and low levels of anxiety, individuals in the high-anxiety group showed a strengthened association (steeper slope) between amyloid-positive status and cognitive performance on measures of global cognition, verbal memory, language, and executive function, controlling for age, education, APOE genotype, vascular risk factors, and depressive symptoms (Pietrzak et al., 2015). These findings highlight the negative role of anxiety on the relationship between elevated amyloid levels and cognitive performance.

Anxiety and depression are associated with risk for cognitive decline and dementia (Almeida et al., 2017; Becker et al., 2018; Saczynski et al., 2010; Santabárbara, Lipnicki, et al., 2019; Santabárbara, Villagrasa, et al., 2019). In a cohort study of 949 individuals (mean age = 79), participants endorsing late-life depressive symptoms (as measured by the Center for Epidemiologic Studies Depression Scale – CES-D) at baseline had more than a 50% risk of developing AD over a 17-year follow-up period (hazard ratio = 1.76), accounting for age, sex,

education, and APOE-4 status (Saczynski et al., 2010). Further, there was a dose-response relationship between depressive symptoms and risk for dementia, with each 10-point increase in CES-D score increasing AD risk by 39%. In a nationwide twin study (N = 41727) examining the association between depression and risk of dementia across the lifespan, mid-life onset of depression, late-life onset of depression, and lifelong depression were all associated with dementia at an 18-year follow-up (Yang et al., 2021). While there is evidence that depression can increase dementia risk across the lifespan, it remains unclear whether depression functions as a risk factor or a prodromal manifestation of dementia, as depressive and related neuropsychiatric symptoms may reflect emerging cognitive decline and underlying neuropathology. Consequently, researchers have suggested that depression with onset at mid-life (compared to late-life) may represent a more reliable risk factor for dementia (see Livingston et al., 2024).

Furthermore, Brendel et al. (2015) investigated biomarkers and depressive symptoms in individuals with MCI (N = 371) and found that individuals who were amyloid positive *and* had depressive symptoms (as measured by the Neuropsychiatric Inventory Questionnaire) had greater amyloid load in the frontotemporal and insular cortices than amyloid positive participants without depression. Additionally, MCI individuals with both depressive symptoms and high amyloid load had a faster progression to AD. This result is supported by other longitudinal studies that show that depressive symptoms (or a diagnosis of depression) in MCI at baseline appears to predict progression to AD (Richard et al., 2013; Van der Mussele et al., 2014). Similarly, Rapp et al. (2008) examined the presence of neuritic plaques and neurofibrillary tangles in the brains of individuals with AD with and without comorbid depression, and found that individuals with AD and comorbid depression showed higher levels of cortical tangle formation had increased odds for advanced neuropathology compared to those without comorbid

depression, even after accounting for age, gender, level of education and cognitive status (Rapp et al., 2008).

Similar to depression, anxiety symptoms at baseline are associated with elevated dementia risk. Longitudinal studies have found associations between anxiety and risk for cognitive impairment at follow-up in men (Gallacher et al., 2009) and women (Kassem et al., 2018), though there are conflicting results in the literature (see de Bruijn et al., 2014 as an example). A meta-analytic review of 20 studies reported that clinically significant anxiety (based on either a validated scale or a diagnosis) predicted incident cognitive impairment (as measured by cognitive performance on measures of risk ratio = 1.77) and dementia (risk ratio = 1.57) over time (Gulpers et al., 2016). Interestingly, the risk of dementia was higher in adults aged 80 years and older, indicating that anxiety could be a prodromal feature of dementia. Additional meta-analyses of prospective cohort studies show that anxiety increases dementia risk by 24% to 35% at various follow-up intervals (Becker et al., 2018; Santabárbara et al., 2020; Santabárbara, Lipnicki, et al., 2019). Longitudinal findings from Zaragoza Dementia and Depression Project on over 300 individuals (aged 65 years or older) further demonstrate that clinically significant anxiety predicted AD risk at several time points (Gracia-García et al., 2023; Santabárbara, Villagrasa, et al., 2019). Both studies found a significant association between clinically significant anxiety at baseline (as measured by Geriatric Mental State-Automated Geriatric Examination for Computer Assisted Taxonomy) and AD risk (established using DSM-IV criteria) over 4.5 (Santabárbara, Villagrasa, et al., 2019) and 10 years (Gracia-García et al., 2023), while other studies have found associations between anxiety symptoms (State Trait Anxiety Inventory) and risk for dementia after 28 years (Petkus et al., 2016), with all studies controlling for potential confounding variables like depressive symptoms. These studies indicate that anxiety was

associated with dementia risk regardless of the follow-up period, with longer follow-up intervals providing support for anxiety as a risk factor for dementia. Nevertheless, whether anxiety is a prodromal symptom or a risk factor of dementia continues to be debated. Taken together, these findings indicate that depression and anxiety contribute to risk for cognitive decline and may also exacerbate underlying neuropathological processes, thereby accelerate cognitive decline and increase the risk of progression to dementia.

Overall, there is consistent evidence that poor social engagement, small social networks, reduced social participation, and even depression and anxiety are all associated with risk for cognitive decline and dementia incidence; however, methodological variability and limitations in existing research must be acknowledged (e.g., measurement of psychosocial factors, adjustment of confounding variables, different follow-up intervals, few repeated assessments).

Overview of the Present Research

The literature review has thus far has outlined relationships and potential mechanisms between sensory and cognitive function, sensory and psychosocial function, and psychosocial factors and cognition. While prior studies to date have established these bivariate links, a comprehensive understanding of the tri-directional relationship remains understudied, especially in clinical populations with or at risk for dementia (e.g., MCI, AD). The existing literature has often been constrained by fragmented studies, typically focusing on isolated social and cognitive measures. As such, important gaps in the literature include 1) integrating diverse measures of sensory, psychosocial, and cognitive function and 2) examining these interrelationships in clinical groups with varying degrees of cognitive impairment. The present thesis aims to address these important clinical gaps by characterizing sensory, psychosocial, and cognitive function and the interaction between these factors in cognitively healthy control groups and individuals

diagnosed with MCI and AD. This research will further our knowledge of sensory-psychosocial-cognitive interactions at different stages of cognitive function, shed light on the role of potentially modifiable risk factors on cognitive performance (and underlying mechanisms), and inform preventative strategies in dementia care.

In the current set of studies, I investigated cross-sectional relationships between sensory, psychosocial, and cognitive function using the COMPASS-ND dataset, the observational cohort study of CCNA (https://ccna-ccnv.ca/compass-nd-study/). In Study 1 (Chapter 3), we examined the relationship between various psychosocial measures and cognitive performance in multiple domains in individuals with MCI. We measured psychosocial function by assessing measures of social participation, social engagement, social support, quality of life, loneliness, and psychological symptoms (depression, anxiety). Furthermore, cognitive function was derived from a principal component analyses with composite scores derived from 11 cognitive tests into five cognitive domains: memory, executive function, processing speed, working memory, verbal fluency. Multiple linear regression models were used to test the effects of various psychosocial factors on cognitive performance, controlling for age, sex, education, MoCA scores, and living circumstances. Following this, Study 2 (Chapter 4) characterized sensory (speech-reception thresholds, contrast sensitivity), psychosocial (depression, anxiety, quality of life, social support, isolation), and cognitive (memory, executive function, verbal fluency, processing speed) function in cognitively healthy controls, and individuals diagnosed with MCI and AD. In addition to describing sensory-psychosocial-cognitive associations in each group, we conducted a moderated moderation analysis to determine if psychosocial function and diagnostic group membership jointly modified the relationship between sensory function and cognitive performance. The following manuscripts provide detailed descriptions of these studies.

Chapter 3: Manuscript I (Study 1)

Psychosocial Function in Mild Cognitive Impairment:

Social Participation is Associated with Cognitive Performance in Multiple Domains

Rehan, S., & Phillips, N.A. (2025). Psychosocial function in mild cognitive impairment: Social participation is associated with cognitive performance in multiple domains. *Journal of Applied Gerontology, 44*(10): 1629-1640. doi:10.1177/07334648241311166

Note: Supplemental materials for this manuscript are provided in Appendix A. Minor changes to formatting were made to make the manuscript consistent with the rest of the dissertation.

Abstract

Psychosocial function is associated with cognitive performance cross-sectionally and cognitive decline over time. Using data from the COMPASS-ND study, we examined associations between psychosocial and cognitive function in 126 individuals with mild cognitive impairment, an at-risk group for Alzheimer's disease (AD). Psychosocial function was measured using questionnaires about mental health, social support, and social engagement. Composite scores for five cognitive domains were derived using principal component analysis. Multiple linear regression models were used to test the effects of various psychosocial factors on cognitive performance, controlling for age, sex, education, MoCA scores, and living circumstances. We found that low current participation in one's social networks, over other psychosocial factors, was associated with worse verbal fluency and processing speed scores than those endorsing normal or high social participation. Our findings provide groundwork for further psychosocial-cognitive analyses in individuals at-risk for AD to understand the role of poor social engagement in cognitive decline.

Introduction

The number of older Canadians living with Alzheimer's disease (AD) is high and expected to increase exponentially over the next decade. Given the profound personal and societal costs of AD, identifying modifiable risk factors is a public health priority. Cognitive function in older adults can be influenced by a broad range of modifiable risk factors (e.g., poor diet, physical inactivity). In a recent systematic review, social isolation has been identified as one modifiable risk factor that hypothetically can prevent or delay up to 40% of dementias at the population level (Livingston et al., 2024). As adults age, social relationships and levels of engagement are modified due to multiple reasons, such as migration of family and friends, reduced social network size, and declining health and cognitive abilities (Cudjoe et al., 2020). Although further research is required to better understand the temporal association between poor social function and cognitive decline, understanding psychosocial functioning in groups with (or at risk for) dementia is an important target for potential intervention. The aim of the current study was to examine associations between psychosocial factors and cognitive performance in individuals with mild cognitive impairment (MCI), who are at-risk for developing AD.

In older adults, social relationships play an important role in the protection against depression, coronary heart disease, functional decline, and all-cause mortality (Holt-Lunstad et al., 2010). Similarly, social engagement protects against cognitive decline and dementia through multiple mechanisms (Berkman et al., 2014; Sommerlad et al., 2023). Early theories suggest that active social engagement offers cognitive stimulation, which builds cognitive reserve (Stern, 2012). An enriched cognitive reserve then shapes neural pathways that can optimize cognitive performance and compensate for underlying neuropathology through alternative brain networks or cognitive strategies, thereby reducing cognitive decline. It is proposed that there is a dual

effect of cognitive reserve, whereby high levels of engagement are associated with positive cognitive function, and consequently, high levels of overall functioning promote an engaging and active lifestyle (Kelly et al., 2017). Finally, social relationships can provide resources that buffer the impact of stress on cognitive health.

Social relationships are divided into structural and functional aspects (Berkman et al., 2014). Structural factors describe characteristics about social networks (e.g., size of social networks, the number of family and friends, living circumstances, marital status) and social activities (e.g., amount of participation and engagement with others, attending community activities), indicating one's social connectedness and network ties. Functional measures assess the role and support that is fulfilled by the social network (e.g., perceived social support, loneliness). However, heterogeneity in definitions and measurements of social relationships and a lack of intervention studies have prevented consensus on understanding the role of social function in cognitive decline (Kelly et al., 2017).

Psychosocial Relationships and Cognitive Decline

Multiple meta-analyses provide longitudinal evidence that structural social factors, like social network size, number of social ties, and participation in social activities, are associated with increased dementia risk in late life over and above socioeconomic circumstances, health behaviours, and physical health (Kelly et al., 2017; Kuiper et al., 2016; Sommerlad et al., 2023). There is substantive evidence that reduced participation in social activities and fewer network ties can predict dementia onset and severity (Dyer et al., 2021; Kotwal et al., 2016; Kuiper et al., 2015, 2016; Piolatto et al., 2022; Wang et al., 2023). In a recent systematic review of 40 cohort studies comparing the influence of multiple social factors on the risk for dementia in cognitively healthy older adults, frequent social contact and engagement with others at baseline were found

to be associated with a decreased risk of dementia, compared to social support (Wang et al., 2023). Moreover, several psychological (e.g., depression, anxiety) and factors of perceived social function (e.g., loneliness, social isolation) predict cognitive decline and dementia (Freire et al., 2017; Shankar et al., 2013; Shen et al., 2022; Sutin et al., 2020). Overall, there is consistent evidence that poor social engagement, small social networks, reduced social participation, and even psychological symptoms are all associated with risk for cognitive decline and dementia incidence. However, due to limitations in longitudinal research (e.g., short follow-up intervals, few repeated assessments), it is proposed that there is likely a bidirectional relationship between psychosocial function and dementia, such that low participation contributes to cognitive decline, which may further reduce levels of social engagement or psychosocial well-being (Sommerlad et al., 2023).

Psychosocial Relationships and Cognitive Function

Many reviews have examined various social factors and their impact on cognitive performance, such as loneliness (Boss et al., 2015), social isolation (I. E. M. Evans et al., 2019), social networks (Yoo, 2022), social activity (Brown et al., 2012; I. E. M. Evans et al., 2019), and social support (Kelly et al., 2017). Each of these reviews presents unequivocal findings regarding positive associations between psychosocial and cognitive functions, such that better psychosocial function at baseline is associated with better cognitive performance at follow-up; however, results vary across studies regarding which specific cognitive domains are associated with social variables. In reviews assessing the role of social networks and social activity on cognitive outcomes in cognitively healthy older adults, frequent participation in social activities was most strongly associated with better global cognitive function, memory, executive function, visuospatial abilities, and processing speed (I. E. M. Evans et al., 2019; Kelly et al., 2017).

Similarly, other reviews indicate that quantitative (e.g., network size, complexity) social measures are more strongly associated with changes in episodic memory, working memory, and processing speed compared to qualitative (e.g., relationship satisfaction) measures (Yoo, 2022). This finding is supported by longitudinal studies examining the role of social networks and social engagement on cognitive function, which conclude that rich social networks and frequent social engagement were associated with better verbal fluency and memory cross-sectionally (Stoykova et al., 2011) and slower memory decline (Barnes et al., 2004; Ertel et al., 2008) and better verbal fluency (Brown et al., 2012) over time in cognitively healthy older adults.

Factors of perceived social function and psychological well-being are also associated with cognitive performance in cognitively healthy older adults. For example, loneliness is linked with decline in global cognition, perceptual speed and visual memory cross-sectionally (O'Luanaigh et al., 2012) and memory, perceptual speed, and visuospatial ability over time (Shankar et al., 2013). Moreover, individuals with depressive and anxiety symptoms have worse memory, language, processing speed, and executive function performance compared to controls (Beaudreau & O'Hara, 2009; Hamilton et al., 2014).

Rationale

Most studies on social-cognitive studies relationships have focused on cognitively healthy older adults or assessed the relationship between psychosocial factors and cognitive impairment over time (e.g., progression to dementia at follow-up). The effects of psychosocial variables on cognitive function have rarely been researched in older adults at risk for AD, particularly in the early stages of cognitive impairment where social engagement might have significant protective effects. Given that 1) psychosocial factors contribute to dementia risk and 2) are associated with cognitive performance in cognitively healthy older adults, it is important

to examine the relationship between psychosocial and cognitive function in clinical groups with existing cognitive impairment (e.g., MCI) to better understand whether (and which) psychosocial factors are linked to cognitive function. This is particularly critical for groups at risk for AD to elucidate the pathways in which poor psychosocial function contributes to cognitive decline. Moreover, while many systematic reviews conclude consistent effects of psychosocial factors on cognitive outcomes, results are varied and studies have focused on only single, isolated aspects of social relationships (e.g., focusing on structural or functional social variables) or lack comprehensive analysis of cognitive function (e.g., exploring few cognitive domains, over-reliance on a single measure for assessing cognitive abilities). Therefore, the aim of the current study was to explore associations between various psychosocial factors (ranging from psychological symptoms to structural and functional social measures) and multiple cognitive domains (by using a comprehensive neuropsychological battery to assess memory, executive function, verbal fluency, working memory, and processing speed) in individuals with MCI; and more broadly, for these cross-sectional associations to serve as a starting point in exploring and understanding larger, longitudinal social-cognitive relationships in clinical populations at earlier stages of AD.

Methods

Using the COMPASS-ND dataset (Data Release 5), we analyzed data from 126 participants who met the criteria for MCI (M_{Age} = 71.5±6.4, $M_{Education}$ = 15.4±3.9). COMPASS-ND is the clinical study of the Canadian Consortium on Neurodegeneration in Aging (CCNA; Chertkow et al., 2019). Participants completed intake interviews and comprehensive evaluations, including clinical and neuropsychological assessment. The study was approved by the Jewish General Research Ethics Board. Data used in this paper are stored on the Longitudinal Online Research Information System (https://www.ccna.loris.ca; Das et al., 2011; Mohaddes et al., 2018). General inclusion and exclusion criteria for the study are listed elsewhere (Chertkow et al., 2019).

MCI Criteria

Participants with MCI were selected based on the following criteria: 1) concern regarding a change in cognition from previous levels based on the participant's or an informant's report; 2) impairment in one or more cognitive domains that is greater than what would be expected for the participant's age and education: WMS-III Logical Memory II score below education-adjusted ADNI cutoffs, CERAD word list recall score less than 6, global CDR score > 0, and MoCA score between 13-24; 3) assigned a CDR score of ≤.5 to not be given a diagnosis of dementia; 4) have preservation of independence in functional abilities by having a score greater than 14/23 on the Lawton-Brody Instrumental Activities of Daily Living (IADL) scale; and 5) absence of diffuse subcortical cerebrovascular disease.

Measures

Psychological Symptoms

Geriatric Depression Scale (GDS). The GDS is a 30-item questionnaire for assessing depressive symptoms in older adults (Yesavage, 1988). It uses a "yes/no" response format to inquire about levels of enjoyment, interest, motivation, and social interactions over the past week. Scores range from 0-30: 0-9 is normal, 10-19 indicate mild depression; and 20-30 indicate severe depression.

Generalized Anxiety Disorder Scale (GAD-7). The GAD-7 is a 7-item screening tool for assessing anxiety symptoms in adults (Spitzer et al., 2006). Questions assess how often participants experience different symptoms of anxiety over the past two weeks. Responses range from "not at all" to "nearly every day", scored from 0-3. Total scores range from 0-21: 0-4 indicate minimal anxiety, 5-9 indicate mild anxiety, 10-14 indicate moderate anxiety; and 15+ indicate severe anxiety.

Social Factors

The COMPASS-ND dataset includes self-reported data on several social factors, including the type and frequency of social engagement in one's network (e.g., amount of participation in community activities, frequency of interaction with one's social network) and social function (e.g., feelings of loneliness, social support, and wanting to participate in more social activities). These data were collected prior to the COVID-19 pandemic.

Measures of Social Structure.

Living Arrangements. Current living circumstances were measured by a self-reported question: "With whom do you live?".

Social Network. Social network availability and engagement were measured using a collection of questions about levels of perceived social engagement. Participants rated regarding the frequency of current participation with one's social network, including frequency of telephone and in-person contact. To measure the frequency of current social participation, participants were asked "Taking only your current situation into consideration, how would you rate your participation/involvement in social activities?" Scores of 0-2 were given to response categories matching "low", "normal", and "high". To measure frequency of telephone contact, participants were asked "In the past week, how many times did you talk to someone—friends, relatives, or others—on the telephone?" To measure frequency of time spent with others, participants were asked "In the past week, how many times did you spend time with someone who does not live with you, for instance you went to see them or they came to visit you, or you went out to do things together?" For both questions, responses were scored from 0-4, corresponding to "not at all", "once", "twice", "3-4 times", and "once or more a day".

Social Participation. Participants answered questions about the frequency and types of social activities they participated in with others (e.g., volunteer work, community and professional activities, religious activities). Scores of 0-4 correspond to responses of "never", "at least once a year", "at least once a month", "at least once a week", and "at least once a day". Scores were categorized as normal (one or more social activities a week) and low social participation (no social activities per week; based on Hämäläinen et al., 2019).

Measures of Social Function.

MOS Social Support Survey. This 19-item questionnaire measured the perceived availability of social support (Sherbourne & Stewart, 1991). A composite score (0-100) of

emotional/informational support, tangible support, affectionate support, and positive social interactions was used.

Quality of Life. This self-report questionnaire measured subjective perception of the participant's position in life, in context of their health, comfort, and overall happiness. This scale has 13 items with a total score ranging from 0-52.

Loneliness. Loneliness was measured based on a "yes/no" response format for one item in the social support questionnaire: "Do you feel lonely, or do you feel very lonely?"

Cognitive Function

Cognitive function was assessed in five domains using a variety of neuropsychological tests. Composite scores of memory, executive function, processing speed, working memory, and verbal fluency were derived from a principal component analysis of test scores; test administration and selection are described elsewhere (Phillips et al., 2025). Composite scores were created from specific tests: memory from delayed recall scores on the Rey Auditory Verbal Learning Test, the Benton Visual Memory Test-Revised, and the CCNA-CIMA-Face-Name Association Task, executive function from ratio scores on the Inhibition and Switching conditions of the D-KEFS Color-Word Interference task, processing speed from scores on the WAIS-III Digit Symbol-Coding Test and the CCNA Reaction Time measures, working memory from the WAIS-III Digit Span total score and a ratio score of the Trail Making Test, verbal fluency from scores on phonemic (letter) and semantic (category) fluency on the D-KEFS Verbal Fluency Test. Higher component scores signify better memory, working memory, and verbal fluency but indicate poorer processing speed and executive function.

Statistical Analyses

Data analyses were conducted using R and RStudio (Version 3.6.2). There were less than 6% missing data for psychosocial variables and less than 5% for cognitive variables, which were addressed using mean imputation. We used linear regression models to test the direct effects of psychosocial variables on cognition (i.e., memory, executive function, processing speed, working memory, and language), controlling for age, sex, education, and MoCA scores, and living circumstances (living alone). Into each regression, we entered those control variables, followed by predictor variables of GAD-7 and GDS scores, quality of life score, social support score, loneliness (yes/no), current social participation rating, frequency of telephone participation, frequency of time spent with others, and participation in social activities (low/normal). Each regression was done per cognitive domain, with five regressions calculated overall, to determine which specific psychosocial measures were associated with cognitive performance across multiple domains.

Results

In our MCI sample (N=126), sex was slightly imbalanced (60% M, 40% F). Most participants (95%) lived with at least another person, and 80% were married or in a common-law partner. Psychological questionnaires indicated mild levels of anxiety (*M*=4.3±4.3) and depression (*M*=6.8±4.9) on average. Participants reported adequate social support (*M*=79.5±19.7) and quality of life (*M*=39.8±5.7). Most participants endorsed either "low" (38%) or "normal" (52%) current social participation, compared to high (10%) current participation. Regarding social participation in community activities, 18% had "low" participation versus 82% with "normal" participation. Regarding telephone contact per week, 2% reported none, 6% reported once, 23% reported twice, 42% reported 3-4 time per week, and 28% reported once or more a day. Regarding time spent with others in-person per week, 9% reported none, 16% reported once, 28% reported twice, 40% reported 3-4 time per week, and 7% reported once or more a day. Moreover, 15% reported feelings of loneliness.

Relationships between Psychosocial Function and Cognitive Performance

Memory

The overall regression was statistically significant (see Table 1). No psychosocial measures were significantly associated with memory scores.

Executive Function

The overall regression model was not statistically significant (see Table 2). No psychosocial measures were significantly associated with executive function scores.

Verbal Fluency

The overall regression was statistically significant (see Table 3). Current social participation was significant associated with verbal fluency performance. Specifically, those

endorsing “low” current social participation (M=-.14±1.03) had worse verbal fluency scores than those endorsing “normal” current social participation (M=-.05±.91, β=.47, $p<.05$) and “high” current social participation (M=.81±1.03; β=1.08, $p<.001$). We found no statistically significant differences between men and women on verbal fluency.

Table 1. Regression Model Testing Multiple Psychosocial Factors on Memory

Regression Model (Memory)			
Predictor	B	SE	T-value
Age			
(Years)	-.04	.01	-3.12**
Sex			
Male	-.28	.18	-1.55
Education			
(Years)	.02	.02	.43
MoCA Score			
(Total Score)	.15	.03	5.54***
Living Circumstances			
Living with spouse, common-law partner, family member, or friend	Ref.		
Living alone	.06	.28	.22
Geriatric Anxiety Disorder Scale (GAD-7)			
(Total Score)	-.04	.02	-1.53
Geriatric Depression Scale (GDS)			
(Total Score)	.03	.02	1.36
Quality of Life			
(Total Rating)	.04	.02	1.95
Social Support			
Total Score	-.01	.00	-2.06*
Loneliness			
No	Ref.		
Yes	-.22	.28	-.77
Current Social Participation			
Low	Ref.		
Normal	.11	.18	.61
High	-.07	.31	-.23
Telephone Frequency			
None	Ref.		
Once per week	-1.38	.82	-1.67
Twice per week	-1.46	.79	-1.86
Three-four times per week	-1.45	.78	-1.86
Once or more per day	-1.23	.81	-1.52
Time Spent with Others Frequency			
None	Ref.		
Once per week	.57	.38	1.47
Twice per week	.49	.38	1.3
Three-four times per week	.40	.38	1.04
Once or more per day	.45	.48	.92
Desire for Social Participation			
No			
Yes	.08	.16	.51
Amount of Social Activities			
Normal	Ref.		
Low	.28	.21	1.32

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, Ref. = reference condition. participation, participants reporting “no” were used as the referent group

Table 2. Regression Model Testing Multiple Psychosocial Factors on Executive Function

Regression Model (Executive Function)			
Predictor	B	SE	T-value
Age			
(Years)	.03	.02	2.19*
Sex			
Male	-.45	.21	-2.21*
Education			
(Years)	-.04	.02	-1.51
MoCA Score			
(Total Score)	-.07	.03	-2.26*
Living Circumstances			
Living with spouse, common-law partner, family member, or friend	Ref.		
Living alone	.09	.32	.28
Geriatric Anxiety Disorder Scale (GAD-7)			
(Total Score)	-.02	.03	-.74
Geriatric Depression Scale (GDS)			
(Total Score)	.02	.03	.60
Quality of Life			
(Total Rating)	.00	.02	.02
Social Support			
Total Score	.01	.01	1.10
Loneliness			
No	Ref.		
Yes	.03	.33	.11
Current Social Participation			
Low	Ref.		
Normal	.07	.21	.35
High	.25	.36	.70
Telephone Frequency			
None	Ref.		
Once per week	.37	.95	.39
Twice per week	.06	.91	.07
Three-four times per week	.43	.91	.48
Once or more per day	-.17	.94	-.18
Time Spent with Others Frequency			
None	Ref.		
Once per week	-.02	.45	-.04
Twice per week	-.09	.44	-.22
Three-four times per week	.09	.44	.20
Once or more per day	-.10	.56	-.18
Desire for Social Participation			
No	Ref.		
Yes	-.10	.19	-.51
Amount of Social Activities			
Normal	Ref.		
Low	-.33	.24	-1.36

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, Ref. = reference condition. participation, participants reporting “no” were used as the referent group.

Table 3. Regression Model Testing Multiple Psychosocial Factors on Verbal Fluency

Regression Model (Verbal Fluency)			
Predictor	B	SE	T-value
Age			
(Years)	.01	.01	.42
Sex			
Male	-.06	.18	-.33
Education			
(Years)	.03	.02	1.27
MoCA Score			
(Total Score)	.13	.03	4.41***
Living Circumstances			
Living with spouse, common-law partner, family member, or friend	Ref.		
Living alone	-.10	.28	-.35
Geriatric Anxiety Disorder Scale (GAD-7)			
(Total Score)	-.02	.02	-.88
Geriatric Depression Scale (GDS)			
(Total Score)	.02	.02	1.07
Quality of Life			
(Total Rating)	.01	.02	.59
Social Support			
Total Score	-.01	.01	-1.88
Loneliness			
No	Ref.		
Yes	.06	.29	.21
Current Social Participation			
Low	Ref.		
Normal	.47	.18	2.53*
High	1.08	.32	3.42***
Telephone Frequency			
None	Ref.		
Once per week	1.04	.83	1.25
Twice per week	1.20	.80	1.51
Three-four times per week	1.16	.79	1.48
Once or more per day	.89	.82	1.09
Time Spent with Others Frequency			
None	Ref.		
Once per week	-.76	.39	-1.94
Twice per week	-.14	.38	-.36
Three-four times per week	-.49	.39	-1.36
Once or more per day	-.53	.49	-1.08
Desire for Social Participation			
No	Ref.		
Yes	-.13	.16	-.80
Amount of Social Activities			
Normal	Ref.		
Low	.60	.21	2.78**

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, Ref. = reference condition. participation, participants reporting “no” were used as the referent group.

Processing Speed

The overall regression was statistically significant (see Table 4). Although not reaching statistical significance, there was a trend of social participation associated with processing speed scores. Specifically, those endorsing "low" current social participation (*M*=.11±1.09) had slower processing speed than those endorsing "normal" current social participation (*M*=.00±.92, β=-.40, p=.058) and "high" social participation (*M*=-.46±.95, β=-.70, p=.056). We found that men performed better on processing speed tests compared to women; however, this difference was not statistically significant (β=-.39, t=-1.89, p=.07).

Working Memory

The overall regression model was statistically significant (see Table 5). No psychosocial measures were significantly associated with working memory scores.

Post-hoc Analyses on Current Social Participation

Further analyses of current social participation in our sample[2] demonstrated that participants with low (N=49), normal (N=65), and high (N=12) current participation had similar age, education, and living circumstances (see Table S1). There were significant differences between levels of social participation on depression and quality of life scores, with those with low social participation endorsing higher depressive symptoms and lower quality of life than those with normal and high social participation. Of the women, 16% reported high participation, 49% reported normal participation, and 35% reported low participation. Of the men, 5% reported high participation, 53% reported normal participation, and 42% reported low participation. These differences in social participation between men and women were not statistically significant. Moreover, adding an interaction between sex and current social participation into the regression

[2] Post-hoc analyses on age, sex, education, living circumstances, and other psychosocial differences between social participation categories were completed following our regression analyses.

models for verbal fluency and processing speed did not account for significant additional variance.

Table 4. Regression Model Testing Multiple Psychosocial Factors on Processing Speed

Regression Model (Processing Speed)			
Predictor	B	SE	T-value
Age			
(Years)	.01	.01	.94
Sex			
Male	-.39	.21	-1.89
Education			
(Years)	-.03	.02	-1.15
MoCA Score			
(Total Score)	-.08	.03	-2.44*
Living Circumstances			
Living with spouse, common-law partner, family member, or friend	Ref.		
Living alone	-.06	.32	-.17
Geriatric Anxiety Disorder Scale (GAD-7)			
(Total Score)	-.01	.03	-.43
Geriatric Depression Scale (GDS)			
(Total Score)	-.03	.03	-1.25
Quality of Life			
(Total Rating)	-.03	.02	-1.33
Social Support			
Total Score	.01	.01	1.34
Loneliness			
No	Ref.		
Yes	.11	.33	.34
Current Social Participation			
Low	Ref.		
Normal	-.40	.21	-1.91
High	-.69	.36	-1.93
Telephone Frequency			
None	Ref.		
Once per week	-.88	.95	-.93
Twice per week	-.44	.91	-.49
Three-four times per week	-.95	.90	-1.05
Once or more per day	-.95	.93	-1.02
Time Spent with Others Frequency			
None	Ref.		
Once per week	.31	.44	.71
Twice per week	.09	.44	.21
Three-four times per week	.29	.44	.67
Once or more per day	.57	.59	1.03
Desire for Social Participation			
No	Ref.		
Yes	.15	.19	.79
Amount of Social Activities			
Normal	Ref.		
Low	-.16	.24	-.66

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, Ref. = reference condition. participation, participants reporting “no” were used as the referent group.

Table 5. Regression Model Testing Multiple Psychosocial Factors on Working Memory

Regression Model (Working Memory)			
Predictor	B	SE	T-value
Age			
(Years)	-.01	.02	-.50
Sex			
Male	-.44	.21	-2.08*
Education			
(Years)	-.04	.03	-1.71
MoCA Score			
(Total Score)	-.11	.03	-3.45***
Living Circumstances			
Living with spouse, common-law partner, family member, or friend	Ref.		
Living alone	.06	.33	.17
Geriatric Anxiety Disorder Scale (GAD-7)			
(Total Score)	.02	.03	.53
Geriatric Depression Scale (GDS)			
(Total Score)	-.00	.03	-.09
Quality of Life			
(Total Rating)	.01	.02	.43
Social Support			
Total Score	.00	.01	.37
Loneliness			
No	Ref.		
Yes	.02	.34	.06
Current Social Participation			
Low	Ref.		
Normal	-.16	.22	-.75
High	-.27	.37	-.72
Telephone Frequency			
None	Ref.		
Once per week	-.20	.98	-.20
Twice per week	.54	.93	.58
Three-four times per week	.41	.93	.44
Once or more per day	.20	.96	.21
Time Spent with Others Frequency			
None	Ref.		
Once per week	-.05	.46	-.10
Twice per week	-.16	.45	-.36
Three-four times per week	-.20	.45	-.43
Once or more per day	-.20	.58	-.34
Desire for Social Participation			
No	Ref.		
Yes	.01	19	.04
Amount of Social Activities			
Normal	Ref.		
Low	-.08	.25	-.33

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, Ref. = reference condition. participation, participants reporting “no” were used as the referent group.

Discussion

The goal of the present study was to examine associations between psychosocial function and cognitive performance in multiple domains in individuals with MCI. We found that current social participation within one's social network was uniquely associated with cognitive performance on neuropsychological tests of verbal fluency and processing speed, after accounting for demographic factors, MoCA scores, living circumstances, and all other psychosocial variables. There were no associations between psychosocial factors and cognitive performance on memory, executive function, and working memory.

Through our post-hoc analyses, we found limited evidence of sex differences across social participation categories and no interaction between sex and current participation on verbal fluency or processing speed performance. The high participation group had few participants and were mostly female; however, our findings were largely driven by cognitive performance in the larger, more balanced low participation group. In addition, we controlled for significant differences in depression and quality of life by entering these predictors before current social participation in our analyses. We also considered lifetime social participation versus current social participation, which indicated that 53% of people with normal lifetime participation and 10% of people with high lifetime participation now reported current low social participation. This means that many participants currently reporting low participation had normal or high lifetime participation, indicating a decline in perceived participation over time. These changes in levels of perceived engagement can be associated with individual factors (e.g., changes in health, increasing frailty, chronic disease, disability, fewer opportunities for physical and cognitive stimulation) and changes in social networks related to aging (e.g., reduced network size due to death or migration of family and friends); as such, these variables may be implicated in our low

participation group. While other studies have linked social participation with cognitive function in various domains (e.g., memory, working memory, executive function) in cognitively healthy older adults (see Kelly et al., 2017 for a systematic review), we found relationships between low social participation and poor processing speed and verbal fluency scores in those with MCI. This suggests that social participation may influence cognitive performance differently in MCI compared to cognitively healthy older adults.

We found that that low current social participation was associated with poorer verbal fluency scores in individuals with MCI. Given that social interactions typically involve word generation and verbal fluency (i.e., accessing one's lexical and semantic networks and retrieving words from vocabulary), one's level of social participation may indicate how often these skills are practiced through interactions with others. Previous evidence demonstrates that high social engagement and participation are associated with better performance on verbal fluency in cognitively healthy older adults (Bourassa et al., 2017; Brown et al., 2012). While these studies have measured social participation using the number of social activities per week or the number of people interacted with regularly, we measured social participation using both objective (participation in number of activities) *and* subjective (rating of current participation) methods and found that only subjective perceptions of social participation were associated with verbal fluency. While our findings are not entirely consistent with previous evidence on social activities and verbal fluency in cognitively healthy individuals, our results corroborate a more general link between social participation and verbal cognitive performance and suggest a particular association between perceived current participation and verbal fluency in individuals with MCI. This suggests that frequent communication and engagement with others may provide opportunities to exercise and facilitate verbal skills (e.g., lexical access, semantic retrieval), or

alternatively, participants with higher verbal ability may be able to better maintain relationships and interactions; although longitudinal analyses are required to confirm these hypotheses.

Although not statistically significant, we observed a trend between current social participation and processing speed, such that low social participation was associated with slower processing speed in individuals with MCI. Importantly, processing speed is a sensitive marker of cognitive aging and is less resistant to age-related cognitive decline, compared to other cognitive abilities (Lindenberger et al., 1993). In fact, this decline in processing speed is thought to underpin cognitive decline in more complex cognitive abilities (Lindenberger et al., 1993). As such, we consider processing speed as a fundamental, lower-level cognitive process that influences age-related decline in other complex cognitive tasks. Previous research demonstrates a link between processing speed and social participation in cognitively healthy older adults (Ghisletta et al., 2006; Lövdén et al., 2005). While our findings did not reach a conventional criterion for statistical significance, they extend a previous link between social participation and processing speed in individuals with MCI.

The Role of Social Participation in Cognitive Function

We investigated the role of multiple psychosocial variables on cognitive performance and found that only perceived current social participation was linked with cognitive function, even after controlling for living circumstances, depression, and loneliness. Current social participation was not highly correlated with other psychosocial variables – correlations between current social participation and other psychosocial measures entered in the regression models ranged from r=.1–.3, except for quality of life (r=.39). This lowers that the possibility that our results are explained by other psychosocial variables (e.g., one's current social participation being driven by depression or anxiety about their levels of participation). Additionally, the difficulty of

determining the directionality of social-cognitive relationships and the possibility of reverse causality (i.e., poor cognitive function is not a consequence but rather a cause of reduced social participation) is a well-documented concern in the literature (Sommerlad et al., 2023). Although it is difficult to rule out this possibility, we attempt to address this by using MoCA scores as covariates; that is, the relationship between social participation and cognitive performance in processing speed and verbal fluency is reliable regardless of the participant's cognitive status. As such, these results should be considered as a useful starting point to test future hypotheses on social-cognitive relationships.

To explain the pathways between social participation and cognitive performance, it is hypothesized that social participation and engagement with one's social network may mitigate the impact of negative physiological consequences of stressors, or act as a resource to enhance well-being and adaptive lifestyle behaviours (Berkman et al., 2014). Another possible mechanism is via the role of social engagement in offering cognitive stimulation, which can preserve cognitive and neural networks (Berkman et al., 2014; Stern, 2012). Compared to memory and executive function domains, it is possible that lower-order abilities in our processing speed and fluency tasks are implicated in a complex set of cognitive processes that occur more frequently during social participation (e.g., processing speech, searching through language networks, sequencing words and sentences, monitoring verbal cues and speech). Particularly in our sample with MCI, we hypothesize that social participation may offer cognitively stimulating opportunities or have a protective effect against decline in lower-level cognitive processes, which requires further testing using longitudinal data.

Limitations and Future Directions

Although the COMPASS-ND dataset includes diverse psychosocial information, the psychometric nature of tests available may have affected our lack of findings for other psychosocial variables. For example, some measurements of psychosocial variables were not standardized or were limited to a singular question or item within a questionnaire (e.g., loneliness). Regarding study design, we used mean imputation for missing data and included a high number of variables in our analyses with a limited sample size, which could have impacted power and reliability of findings. Although this study was novel in examining cross-sectional associations between psychosocial and cognitive function in MCI, we could not determine the directionality, temporal nature, and mechanisms of these results without longitudinal data. Furthermore, future research comparing cognitively healthy controls and clinical groups (e.g., MCI, AD) with greater variability in psychosocial profile and cognitive performance will clarify how psychosocial function impacts complex cognitive processes, particularly as cognitive performance changes due to increasing cognitive impairment or conversion to AD.

In our study, we found that social participation has a positive relationship with cognitive performance in multiple domains in individuals with MCI. Specifically, we found that low current social participation was associated significantly with poorer verbal fluency and near-significantly with slower processing speed. To our knowledge, this is the first study to explore associations between a range of psychosocial factors and cognitive performance in various domains in at-risk diagnostic group. Our findings extend the social-cognitive associations found in previous studies with cognitively healthy older adults to individuals with MCI, and suggest that interventions encouraging social participation and interactions with others may be stimulating and helpful in promoting better cognitive function in those at-risk for developing AD.

Chapter 4: Manuscript II (Study 2)

Bridging the Gap: Psychosocial Function Moderates the Link between Sensory and Cognitive Performance Differently across Normal Cognition, Mild Cognitive Impairment, and Alzheimer's Disease

Rehan, S., Mehrabi, F., Mick, P., Pichora-Fuller, M.K., Wittich, W., & Phillips, N.A. (2026). Bridging the gap: Psychosocial function moderates the link between sensory and cognitive performance differently across normal cognition, mild cognitive impairment, and Alzheimer's disease. *Manuscript submitted for publication in the Journal of Aging and Health.*

Note: A version of this study is under revision for *Journal of Aging and Health*, February 2026. Supplemental materials for this manuscript are provided in Appendix B. Minor changes to formatting and citation style were made to make the manuscript consistent with the rest of the dissertation.

Abstract

Sensory and psychosocial factors are associated with cognitive function and risk for Alzheimer's disease (AD). Sensory challenges can reduce communication and mobility, limit social engagement, and accelerate cognitive decline. Interactions among sensory, psychosocial, and cognitive function remain understudied in groups with (or at risk for) AD. Using cross-sectional data from COMPASS-ND, we assessed sensory (speech-in-noise thresholds, contrast sensitivity), psychosocial (depression, anxiety, quality of life, social support, social isolation), and cognitive (memory, executive function, verbal fluency, processing speed) function in cognitively unimpaired controls (N=123), individuals with mild cognitive impairment (MCI;N=348), and AD (N=151). Moderated moderation analyses tested whether psychosocial factors and diagnostic group jointly influenced sensory-cognitive links. Compared to controls, individuals with MCI and AD showed worse sensory and psychosocial function. Poor psychosocial function strengthened the sensory-cognitive association in MCI and AD, suggesting that individuals with cognitive impairment and poor psychosocial functioning may be particularly vulnerable to sensory effects on cognition.

Introduction

With global population aging, the number of older adults living with Alzheimer's disease (AD) is rising steadily. As such, identifying and understanding risk factors is a public health priority. The 2024 report of the *Lancet* Commission on dementia prevention, intervention, and care identified several potentially modifiable risk factors that can hypothetically prevent or delay up to 45% of dementia cases, with hearing loss accounting for about 7% of the population attributable fraction for risk (Livingston et al., 2024). Indeed, sensory (hearing and vision) impairments are highly prevalent among older adults (Chen et al., 2024; Mick et al., 2021) and both are associated with dementia risk.

Several non-mutually exclusive hypotheses have been proposed to explain mechanisms to account for the association between sensory loss and cognitive decline. For example, the common-cause hypothesis suggests that a common pathological process (e.g., inflammation or vascular factors) contributes to both sensory and cognitive changes (Lindenberger & Baltes, 1994). The information degradation hypothesis posits that in the moment, increased effort to compensate for degraded sensory input (e.g., while listening or reading) reduces the availability of cognitive resources for higher-level cognitive processing (e.g., remembering), placing greater demands on neural networks and brain structures (Monge & Madden, 2016; Tun et al., 2009). The sensory deprivation hypothesis builds upon on this idea, proposing that sensory loss leads to gradual and persistent pathological changes contributing to brain atrophy and disrupted connectivity (Lin et al., 2014; Wingfield & Peelle, 2015). Finally, it is hypothesized that the association between sensory and cognitive decline may be mediated by other factors (e.g., social isolation, depression). For example, individuals with hearing loss may experience communication difficulties and avoid environments that are challenging (e.g., noisy social gatherings), consequently withdrawing from

previously enjoyed activities or interactions, (Heffernan et al., 2022; Mick et al., 2014) thereby reducing cognitive stimulation. This hypothesis is supported by evidence that social isolation and other psychosocial factors (e.g., depression) are associated with sensory loss and may increase the risk of cognitive decline and dementia (Fratiglioni et al., 2004; Moon et al., 2024; Yorgason et al., 2022; Zhao et al., 2023).

To better understand the pathways between sensory and cognitive decline, exploring the role of psychosocial functioning in groups with (or at risk for) dementia is an important target for research. The aims of the current study are three-fold: 1) to characterize sensory and psychosocial function in older adults with (or at risk for) dementia, 2) to explore bivariate associations between sensory, psychosocial, and cognitive function, and 3) and to evaluate if psychosocial function moderates the relationship between sensory and cognitive performance in cognitively normal age-matched controls, individuals with mild cognitive impairment (MCI), and individuals with mild AD.

Sensory Loss and Cognitive Decline

The prevalence of sensory impairments increases with age and can have negative effects on functional independence and quality of life. Globally, an estimated 1.5 billion people experience some degree of hearing loss, which is projected to reach 2.5 billion people by 2050 (World Health Organization, 2021). There is substantial evidence within population- and cohort-based observational studies to demonstrate that hearing loss (based on self-report or behavioural measures) is associated with cognitive function cross-sectionally (Brewster et al., 2021) and with cognitive decline over time (Deal et al., 2015; Lin, Ferrucci, et al., 2011). For example, in the Baltimore Longitudinal Study of Aging, hearing loss (as measured by pure-tone audiometry) in cognitively healthy older adults (> 55 years) was independently associated with decline in non-

verbal and verbal measures of cognition (learning, memory and executive function) over five years (Lin, Ferrucci, et al., 2011). Hearing loss is also associated with accelerated risk for cognitive impairment and dementia (Deal et al., 2017; Lau et al., 2022; Lin, Metter, et al., 2011; Myrstad et al., 2023), although findings are nuanced due to heterogeneity in study methodology and design (e.g., evaluation of hearing and cognition, follow-up periods, sample sizes, confounding variables). Individuals with mild-moderate audiometric hearing impairment have a greater risk of developing incident dementia over 9-12 years compared to those with normal hearing (Deal et al., 2017; Lin, Metter, et al., 2011), with dementia risk increasing proportionally with the severity of hearing loss (Deal et al., 2017; Myrstad et al., 2023). Similarly, older adults with poor speech-in-noise hearing at baseline had an increased risk of developing dementia over 11 years compared to individuals with normal hearing (Stevenson et al., 2022).

Visual impairment is considered another potentially modifiable risk factor for AD (population attributable fraction of 2%; Livingston et al., 2024) and becomes increasingly prevalent with age. In 2023, the WHO estimated that globally more than 2.2 billion people have a near or distance vision impairment. (World Health Organization, 2023). Poor visual function, typically measured by visual acuity and contrast sensitivity, is associated with lower cognitive performance on tests of processing speed, visuospatial abilities, and working memory cross-sectionally (Salthouse et al., 1996; Skeel et al., 2006), and with tests of global cognition, memory, language, and attention longitudinally (Swenor et al., 2019; Varadaraj et al., 2021). The relationship between vision and cognition can differ based on the visual measure used, with contrast sensitivity being associated with decline across more cognitive domains than other visual measures (Varadaraj et al., 2021). Furthermore, poor visual acuity and contrast sensitivity are associated with incident dementia (Almidani et al., 2024; Zhu et al., 2022). In a prospective study

following 117,187 cognitively healthy adults over a median of six years, Zhu and colleagues (2022) reported that visual impairment at baseline (visual acuity worse than 0.3 logMAR units in the better-seeing eye) was associated with increased risk of dementia, with risk increasing progressively as acuity worsened. More recently, a retrospective cohort study reported that worsening contrast sensitivity over time, but not visual acuity, was associated with greater likelihood of incident dementia (Almidani et al., 2024).

Sensory Loss and Psychosocial Function

Psychosocial function has been proposed as a potential pathway between sensory and cognitive declines as older adults with sensory deficits experience various psychosocial changes that impact communication, quality of life, and functional independence. For example, hearing loss can reduce a person's ability to interact and engage with their environment. Often, individuals with hearing loss withdraw from situations in which they have difficulty listening, understanding, and communicating, potentially leading to social isolation and feelings of loneliness and depression (Mick et al., 2014). Compared to those with normal hearing, older adults with hearing loss report more depressive and anxiety symptoms (Lawrence et al., 2020) and participate less in social activities (Wells et al., 2020). Similarly, older adults with visual impairment can experience activity and mobility restrictions (e.g., difficulty reading print, recognizing faces, navigating unfamiliar places), thereby limiting engagement in activities of daily living (e.g., reading, driving) and reducing the frequency and quality of their social interactions and participation in activities outside the home (Heyl et al., 2005), potentially leading to social isolation and psychological changes (Shah et al., 2020; Xiang et al., 2020). Compared to those with normal vision, individuals with visual impairment at baseline are more likely to poor emotional well-being (Xiang et al., 2020, Noran et al., 2009) over time.

Psychosocial Function and Cognitive Function

Social interactions and engagement in cognitively stimulating social activities are proposed to enhance cognitive reserve (Stern, 2002) and protect against cognitive decline and dementia (Fratiglioni et al., 2004). Moreover, social isolation (in late life) and depression (in mid-life) are identified as potentially modifiable risk factors for dementia in the 2024 Lancet Commission paper (population attributable fraction of 5% and 3%, respectively; Livingston et al., 2024). Structural aspects of social relationships, such as social network size and participation in social activities, are associated with increased dementia risk in late life over and above the contributions of socioeconomic circumstances, lifestyle behaviours, and health (Kelly et al., 2017; Kuiper et al., 2015). For instance, a smaller social network size, reduced social participation, and less frequent contact with one's social network are also associated with dementia incidence and severity (Kotwal et al., 2016; Kuiper et al., 2015; Saito et al., 2018). Functional aspects of social relationships (e.g., loneliness) and psychological symptoms (e.g., depression, anxiety) are also associated with risk for cognitive impairment and dementia (Freire et al., 2017; Sutin et al., 2020)

Mediating/Moderating Role of Psychosocial Variables in the Sensory-Cognitive Relationship

Recent studies have examined whether psychosocial factors mediate or moderate the relationship between sensory impairment and cognition, though findings are inconsistent. There is some longitudinal evidence that social isolation or poor social engagement mediate the association between sensory impairments (hearing and vision) and cognitive functioning in cognitively healthy older adults, (Yorgason et al., 2022; Zhao et al., 2023) though others have found limited evidence for social isolation mediating the link between hearing (measured by pure-tone hearing and speech-in-noise reception thresholds) and global cognitive function (Arjmandi et al., 2024). Depressive symptoms and loneliness have also been shown to mediate the link between sensory impairment

(hearing and vision) and cognitive status or performance (Moon et al., 2024; Zhao et al., 2023; Zheng et al., 2025). In moderation studies, lower social engagement was associated with higher odds of global cognitive impairment among nursing home residents, and this association was stronger for residents with moderate to severe hearing or vision impairment compared to those without any impairments (Xu et al., 2024). In a study that assessed both the mediating *and* moderating effects of psychosocial function between sensory and cognitive function, loneliness moderated, but did not mediate, the association between visual acuity and decline in global cognitive function over time in cognitively healthy older adults (Ge et al., 2023). In the same study, there was no moderation or mediation effect of loneliness between pure-tone hearing and cognitive function. Overall, there is some evidence of psychosocial factors mediating and/or moderating the relationship between sensory loss and cognitive function in cognitively healthy populations. However, research remains inconsistent due to methodological limitations (e.g., the measurement of sensory loss and cognitive function) and has focused largely on cognitively healthy older adults.

Rationale

Though emerging evidence considers the interplay of all three factors in cognitively healthy older adults, the potentially synergistic sensory-psychosocial-cognitive relationship remains largely unexplored in older adults with (or at risk for) AD. This gap is particularly important given that both sensory loss and psychosocial function are potentially modifiable risk factors for cognitive decline and dementia. Moreover, clinical groups with cognitive impairment show a higher prevalence of sensory and psychosocial difficulties compared to cognitively healthy older adults. While research shows inconsistent mediation/moderation effects in cognitively healthy samples, interactive effects may be more pronounced in groups with poorer sensory and psychosocial function at advanced levels of cognitive decline (MCI, AD). Therefore, examining

the tri-directional relationship in these clinical populations is critical for elucidating potential pathways through which sensory and psychosocial function may contribute to cognitive decline. Finally, to date, no studies have yet assessed moderation effects in the sensory-psychosocial-cognitive relationship by using multiple aspects of sensory function (e.g., hearing *and* vision), structural and functional aspects of social function and psychological well-being, and cognitive performance across several domains.

Therefore, the purposes of this exploratory study are three-fold. First, we aimed to characterize sensory and psychosocial function in cognitively healthy controls, and individuals with MCI and AD. We hypothesized that sensory and psychosocial function would be worse in individuals with cognitive impairment (MCI, AD) compared to cognitively healthy controls. Second, we examined the bivariate relationships between sensory, psychosocial, and cognitive measures. We hypothesized that better sensory function would be associated with better cognitive performance, that better sensory function would be associated with better psychosocial functioning, and that better psychosocial functioning would be associated with better cognitive performance. Third, we explored whether psychosocial factors such as depression, anxiety, quality of life, social support, or social isolation mediate or moderate the association between sensory function (i.e., behavioural measures of hearing and vision) and cognitive performance (e.g., memory, executive function, verbal fluency, processing speed), and whether these relationships vary across diagnostic groups (see Figure 1). We hypothesized that sensory loss is associated with cognitive decline via the indirect pathway of poor psychosocial function (mediation), and that this effect would be moderated by diagnostic group (i.e., mediation effects in MCI and AD only). In the absence of mediation effects, we hypothesized that poor psychosocial function may modify the strength of the sensory-cognitive associations in groups with cognitive impairment (MCI and AD).

That is, we expected that the effect of sensory loss on cognitive performance would be stronger in those with poor psychosocial function, and that this effect would be more pronounced in the MCI and AD groups compared to cognitively healthy controls.

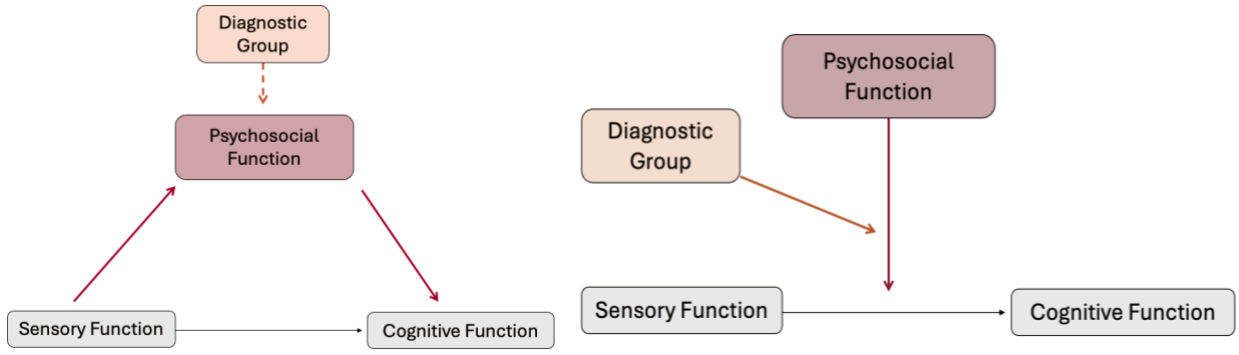


Figure 1.
LEFT: Conceptual model of **moderated mediation**: the association between sensory and cognitive function is mediated by psychosocial function (mediator) and further influenced by diagnostic group (moderator).

RIGHT: Conceptual model of **moderated moderation**: the association between sensory and cognitive function is moderated by psychosocial function (primary moderator) and further influenced by diagnostic group (secondary moderator).

Methods

Using the Comprehensive Assessment of Neurodegeneration and Dementia (COMPASS-ND) baseline dataset (Data Release 7), we analyzed data from three groups: cognitively unimpaired controls (CU, N = 130), individuals with MCI (N = 375), and individuals with mild AD (N = 170). Following exclusion of 53 participants with substantial missing data (defined as missing values on ≥ 2 sensory variables, ≥3 cognitive tests, and/or ≥3 psychosocial variables), the final sample consisted of 123 CU participants, 348 MCI participants, and 151 AD participants.

COMPASS-ND is the clinical study of the Canadian Consortium on Neurodegeneration in Aging (CCNA; Chertkow et al., 2019). Participants completed intake interviews and comprehensive evaluations, including clinical and neuropsychological assessment. All data were collected prior to the COVID-19 pandemic. Data from the COMPASS-ND study used in this paper are stored on the Longitudinal Online Research Information System (LORIS; Das et al., 2011; Mohaddes et al., 2018).

All participants were 60 years of age or older, were proficient in English and/or French, and were required to have a study partner (see Chertkow et al., 2019 for detailed information regarding the inclusion and exclusion criteria for the COMPASS-ND study). Criteria for categorization in the cognitively unimpaired (CU) group included an absence of concern regarding cognition and normal performance on cognitive tests. Criteria for categorization in the MCI group included cognitive concerns and impairment in one or more cognitive domains, with preservation of independence in functional abilities, along with an absence of diffuse, subcortical cerebrovascular disease. Criteria for categorization in the AD group included gradual and progressive change in memory and/or other cognitive functions over more than six months,

evidence of significant decline in at least 2 cognitive domains, and impairment of functional abilities, with non-AD causes of dementia ruled out.

Measures

Sensory Function

Canadian Digit Triplet Test (CDTT). This test, administered in English or French, assesses the participant's speech-reception threshold (SRT) as the signal-to-noise ratio (SNR) at which triplets of spoken digits are recognized correctly 50% of the time (Ellaham et al., 2016). Participants listened to sets of three digits presented in speech-shaped background noise and repeated what they heard. The CDTT uses an adaptive 1-up-1-down procedure; the dB level of the speech decreases (becomes more difficult) after a correct response (all three digits repeated correctly) and increases (becomes less difficult) after an incorrect response. The standard deviation of the responses and the number of reversals were used to identify erratic runs. Lower SRTs indicate better speech perception in noise.

While a measure of pure-tone hearing was also available in the COMPASS-ND dataset, we selected speech-in-noise hearing (CDTT) as the measure of auditory function as it provides a continuous measure suitable for moderation analyses, whereas pure-tone thresholds were categorical. Additionally, CDTT scores may better capture real-world listening ability and its relevance to psychosocial and cognitive outcomes.

The MARS Contrast Sensitivity Test. This test measured participants' contrast sensitivity (Dougherty et al., 2005). Participants held the chart at a 50 cm distance and read progressively lower-contrast letters (2 degrees of visual angle, with spatial frequency at 1.25 cycles per degree). The logCS score was calculated by identifying the lowest contrast value prior to two consecutive errors and subtracting the number of prior errors. Higher scores indicate better contrast sensitivity.

Psychosocial Factors

Geriatric Depression Scale (GDS). The long-form GDS is a 30-item questionnaire and screening tool for assessing depressive symptoms in older adults (Yesavage, 1988). Participants use a "yes/no" response format to questions about levels of enjoyment, interest, motivation, and social interactions over the past week. Scores range from 0-30: scores from 0-9 are categorized as normal, 10-19 indicate mild depression; and 20-30 indicate severe depression.

Generalized Anxiety Disorder Scale (GAD-7). The GAD-7 is a 7-item screening tool for assessing anxiety symptoms in adults (Spitzer et al., 2006). Questions assess how often participants experience different symptoms of anxiety (e.g., excessive worrying, trouble relaxing, feeling restless) over the past two weeks. Total scores range from 0-21: scores from 0-4 indicate minimal anxiety, 5-9 indicate mild anxiety, 10-14 indicate moderate anxiety; and 15+ indicate severe anxiety.

Social Isolation. We used an adapted version of the Canadian Longitudinal Study of Aging Social Isolation Index (CLSA-SII) developed by Wister et al., (2019) This scale includes living arrangement, marital status, social telephone contact, social in-person contact, and participation in community activities. Marital status and living arrangements were dichotomously coded as 0 (living with others, married/partnered) or 10 (living alone). Responses on social contact measures (telephone, in-person, and community participation), were converted from 5-point Likert ordinal scales to values of 0, 2.5, 5, 7.5, and 10. The CLSA-SII was calculated as the mean of these five variables, with higher scores indicating greater social isolation.

MOS Social Support Survey. This 19-item validated survey measured the perceived availability of social support in multiple domains (Sherbourne & Stewart, 1991). A composite score (0-100) of the perceived availability of emotional/informational support, tangible support,

affectionate support, and positive social interactions was used, with a higher score indicating more social support.

Quality of Life (QOL). This questionnaire measured subjective perception of the participant's position in life, in the context of their health, comfort, and overall happiness. Scores range from 0-52, with a higher score indicating better quality of life.

Cognitive Function

Cognitive function was assessed in four cognitive domains through various neuropsychological tests, including memory, executive function, processing speed, and verbal fluency. Memory was assessed using delayed recall scores on the Rey Auditory Verbal Learning Test (RAVLT) and the Benton Visual Memory Test (BVMT). Executive function was measured using a ratio score on the Reitan Trail Making Test (TMT, B/A). Processing speed was measured using a total score from the WAIS-III Digit-Symbol Test. Verbal fluency was measured using a total score from the letter fluency condition of the D-KEFS Verbal Fluency Test. Phonemic (letter) fluency was selected over semantic (category) fluency, as the latter is thought to rely more heavily on semantic networks that are disrupted in clinical populations with cognitive impairment (Monsch et al., 1992). To ensure that cognitive scores were not influenced by the sensory modality of test administration, we tested associations between CDTT SRTs and scores on the BVMT (visual memory) and CS and RAVLT (auditory memory). More details regarding neuropsychological test administration are described elsewhere (Phillips et al., 2025). Higher scores indicate better scores on all cognitive tests.

To address sensory deficits during cognitive testing, a PocketTalker® Ultra was provided to amplify sound for participants who failed the hearing test in the initial screening visit. Efforts were made to provide sufficient lighting and minimize background noise. We also acknowledge

that although subtle sensory deficits may not have been detected and treated, they were unlikely to have significantly influenced cognitive testing outcomes.

Statistical Analyses

Data analyses were completed using R (Version 3.6.2). Missing data were imputed with multivariate multiple imputation. For ease of interpretation, certain variables (CDTT, TMT ratio) were reverse coded so that a higher score indicated better performance for all variables in our analyses. We calculated descriptive statistics and multiple linear regressions to evaluate group differences in sensory and psychosocial measures, controlling for age, sex, and living circumstances (i.e., living alone or with others). Sex-related differences in sensory and psychosocial variables were examined across the sample and within diagnostic groups. For post-hoc comparisons between groups, we used the Tukey adjustment for multiple comparisons and Cohen's *d* for effect size estimation.

To assess prerequisites for moderated mediation analyses (i.e., relationships between predictor-moderator and predictor-outcome variables), bivariate relationships between sensory, psychosocial, and cognitive variables were assessed using partial correlations within each group. We examined main effects in the entire sample using regressions, controlling for age, sex, and education: 1) sensory variables on psychosocial factors (separate models for each psychosocial variable) and 2) sensory variables on cognitive performance (separate models for each cognitive domain).

We conducted moderated moderation analyses using Hayes' PROCESS macro for RStudio ("processR" package; Hayes, 2018). Given the exploratory nature of our study, we tested three-way interaction effects (Model 3) to examine whether the relationship between sensory function and cognitive performance was jointly moderated by psychosocial factors (primary moderator)

and diagnostic group (secondary moderator), controlling for age, sex, education, and annual household income (see Figure 1). Diagnostic group is not expected to influence the relationship between the independent (sensory) and outcome (cognitive function) variables; instead, it determines when psychosocial function will influence the strength of the direct sensory-cognitive relationship. Due to PROCESS macro limitations for multiple groups, we ran pairwise analyses comparing CU to MCI (CU as reference) and MCI to AD (MCI as reference). We used 35 total models to test the moderating effects of five psychosocial factors on sensory-cognitive associations, for each set of pairwise analyses. All effect sizes (β) reported in the tables are derived from full regression models, with significance determined using 95% bias-corrected bootstrap confidence intervals (n = 5000). To interpret the combined moderating effect of psychosocial variables and diagnostic group on cognitive performance, simple slopes were examined at three moderator levels (16^{th}, 50^{th}, and 84^{th} percentiles), representing low, average, and high levels of psychosocial measures.

Results

Table 1 lists the demographics and descriptive statistics on sensory and psychosocial measures in the CU, MCI, and AD groups. The AD group was significantly older compared to both the MCI and CU groups, while the MCI group was significantly older compared to the CU group. There was a significant difference in sex across the diagnostic groups, such that the CU group was predominantly female (76%). Compared to the other groups, the AD group had the smallest proportion of individuals who lived alone and the highest proportion of individuals who were married or in a common-law partnership.

Diagnostic Group Comparisons on Sensory Measures

The CU group had significantly higher CDTT SRTs (better speech-in-noise thresholds) compared to the MCI (d = .32) and AD (d = .59) groups, and the MCI group had higher CDTT SRTs compared to the AD group (d = .27). The CU group had significantly higher CS scores compared to the MCI (d = .34) and AD (d = .78) groups, and the MCI group had better contrast sensitivity compared to the AD group (d = .44).

Diagnostic Group Comparisons on Psychosocial Measures

There were significant differences among diagnostic groups in depressive symptoms, anxiety symptoms, quality of life (QOL) ratings, overall social support, and social isolation index scores controlling for age, sex, and living circumstances (see Figure 2). Post-hoc pairwise tests demonstrated that the CU group endorsed significantly fewer depressive symptoms on the GDS compared to the MCI (d = -1.02) and AD (d = -.83) groups. The CU group endorsed significantly fewer anxiety symptoms compared to the MCI (d = -.56) and AD (d = -.34) groups. The CU group endorsed higher QOL compared to the MCI (d = .79) and AD groups (d = .81). Regarding social isolation, the CU group had a significantly lower social isolation score compared to the MCI (d =

-.41) and AD (d = -.65) groups. The MCI group was significantly less isolated compared to the AD group (d = -.24).

Table 1. Demographics and Descriptives on Sensory and Psychosocial Variables for CU, MCI, and AD Groups

Demographics	CU (N = 123)		MCI (N =348)		AD (N = 151)		F/X^2 Statistics			
	Mean	±SD	Mean	±SD	Mean	±SD	F	Post-hoc	ω^2	X^2
Age (years)	69.7	5.73	73.2	6.93	75.1	7.19	22.0***	CIE > MCI > AD	-	-
Education (years)	15.5	2.32	14.9	2.95	15.0	2.96	1.63	-	-	-
Female (%)	76.4		42.0		41.1		-	-	-	47.7***
Married or in common-law partnership (%)	74.0		79.9		82.8		-	-	-	3.31
Living alone (%)	24.4		17.0		11.3		-	-	-	7.44*
Sensory Variables[1]										
CDTT SRT[2]	10.3	1.34	9.1	2.35	8.32	2.36	33.62***	CIE < MCI < AD	.17	
MARS Contrast Sensitivity	1.73	.14	1.64	.18	1.55	.20	37.87***	CU > MCI > AD	.19	

Note. * p = <.05, ** p = <.01; *** p < .001; CDTT SRT = Canadian Digit Triplet Test Speech Reception Threshold; post-hoc results include Tukey adjustment for multiple comparisons; controlling for age and sex
[1] variables are coded so that higher scores indicate better speech-in-noise hearing, better contrast sensitivity
[2] CDTT SRTs are negative values but are presented as positive here due to reverse coding

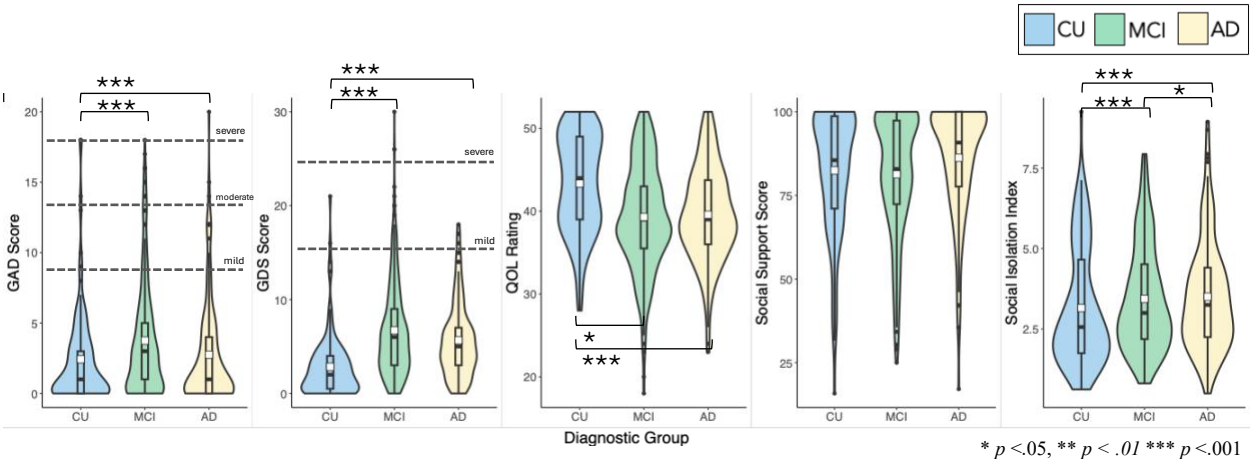


Figure 2. Group differences in psychosocial function across diagnostic groups (CU, MCI, AD), controlling for age, sex, and living circumstances. Psychosocial measures (from left to right) include 1) GAD (anxiety), 2) GDS (depression) 3) quality of life, 4) social support, and 5) social isolation.

Associations between Sensory, Psychosocial, and Cognitive Measures

In analyses adjusted for age, sex, and education, bivariate correlations between sensory, psychosocial, and cognitive variables were very weak to weak (r = .04 – .26) in the CU group (see Supplementary Figure 1A), MCI group (r = .01 – .21; see Supplementary Figure 1B), and in the AD group (r = .03 – .26; see Supplementary Figure 1C), with stronger associations observed between variables within each domain (e.g., GDS with GAD in the psychosocial domain) across all groups.

Across the full sample (all groups combined), linear regression analyses showed that better CDTT performance was associated with better delayed recall on both memory measures (RAVLT/BVMT), processing speed (DSST), and letter fluency (Table 2A). Better CS was associated with better delayed recall on both memory measures (RAVLT/BVMT), executive function (TMT), processing speed (DSST), and letter fluency (Table 2A). For psychosocial outcomes, CDTT SRTs and CS scores were significantly associated with QOL, but not with other psychosocial variables (Table 2B). Mostly weak or absent associations between sensory measures (predictor) and psychosocial measures (moderator) did not support the requirements for further moderated mediation analyses.

Moderated Moderation Analyses

Supplementary Table 1 summarizes the moderation effects of psychosocial factors on sensory-cognitive relationships in CU, MCI, and AD groups. This table shows that no moderation effects were observed for either episodic memory measures (RAVLT, BVMT). Effects were limited to measures of processing speed (DSST), executive function (TMT), and verbal fluency (letter fluency).

Table 2A. Linear Regressions Testing Sensory Variables on Cognitive Performance (All Groups Collapsed)

Outcome	Predictor	B	SE	T-value
BVMT Delayed	Age			
	(Years)	-.07	.02	-3.36
	Sex			
	Female	*Ref.*		
	Male	-.58	.27	-2.17*
	Education			
	(Years)	.12	.05	2.56*
	CDTT SRT			
	(Score)	.28	.06	4.32***
	MARS Contrast Sensitivity			
	(Score)	4.40	.76	5.78***
RAVLT Delayed	Age			
	(Years)	-.06	.03	-2.24*
	Sex			
	Female	*Ref.*		
	Male	-2.23	.32	-7.08***
	Education			
	(Years)	.11	.05	1.99*
	CDTT SRT			
	(Score)	.25	.08	3.32***
	MARS Contrast Sensitivity			
	(Score)	5.50	.91	6.08***
TMT Ratio	Age			
	(Years)	.01	.01	-1.80
	Sex			
	Female	*Ref.*		
	Male	-.01	.01	-.05
	Education			
	(Years)	-.06	.02	-3.18**
	CDTT SRT			
	(Score)	-.04	.02	-1.53
	MARS Contrast Sensitivity			
	(Score)	-.77	.29	-2.66**
Digit Symbol Test	Age			
	(Years)	-.36	.19	-3.54***
	Sex			
	Female	*Ref.*		
	Male	-3.23	1.23	-2.62**
	Education			
	(Years)	.99	.21	4.61***
	CDTT SRT			
	(Score)	1.20	.30	4.02***
	MARS Contrast Sensitivity			
	(Score)	23.18	3.54	6.55***
Letter Fluency	Age			
	(Years)	-.00	.08	-.01
	Sex			
	Female	*Ref.*		
	Male	04.40	.95	-4.61***
	Education			
	(Years)	1.02	.17	6.18***
	CDTT SRT			
	(Score)	1.19	.23	5.13***
	MARS Contrast Sensitivity			
	(Score)	9.78	2.74	3.57***

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, *Ref.* = reference condition; controlling for age, sex & education.

Table 2B. Linear Regressions Testing Sensory Variables on Psychosocial Factors (All Groups Collapsed)

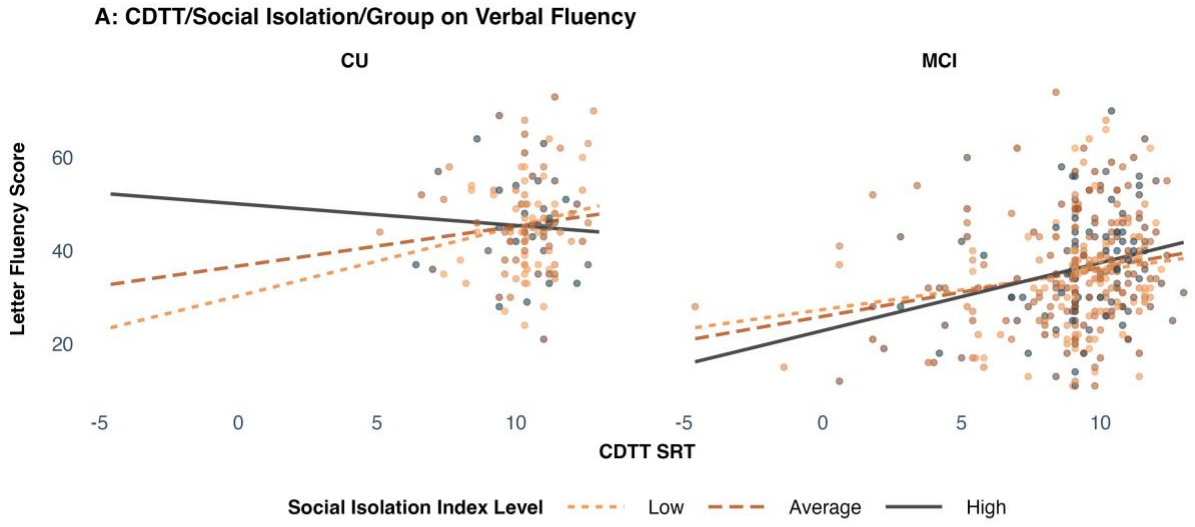
Outcome	Predictor	B	SE	T-value
GDS Score	Age			
	(Years)	-.09	.03	-3.11**
	Sex			
	Female	*Ref.*		
	Male	.04	.38	.11
	CDTT SRT			
	(Score)	-.17	.09	-1.81
	MARS Contrast Sensitivity			
	(Score)	-2.12	1.10	-1.93
GAD Score	Age			
	(Years)	-.08	.03	-3.20**
	Sex			
	Female	*Ref.*		
	Male	-.91	.31	-2.96**
	CDTT SRT			
	(Score)	-.11	.07	-1.52
	MARS Contrast Sensitivity			
	(Score)	.31	.89	.35
QOL Rating	Age			
	(Years)	.03	.04	.94
	Sex			
	Female	*Ref.*		
	Male	.40	.51	.78
	CDTT SRT			
	(Score)	.25	.12	1.15*
	MARS Contrast Sensitivity			
	(Score)	3.86	1.46	2.64**
Social Support	Age			
	(Years)	.02	.13	.20
	Sex			
	Female	*Ref.*		
	Male	3.97	1.33	2.75**
	CDTT SRT			
	(Score)	-.27	.35	-.78
	MARS Contrast Sensitivity			
	(Score)	-2.18	4.17	-.52
SI Index	Age			
	(Years)	.13	.06	2.29*
	Sex			
	Female	*Ref.*		
	Male	-2.24	.68	-3.30**
	CDTT SRT			
	(Score)	-.10	.16	-.59
	MARS Contrast Sensitivity			
	(Score)	-.37	1.96	-.19

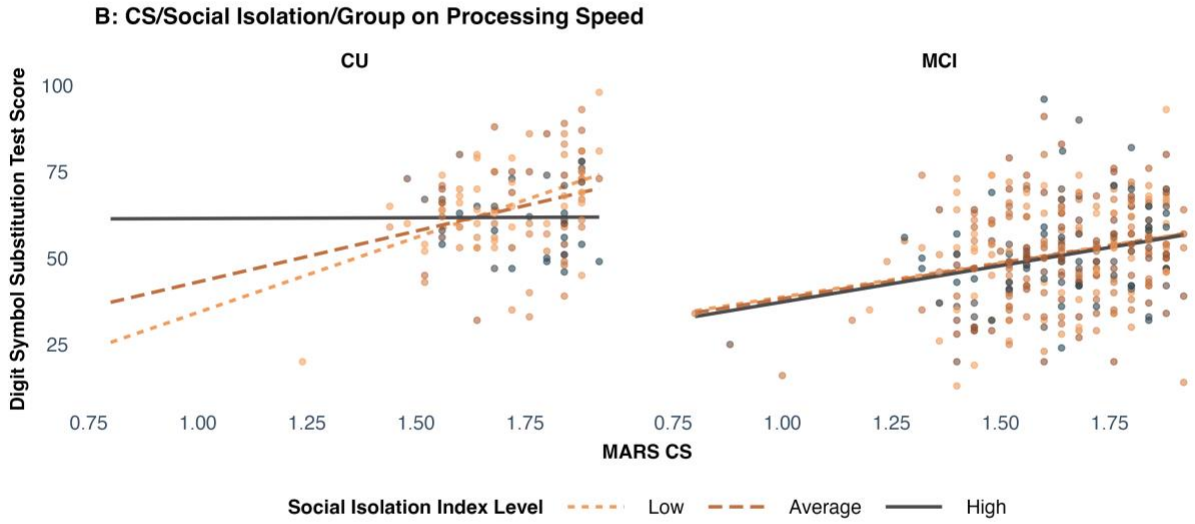
Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, *Ref.* = reference condition; controlling for age & sex

Moderation Analyses Comparing CU and MCI Groups

Hearing-Psychosocial-Cognitive Interactions. There was a significant three-way interaction between CDTT SRTs, social isolation index scores, and diagnostic group on verbal fluency performance ($F(1,459) = 4.18$, $p < .05$; see Supplementary Table 2 and Figure 3A). CDTT SRTs were not associated with verbal fluency performance at any level of social isolation for CU participants. However, in MCI participants, better CDTT performance was associated with better verbal fluency performance at average levels (50^{th} percentile) of social isolation, with this association becoming even stronger at high levels (84^{th} percentile) of social isolation.

Vision-Psychosocial-Cognitive Interactions. There was a significant three-way interaction between CS, social isolation index scores, and diagnostic group on processing speed performance ($F(1,459) = 4.30$, $p < .05$; see Supplementary Table 3 and Figure 3B). In the CU group, better CS was associated with better processing speed performance at average levels of social isolation, with this association becoming even stronger at low levels (16^{th} percentile) of social isolation. In the MCI group, better CS was associated with better processing speed performance across all three levels of social isolation. Though not statistically significant, a similar trend was observed in the three-way interaction between CS scores, GDS scores, and diagnostic group on processing speed performance ($F(1,459) = 4.18$, $p = .07$; see Supplementary Table 4 and Figure 3C). Better CS was significantly associated with better processing speed performance only at low levels of depressive symptoms in CU group. In the MCI group, better CS was associated with faster processing speed at average levels of depressive symptoms, with this association becoming even stronger at high levels of depressive symptoms.


A: CDTT/Social Isolation/Group on Verbal Fluency
CU
MCI
Letter Fluency Score
60
40
20
-5
0
5
10
CDTT SRT
Social Isolation Index Level
Low
Average
High


B: CS/Social Isolation/Group on Processing Speed
CU
MCI
Digit Symbol Substitution Test Score
100
75
50
25
0.75
1.00
1.25
1.50
1.75
MARS CS
Social Isolation Index Level
Low
Average
High

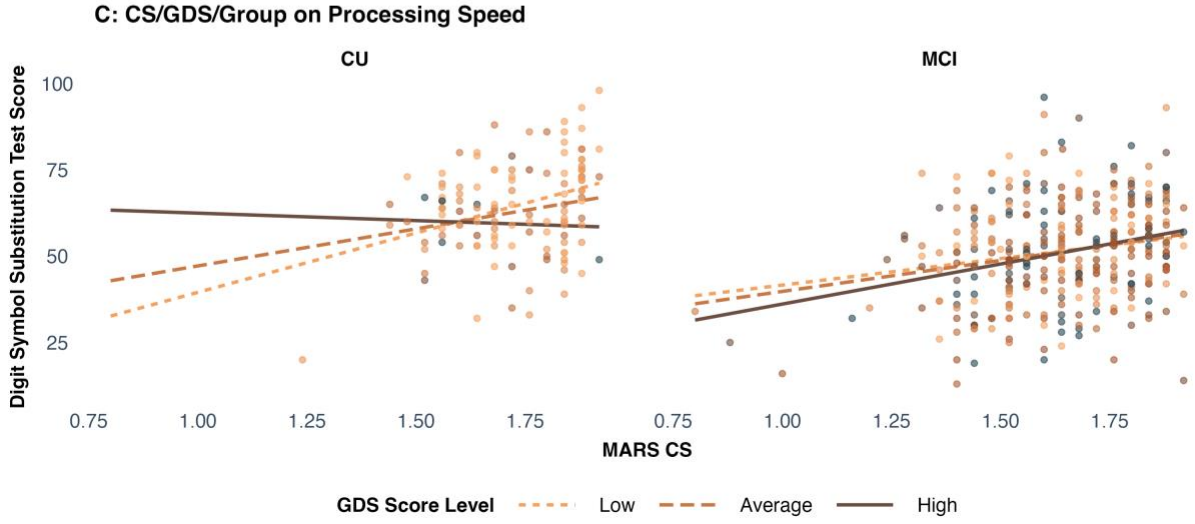

C: CS/GDS/Group on Processing Speed
CU
MCI
Digit Symbol Substitution Test Score
100
75
50
25
0.75
1.00
1.25
1.50
1.75
MARS CS
GDS Score Level
Low
Average
High

Figure 3. Moderation effects of psychosocial factors on cognitive performance in cognitively unimpaired (CU) and mild cognitive impairment (MCI) groups. **A.** Moderation of the relationship between CDTT SRT and letter fluency scores by social isolation across CU and MCI groups. Levels of social isolation represent the 16^{th} (low), 50^{th} (average), and 84^{th} (high) percentiles. **B.** Moderation of the relationship between CS and processing speed scores by social isolation across CU and MCI groups. Levels of social isolation represent the 16^{th} (low), 50^{th} (average), and 84^{th} (high) percentiles. **C.** Moderation of the relationship between CS and processing speed scores by depression (GDS) scores across CU and MCI groups. Levels of depressive symptoms represent the 16^{th} (low), 50^{th} (average), and 84^{th} (high) percentiles.

Moderation Analyses Comparing MCI and AD Groups

Hearing-Psychosocial-Cognitive Interactions. There was a significant three-way interaction between CDTT SRT, MOS Social Support Survey scores, and diagnostic group on processing speed performance ($F(1,487) = 6.15$, $p < .05$; see Supplementary Table 5 and Figure 4A). In the MCI group, better CDTT SRT was associated with faster processing speed performance at average and high levels of social support. In the AD group, better CDTT SRT was associated with faster processing speed performance at high social support levels; and in the opposite direction, better CDTT SRT was associated with slower processing speed performance at low levels of social support.

Vision-Psychosocial-Cognitive Interactions. There was a significant three-way interaction between CS, anxiety symptoms, and diagnostic group on verbal fluency performance ($F(1,487) = 3.99$, $p < .05$; see Supplementary Table 6 and Figure 4B). CS scores were not associated with verbal fluency performance at any level of anxiety symptoms in the MCI group. However, in the AD group, better CS was associated with better verbal fluency performance at low levels of anxiety symptoms.

There was a significant three-way interaction between CS, depressive symptoms, and diagnostic group on processing speed performance ($F(1,487) = 5.06$, $p < .05$; see Supplementary Table 7 and Figure 4C). Better CS was strongly associated with better processing speed performance at average and high levels of depressive symptoms in the MCI group, and better CS was associated with better processing speed performance at high levels of depressive symptoms in the AD group.

There was a significant three-way interaction between CS, social isolation, and diagnostic group on executive function performance ($F(1,487) = 4.35$, $p < .05$; see Supplementary Table 8

and Figure 4D). In the MCI group, better CS scores were associated with better executive function scores at high levels of social isolation. In contrast, better CS was associated with worse executive function scores at high levels of social isolation for AD participants.

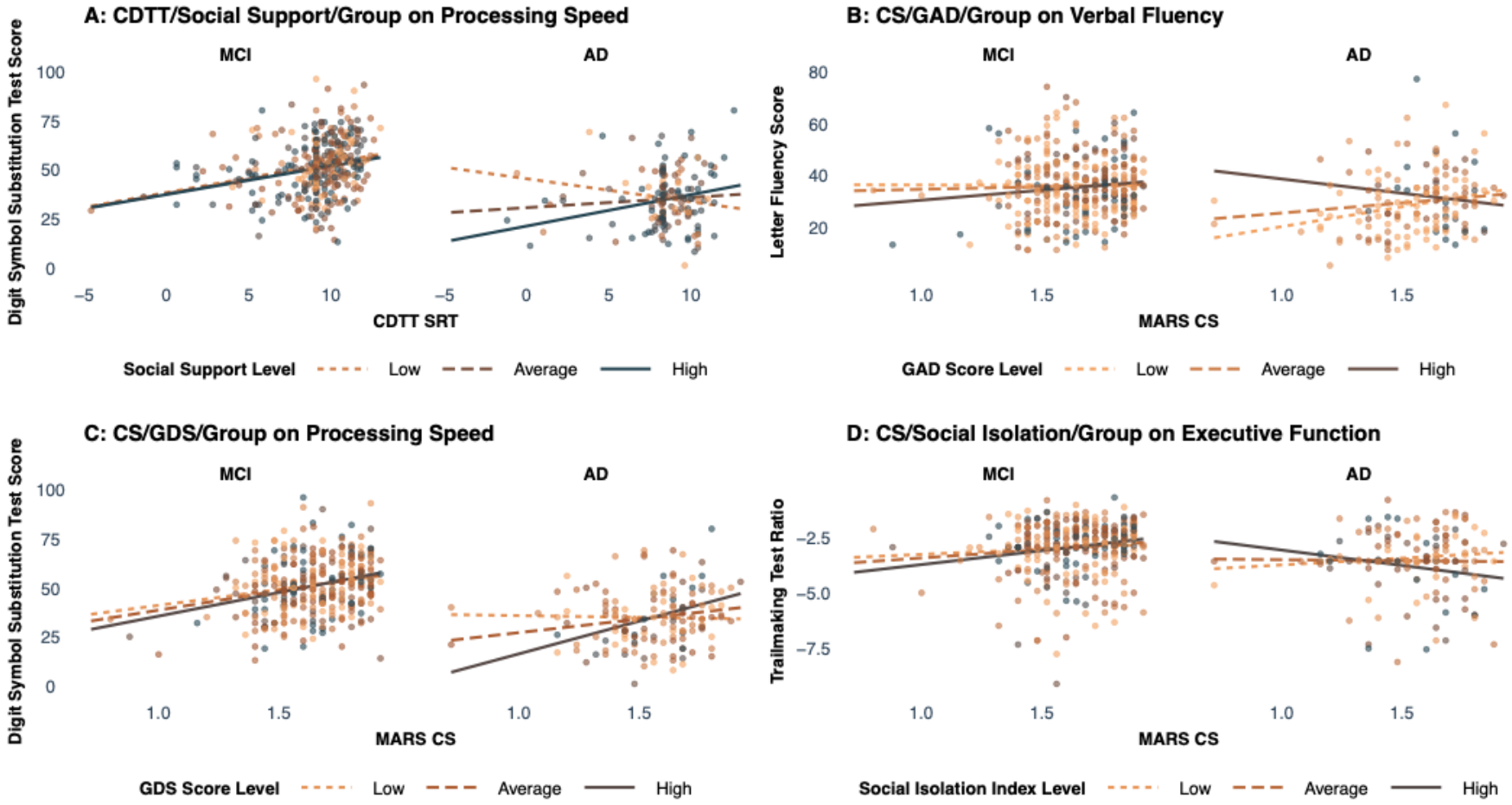


Figure 4. Moderation effects of psychosocial factors on cognitive performance in mild cognitive impairment (MCI) and Alzheimer's disease (AD) groups. **A.** Moderation of the relationship between CDTT and processing speed scores by social support across MCI and AD groups. Levels of social support represent the 16th (low), 50th (average), and 84th (high) percentiles. **B.** Moderation of the relationship between CS and verbal fluency scores by anxiety (GAD) scores across MCI and AD groups. Levels of anxiety symptoms represent the 16th (low), 50th (average), and 84th (high) percentiles. **C.** Moderation of the relationship between CS and processing speed scores by depression (GDS) scores across MCI and AD groups. Levels of depressive symptoms represent the 16th (low), 50th (average), and 84th (high) percentiles. **D.** Moderation of the relationship between CS

and executive function scores by social isolation across MCI and AD groups. Levels of social isolation represent the 16th (low), 50th (average), and 84th (high) percentiles.

Discussion

The aims of this study were to 1) characterize sensory and psychosocial function in CU, MCI, and AD groups, 2) examine links between sensory, psychosocial, and cognitive measures across groups, and 3) assess if psychosocial measures moderated the relationship between sensory and cognitive performance. We found that sensory and psychosocial function were poorer in groups with cognitive impairment (MCI, AD) compared to controls. Across the full sample, better sensory performance was associated with higher QOL and with better cognitive performance in multiple domains. Finally, moderation analyses indicated that psychosocial risk factors (e.g., social isolation, depressive symptoms) commonly modified relationships between sensory and cognitive performance (processing speed, executive function, and verbal fluency), with interaction patterns differing by group. Specifically, poor psychosocial function strengthened the link between sensory and cognitive performance in groups with cognitive impairment.

Characterizing Sensory and Psychosocial Function

Regarding sensory functioning, the CU group had better CDTT SRTs and CS compared to individuals with MCI and AD, indicating overall better sensory performance in those without cognitive impairment. The MCI group showed better CDTT SRTs and CS scores compared to the AD group, suggesting a gradient of sensory decline that parallels cognitive decline. These findings support previous work documenting that individuals with cognitive impairment have worse speech-in-noise hearing and CS relative to cognitively healthy controls (Hutton et al., 1993; Tarawneh et al., 2022).

Regarding psychosocial functioning, the CU group endorsed fewer symptoms of depression and anxiety, better QOL, and less social isolation than the MCI and AD groups. Although psychosocial function was generally within the normal range (i.e., not clinically

elevated) in all groups, CU participants nevertheless showed comparatively better functioning than those with cognitive impairment. These findings are broadly consistent with literature reporting that individuals with cognitive impairment frequently experience depression and anxiety (Ismail et al., 2017; Leung et al., 2021), and have reduced social engagement compared to counterparts (Kotwal et al., 2016).

Relationships between Sensory, Psychosocial, and Cognitive Function

Within each diagnostic group, partial bivariate correlations among sensory, psychosocial, and cognitive variables were generally weak after accounting for age, sex, and education. Regression analyses across the full sample demonstrated robust relationships between sensory measures and cognitive performance in multiple domains: CDTT SRTs and CS scores were each associated with performance on memory, processing speed, and verbal fluency measures, while CS scores were additionally associated with executive function performance. Contrary to our expectation that sensory and psychosocial factors would be closely associated, CDTT and CS scores were associated with QOL only. This suggests that QOL (which reflects broader aspects of functioning like physical health, energy, family, and finances) may capture the functional impact of sensory difficulties better than symptom-focused psychosocial measures. Associations with other psychosocial measures were generally weak or absent, providing limited support for conducting mediation analyses in this dataset.

Moderating Effects of Psychosocial Function Differ by Diagnostic Group

Our hypothesis that poor psychosocial function moderates the sensory-cognitive relationship in groups with cognitive impairment was partially supported.

Moderation Comparing CU and MCI Groups

In moderation analyses comparing CU and MCI groups, associations between sensory function and cognitive performance were strongest at lower levels of psychosocial function in the MCI group. The inverse was true in the CU group in which sensory-cognitive associations were strongest at higher levels of psychosocial function. In the MCI group, better speech-in-noise (CDTT) performance was most significantly associated with better verbal fluency at high levels of social isolation, and better CS scores were associated with faster processing speed at all levels of social isolation (significant) and high levels of depressive symptoms (trend). The pattern is be reversed in the CU group, with associations observed between better CS and better processing speed at low levels of social isolation (significant) and depressive symptoms (trend).

These findings indicate that psychosocial function moderates sensory-cognitive relationships differently in CU and MCI participants. One possible explanation is that CU participants may have greater cognitive resources to compensate for sensory difficulties, which could attenuate the association between sensory function and cognition even when psychosocial burden increases. By contrast, fewer compensatory resources in those with MCI may increase their vulnerability to psychosocial challenges, strengthening sensory–cognitive associations under conditions of greater isolation or depressive symptoms. However, CU participants had largely preserved sensory and psychosocial functioning with no objective cognitive impairment, which may have limited power to detect effects at higher ranges of social isolation or depressive symptoms.

Moderation Comparing MCI and AD

There was partial overlap in moderating effects across MCI and AD, such that relationships between CS and cognitive performance (processing speed, executive function) were strongest at

higher depressive symptoms and social isolation. This overlap may reflect comparable levels of depressive symptoms and social isolation across both groups. Additionally, CDTT performance was associated with faster processing speed at high levels of social support in both groups; however, inspection of group distributions (see Figure 2) shows that social support ratings are clustered near ceiling for MCI and AD participants, suggesting that this effect may be attributed to limited variability. At the same time, moderation effects in the AD group were heterogeneous, including associations that were stronger at *better* levels of psychosocial function (e.g., CS and verbal fluency at low anxiety levels) and unexpected negative sensory-cognitive correlations (e.g., better CS corresponding to poorer executive function, or better CDTT associated with slower processing speed under low social support). These AD-specific findings may reflect heterogeneity in disease severity and symptom profiles, or unmeasured clinical factors associated with advancing impairment (e.g., apathy, fatigue, reduced comprehension), which could contribute to inconsistent or inverse associations. Additionally, individuals with AD typically receive frequent and consistent support from caregivers (e.g., healthcare professionals, support groups, family members), potentially buffering the functional consequences of sensory loss and psychosocial challenges on cognitive performance, thereby altering how sensory loss relates to cognition across various psychosocial contexts (e.g., anxiety compared to social support). Therefore, while psychosocial factors (e.g., social isolation, depressive symptoms, social support) may moderate sensory-cognitive relationships similarly in MCI and AD, moderation effects in AD appear to be more complex and, in some contexts, may differ in direction.

Relationships between Sensory Measures and Cognitive Performance in Moderation Analyses

Moderation effects were not observed for episodic memory across groups, possibly due to ceiling effects for memory performance in the CU group or the strong influence of disease-related neuropathology on memory in MCI and AD, which may limit the extent to which psychosocial factors shape sensory-memory associations. In comparison, cognitive domains requiring efficient integration of sensory input and executive control (e.g., processing speed, executive function, letter fluency) may be more sensitive to psychosocial influences. Sensory-cognitive associations were consistently observed between CS scores and visual-based outcomes (e.g., processing speed and executive function) and between CDTT and verbal fluency.

Common relationships between CS scores and cognitive performance on visual-based processing speed and executive function tasks may reflect shared underlying pathways. Both the DSST and the TMT tasks require integration of multiple cognitive abilities, such as rapid visual scanning, visuo-motor coordination, attention, and processing speed. Since CS is sensitive to subtle changes in the visual system (Cormack et al., 1999), poor CS may indicate changes in low-level visual processes that compromise higher-order cognitive operations required for efficient visual processing and scanning. This interpretation aligns with prior research showing that poor CS is associated with poor performance on visually-based cognitive tasks, including immediate and delayed visual memory (reproduction of a line drawing) and timed visual scanning (Skeel et al., 2006).

The relationship between CDTT SRTs and verbal fluency may occur because hearing difficulties increase the effortfulness of auditory processing and speech perception, depleting cognitive resources available for lexical retrieval (e.g., slowed phonological processing,

degradation of stored representations and networks, less efficient switching strategies; Loughrey et al., 2020). Additionally, phonemic fluency places substantial demands on working memory to retrieve appropriate words while suppressing task-irrelevant associations, and working memory difficulties have also been implicated with age-related hearing loss (McCoy et al., 2005). In support, previous work in cognitively healthy older adults demonstrates that age-related hearing loss is associated with reduced performance on verbal fluency tasks (Classon et al., 2014; Loughrey et al., 2020).

Psychosocial Risk Factors Moderated Sensory-Cognitive Interactions

We found limited evidence that protective psychosocial factors moderated the relationship between sensory and cognitive function. Only one interaction involving social support was observed (which should be interpreted cautiously given ceiling social support ratings in MCI and AD), and no moderation effects were observed for QOL. Instead, we observed that interactions commonly featured psychosocial risk factors (e.g., depressive symptoms, social isolation) as moderators. This pattern aligns with literature linking sensory loss with depression and social isolation (Lawrence et al., 2020; Xiang et al., 2020). For instance, individuals with hearing loss may avoid noisy social settings due to communication difficulties, resulting in social isolation and subsequent feelings of depression (Heffernan et al., 2022; Mick et al., 2014). Similarly, visual decline is associated with activity restrictions and mobility limitations that may reduce opportunities for social participation (Shah et al., 2020). These pathways may explain why negative psychosocial factors (social isolation, depressive symptoms) emerged as frequent moderators in our analyses.

Comparison to Previous Moderation Research

Compared to our study, prior work examining the moderating effect of psychosocial function on sensory-cognitive associations focused mostly on cognitively healthy older adults and varied in the sensory modalities, psychosocial factors, and cognitive outcomes assessed. A previous cross-sectional study demonstrated that only the complexity of social networks and being retired weakly moderated the link between better hearing and better executive function and memory (Hämäläinen et al., 2019). Notably, one study assessing social engagement *and* cognitive impairment (measured by the 5-item MDS Cognitive Performance Scale) in nursing home residents showed that those with no or low social engagement had greater odds of moderate and severe cognitive impairment, and those with additional self-reported sensory impairments (moderator) were more susceptible to the negative impacts of lower levels of social engagement on cognitive scores (Xu et al., 2024). Specifically, residents with low social engagement *and* moderate to severe hearing impairment had a higher risk of severe cognitive impairment compared to residents with high social engagement and no hearing impairment (adjusted OR = 11.3). The study also found a moderating effect of social engagement and visual impairment on severe cognitive impairment (adjusted OR = 33.9). Regardless of methodology, these studies consistently highlight the joint association between sensory and psychosocial measures with cognitive measures. Our study addresses an important gap by extending these analyses to diagnostic groups with cognitive impairment, demonstrating that sensory and psychosocial function influence cognitive performance differently across the spectrum of cognitive impairment.

Interpreting Moderation Effects in the Context of Sensory-Cognitive Mechanisms

In analyses comparing the CU and MCI groups, social isolation moderated the relationship between speech-in-noise performance and verbal fluency, with the hearing-fluency relationship

strongest at higher levels of social isolation in MCI participants. One possible explanation is that hearing loss results in degraded auditory input, while social isolation may limit opportunities to practice linguistic processes critical for verbal fluency (e.g., word retrieval, phonological storage, and working memory). In this context, preserved hearing may serve a compensatory role by supporting more efficient access to phonological representations and reducing the cognitive demands associated with searching and retrieval. These findings align with the cognitive load and information degradation hypotheses, whereby degraded auditory input *and* social isolation may jointly tax cognitive resources that support verbal fluency, aligning with previous research on the combined effects of hearing and psychosocial factors on cognitive outcomes (Powell et al., 2022; Xu et al., 2024).

Social isolation and depressive symptoms moderated relationships between CS and cognitive performance (i.e., executive function and processing speed) in analyses comparing MCI and AD. The overall moderation pattern was similar across groups, such that associations between CS and cognitive outcomes were strongest at low levels of psychosocial function (i.e., higher social isolation and depressive symptoms); however, CS-cognition associations were uniformly positive in the MCI group. One possibility is that depressive symptoms and social isolation reduce environmental engagement and deplete cognitive resources, thereby increasing reliance on optimal visual function. As CS is associated with the ability to carry out activities of daily living (e.g., mobility; Cormack et al., 1999), CS deficits may then disproportionately affect socially isolated individuals by further restricting their ability to engage in social activities and interactions outside of the home, reducing cognitive stimulation and weakening executive skills. Depression may also moderate vision-cognition relationships by disrupting attentional control and slowing information and psychomotor processing (Hammar et al., 2022), which are core components of processing

speed tasks. Combined with poor CS, depressive symptoms may further limit the cognitive resources available for compensation, producing slowed or inefficient processing.

Across both sensory modalities, these findings suggest that poorer psychosocial function may increase individuals' reliance on preserved sensory function to maintain cognitive performance.

Limitations and Future Directions

The cross-sectional design of our study inherently limits our ability to comment on cause-effect relationships and disentangle the temporal sequence between sensory, psychosocial, and cognitive function. Second, limitations in the PROCESS macro prevented simultaneous comparison of all three diagnostic groups, requiring multiple pairwise models and reducing power. Replication in larger samples is needed to clarify whether these trends represent true effects or sample-specific variability. Future studies with larger samples will also be necessary to examine sex-related differences in sensory, psychosocial, and cognitive associations (e.g., Mick et al., 2014; Zheng et al., 2025). Additionally, although the MCI and AD groups demonstrated lower psychosocial function than cognitively healthy controls, symptom levels were not clinically elevated, which likely reduced variability in our estimates. Finally, social measures included take-home self-report questionnaires that were completed by participants or their caretakers (in the case of individuals with AD), which could contribute to the heterogeneity in findings observed in the AD group.

Our study examined the inter-relationships among sensory, psychosocial, and cognitive function in cognitively healthy older adults and individuals with (or at risk for) AD. Our findings show that psychosocial function and diagnostic group membership moderated the relationship between sensory function and cognitive performance. When compared to CU and AD groups, poor

psychosocial function amplified the sensory-cognitive relationship in participants with MCI, a pattern that was also partially observed in the AD group. This suggests that groups with cognitive impairment may be more vulnerable to the compounded effects of emerging sensory (e.g., hearing, vision, and dual sensory impairments) and psychosocial (e.g., reduced social engagement) changes on cognition. In particular, individuals with MCI may benefit most substantially from non-pharmacological strategies targeting sensory and psychosocial function (e.g., hearing and vision screening, social engagement, psychotherapy) to mitigate the joint effects of sensory and psychosocial difficulties on cognitive function. Future longitudinal research is needed to clarify the mechanisms underlying sensory-psychosocial-cognitive associations, as understanding and targeting potentially modifiable risk factors for dementia represents a promising approach toward preserving cognitive health.

Chapter 5: General Discussion

Decades of research have established associations between sensory, psychosocial, and cognitive function, with longitudinal evidence showing that deficits in sensory and psychosocial function are independently linked to an increased risk of cognitive decline and dementia. However, the interaction of the tri-directional relationship among these domains remains understudied, particularly in clinical populations with or at risk for dementia (e.g., MCI, AD). To address these gaps, the overarching goal of this dissertation was to advance our understanding of sensory, psychosocial, and cognitive function in older adults with (or at risk) AD and potential interactions between these factors across two studies. Specifically, the objective of Study 1 was to explore associations between psychosocial function and cognitive performance among individuals with MCI. Building upon these findings, Study 2 aimed to 1) characterize and examine differences in sensory and psychosocial functioning among cognitively healthy controls and individuals with cognitive impairment, and 2) to determine whether psychosocial function mediates or moderates sensory-cognitive relationships, and whether this relationship additionally differs by diagnostic group.

The following sections provide a synthesis of the results obtained from both studies, accompanied by key themes and implications arising from these findings in relation to potential sensory-cognitive mechanisms. The discussion concludes with a review of limitations and avenues for future research.

Summary of Study Findings

Both studies used cross-sectional data from the COMPASS-ND dataset of the Canadian Consortium of Neurodegeneration in Aging. In Study 1, we examined the relationship between various psychosocial factors and cognitive performance across multiple domains in individuals

with MCI, using multiple linear regression analysis. Compared to other measures of psychosocial function (e.g., scores on questionnaires assessing anxiety and depression symptoms, social support, quality of life, loneliness, and frequency of time spent on the telephone and with others), we found that perceived level of current participation in one's social networks (over and above other psychosocial measures) was associated with cognitive performance. More specifically, low current participation was associated with worse verbal fluency and slower processing speed than those endorsing normal or high social participation. We concluded that in individuals with MCI who are at risk for further cognitive decline, social participation may offer cognitively stimulating opportunities (e.g., opportunities to communicate and engage with others) that exercise and maintain cognitive abilities such as processing speed and verbal fluency. These findings helped motivate our investigation into the tri-directional sensory-psychosocial-cognitive relationship in Study 2.

In Study 2, we delineated the sensory and psychosocial profile of cognitively healthy controls and diagnostic groups with cognitive impairment (MCI, AD). Additionally, we investigated bivariate relationships between sensory-cognitive, sensory-psychosocial, and psychosocial-cognitive variables. Although mediation effects could not be tested as sensory-psychosocial correlations were weak, we conducted moderated moderation (three-way interaction) analyses to examine whether psychosocial factors and diagnostic group jointly influenced the relationship between sensory function and cognitive performance. We found that compared to cognitively unimpaired controls, participants with MCI and AD demonstrated worse sensory and psychosocial function. Moderation analyses indicated that psychosocial risk factors (e.g., social isolation, depressive symptoms) commonly modified relationships between sensory and cognitive performance (processing speed, executive function, and verbal fluency), with

interaction patterns differing by diagnostic group. Compared to controls, low levels of psychosocial function strengthened the relationship between sensory and cognitive performance in individuals with MCI and AD, suggesting that individuals with cognitive impairment *and* low levels of psychosocial functioning may be particularly vulnerable to sensory effects on cognition.

Key Themes and Implications

The Profile of Sensory and Psychosocial Function in Groups with Cognitive Impairment

Differences between Groups in Sensory and Psychosocial Function. Previous literature has mostly focused on delineating the relationship between sensory or psychosocial function and cognitive performance in cognitively healthy older adults, with limited research exploring the same associations in groups with cognitive impairment. As such, an important goal for this dissertation was to characterize sensory and psychosocial function in groups with cognitive impairment.

In Study 2, we observed that there were significant group differences in speech-in-noise thresholds and contrast sensitivity. We also observed group differences in pure-tone hearing, though this variable was not included in Manuscript II based on methodological considerations. Speech-in-noise hearing was selected over pure-tone thresholds as it provided a continuous measure of auditory function (facilitating interpretation of moderation effects) and may be more ecologically valid in capturing real-world listening abilities and their impact on psychosocial and cognitive outcomes. Generally, cognitively unimpaired controls had better pure-tone hearing and speech-in-noise thresholds compared to the MCI and AD group, whereas the MCI group demonstrated better speech-in-noise thresholds compared to the AD group. A similar pattern was observed with visual function (as measured by contrast sensitivity), such that controls demonstrated better contrast sensitivity scores compared to the MCI and AD groups, and

individuals with MCI performed better on contrast sensitivity compared to the AD group. These results appear to show a gradient of sensory decline across diagnostic groups with increasing cognitive impairment, consistent with prior studies reporting poor peripheral hearing and central auditory processing (Lau et al., 2022; Littlejohn et al., 2023) and visual acuity, contrast sensitivity, and other measures of visual function (Cronin-Golomb et al., 1995; Rehan et al., 2021; Rizzo, 1998; Uhlmann et al., 1991) in groups with cognitive impairment. Broadly, our findings support previous work demonstrating that hearing and visual deficits are a feature of AD and AD-related changes, even in early prodromal stages (i.e., MCI).

There were significant group differences on many psychosocial measures, including symptoms of depression (GDS) and anxiety (GAD), quality of life, social support, and social isolation. Generally, we observed that the CU group endorsed better psychosocial function (e.g., fewer depressive and anxiety symptoms, less social isolation, and better quality of life and perceived social support) compared to the MCI and AD groups, meanwhile individuals with MCI and AD reported largely comparable levels of psychosocial functioning, though individuals with MCI were significantly less isolated compared to those with AD. While this was excluded in Manuscript II, we also found that the MCI group endorsed more loneliness and desire for social participation compared to controls. Perhaps, individuals with MCI may report greater loneliness than other groups due to preserved insight into their emerging psychosocial and cognitive changes. Overall, these results align with previous literature reporting that individuals with cognitive impairment (i.e., MCI and AD) frequently experience depression and anxiety (Chen et al., 2018; Chi et al., 2015; Ismail et al., 2017; Leung et al., 2021), have reduced social engagement and smaller network sizes compared to cognitively healthy counterparts (Kotwal et al., 2016), and report higher levels of perceived loneliness (Yu et al., 2016). However, it is important to note that

although the MCI and AD groups endorsed a greater amount of depressive and anxiety symptoms compared to controls, their levels of psychological symptoms were not clinically elevated in comparison to previous literature citing significant neuropsychiatric symptoms in clinical populations with cognitive impairment. While causal inferences cannot be inferred from the current study, psychosocial changes observed in those with cognitive impairment may arise from multiple, non-mutually exclusive pathways. These include shared neurobiological factors (e.g., overlapping neurogenerative and vascular pathology (Kim et al., 2016), as well as psychosocial responses (e.g., feelings of depression and anxiety) to an individual's appraisal of their diagnosis and prognosis (e.g., illness burden, worry about perceived decline). Psychosocial changes may also reflect downstream behavioural shifts in one's environment and interpersonal interactions, such as reduced enjoyment of social interactions and decreased engagement following diagnosis (Hackett et al., 2019; Rutherford et al., 2018; Steeman et al., 2006).

Taken together, this dissertation presents that those with MCI and AD have worse sensory and psychosocial functioning compared to their cognitively healthy counterparts. This pattern was evident across multiple sensory modalities (i.e., hearing and vision), as well as several psychosocial factors (e.g., anxiety, depression, social isolation). These results are broadly consistent with previous findings, demonstrating that sensory and psychosocial challenges are common in groups with cognitive impairment and point to the importance of considering how sensory and psychosocial factors relate to cognitive function in clinical populations. In the sections that follow, we build on this framework to explore how sensory and psychosocial factors interact with cognitive performance across diagnostic groups.

Assessing Sex Differences in Sensory and Psychosocial Function. We assessed sex differences in sensory and psychosocial functioning within groups in Study 2, though these analyses were not included in Manuscript II for the sake of brevity.

In the CU and AD groups, there were no differences between male and female participants on speech-in-noise thresholds (CDTT SRTs) or vision (contrast sensitivity) scores. In the MCI group, females had significantly better CDTT SRTs compared to males. In regard to psychosocial functioning, sex differences were observed in both the CU and MCI groups. In the CU group, male and female participants differed on GDS scores and QOL ratings in the CU group, such that females endorsed significantly more depressive symptoms and rated lower QOL compared to males. In the MCI group, there were significant differences between male and female participants on GAD scores, GDS scores, social support, and social isolation. Females endorsed higher GAD and GDS scores, reported less social support, and were more socially isolated compared to males. In contrast, there were no significant differences between males and females on any psychosocial variables in the AD group. This pattern suggests that females who are cognitively healthy or at earlier stages of cognitive impairment (i.e., MCI) may experience a greater psychosocial burden, whereas greater clinical severity and functional decline in AD may reduce variability in psychosocial outcomes between males and females. Furthermore, these sex differences may reflect that women are more likely to report affective distress or feelings of loneliness, have a greater physiological sensitivity to stressors and cortisol, or be reliant on alternative emotional connections compared to men (who may receive more support from their spouses; Kanbay at al., 2023; Hsiao et al., 2023).

Associations between Sensory and Psychosocial Measures with Verbal Fluency and Processing Speed Performance

Both studies measured cognitive performance on a variety of tests spanning multiple domains (e.g., executive function, memory, processing speed, working memory). We commonly observed relationships commonly between (1) psychosocial function and cognitive performance on verbal fluency and processing speed, and (2) sensory function and cognitive performance on these same measures, with psychosocial function moderating the latter relationship. In Study 1, high social participation (as compared to low or normal participation) was associated with better verbal fluency and faster processing speed in individuals with MCI. In Study 2, sensory-psychosocial-cognitive interactions were commonly observed between CS and processing speed and between CDTT scores and verbal fluency across cognitively unimpaired controls and individuals with MCI and AD. Together, our research suggests that verbal fluency and processing speed, compared to other cognitive domains, may be particularly affected by sensory and psychosocial function in our participants.

Associations between Social Participation and Cognitive Performance on Verbal Fluency and Processing Speed (Study 1)

The significant relationship in Study 1 between social participation and verbal fluency may reflect the cognitively stimulating nature of social interactions, which often involve cognitive processes like accessing one's lexical and semantic networks, searching, and retrieving words from vocabulary; Shao et al., 2014). Our findings align with previous research, which demonstrates that cognitively healthy older adults with objectively high social engagement and participation perform better on verbal fluency measures compared to those with low levels of social participation (Bourassa et al., 2017; Brown et al., 2012; Krueger et al., 2009); though the

possibility that participants with better verbal abilities across the lifespan (e.g., vocabulary, verbal fluency) may be able to better maintain relationships and interactions cannot be ruled out. Furthermore, we found a trend between low social participation and slow processing speed. Given that processing speed represents a fundamental, lower-level cognitive process that influences performance in other cognitive abilities (Lindenberger et al., 1993), processing speed may play a foundational role in a range of cognitive abilities involved in social participation, including monitoring and responding to environmental cues, integrating information, and engaging other "executive" processes like planning, attention and working memory. Previous findings with cognitively healthy older adults also demonstrate a link between leisure activity engagement and processing speed (Ghisletta et al., 2006), whereas others reported that baseline levels of social participation (measured by frequency and type of participation in activities) predicted changes in processing speed over time (Lövdén et al., 2005), and importantly, there was limited evidence for associations in the reverse direction (i.e., cognitive performance influencing social engagement).

Prior studies examining social function and cognitive performance have focused on cognitively healthy older adults and examined a different combination of social and cognitive variables. In one of the few cross-sectional studies incorporating multiple social factors and cognitive outcomes, Stoykova and colleagues (2011) assessed the relationship between a composite index of social functioning (social network size, satisfaction with relationships, perception of being understood, and participation in social activities) and cognitive performance on individual tests measuring global cognitive function (MMSE), semantic verbal fluency, abstract thinking, episodic memory and learning, processing speed (measured using the Digit Symbol Substitution Test), and visual memory. They found that the social composite index was

associated with semantic fluency and episodic memory, but not processing speed or other domains. The difference between their findings and ours may reflect differences in study populations and heterogeneity in study design and methodology (e.g., selection and operationalization of social and cognitive measures). For example, we measured cognitive domain scores from multiple tests using principal component analysis and examined social variables individually, whereas Stoykova et al. (2011) used a composite social index. Beyond cross-sectional studies, longitudinal research demonstrates that complex social networks and frequent social engagement are associated with slower memory decline (Barnes et al., 2004; Ertel et al., 2008) and better verbal fluency (Brown et al., 2012) over time in cognitively healthy older adults, and meta-analytic evidence highlights longitudinal associations between social network size and complexity and episodic memory, working memory, and processing speed (Yoo, 2022). These results may suggest that social participation and other measures of function may impact cognitive domains beyond verbal fluency and processing speed over time.

Overall, our findings suggest that frequent conversations and interactions with others, although not directly measured, may facilitate verbal fluency skills and processing speed in individuals with MCI. Our results add to previous literature by demonstrating an association between social participation and performance on verbal fluency and processing speed; however, in older adults with MCI, *perceived* social participation (rather than social support, living arrangement, or frequency of contact with social networks) was most closely related to verbal fluency and processing speed abilities. Although processing speed likely contributed to performance in our verbal fluency domain, processing speed measures the efficiency to which individuals perceive, process, and respond to information (e.g., perceptual encoding and motor output on the Digit Symbol Substitution Test), whereas the verbal fluency tasks likely place

additional demands on lexical access, retrieval and searching, and even "executive" processes like self-monitoring. To support this, the verbal fluency and processing speed tasks in Study 1 loaded onto separate components in our principal component analyses, indicating that they are related but distinct domains and are independently associated with social participation.

Our results suggest that processing speed and verbal fluency abilities are engaged continuously during everyday social participation (e.g., processing spoken language, searching through language networks, sequencing words and sentences, monitoring verbal cues and speech). Accordingly, verbal fluency and processing speed may show stronger associations with social participation in cross-sectional analyses that capture frequent, day-to-day interactions. In comparison, memory and executive function abilities may reflect the cumulative cognitive demands of reduced social participation and psychological well-being across time (e.g., Barnes et al., 2004; Ertel et al., 2008; Yoo, 2022), which may not be detected in cross-sectional research. Further, the absence of a cross-sectional association between social participation and memory may indicate that social participation regularly engages cognitive processes that are less dependent on medial temporal lobe integrity (a core feature of episodic memory impairment), while memory performance may be more strongly driven by underlying neurodegenerative pathology in our MCI participants. Nevertheless, longitudinal research will be necessary to determine whether changes in social participation predict memory decline within the COMPASS-ND cohort.

Associations between Sensory Function and Cognitive Performance on Verbal Fluency and Processing Speed (Study 2)

We observed a consistent association between speech-in-noise thresholds and phonemic verbal fluency in Study 2. Processing speech in the presence of competing auditory input requires

an individual to process auditory information while selectively attending to target speech, and other cognitive processes are also implicated. Others have proposed that increased listening effort and degraded auditory input may reduce resources required for quick processing, searching, and retrieval of lexical information (Loughrey et al., 2020), weaken phonological networks (Andersson, 2002; Classon et al., 2014), or impact other cognitive abilities (e.g., executive control and working memory) that facilitate word search and retrieval (McCoy et al., 2005; Shao et al., 2014). Previous research with cognitively healthy older adults has demonstrated that poor speech-in-noise hearing is associated with poor performance on verbal fluency (Classon et al., 2014; Mamo et al., 2019). Studies have also found relationships between speech-in-noise thresholds and measures of global function, memory, working memory, and executive function (Dryden et al., 2017; Mamo et al., 2019), and other measures of central auditory function (e.g., Dichotic Sentence Identification, Dichotic Digits) also have been linked with executive function (Gates et al., 2010). Interestingly, Mamo et al. (2019) controlled for peripheral audiometric hearing thresholds in their study and found that many significant relationships between speech-in-noise and cognitive performance were attenuated once participants with moderate or greater pure-tone hearing loss were excluded. This raises the possibility that our limited associations between speech-in-noise hearing and other cognitive domains (i.e., memory) may be attributable to the confounding influence of peripheral hearing loss, which was not adjusted for in our analyses. Nonetheless, our results support previous findings linking speech-in-noise hearing to verbal fluency and further extend these associations to clinical populations with MCI and AD.

We also observed a consistent relationship between contrast sensitivity and performance on the Digit Symbol Substitution Test, a measure of processing speed that requires integration of multiple cognitive abilities, such as rapid visual scanning and discrimination, visuo-motor

coordination, attention, motor speed, and even associative learning. Since contrast sensitivity is a sensitive indicator of subtle visual changes in cognitive aging and is strongly linked to cognitive performance (Cormack et al., 1999), poor contrast sensitivity may reflect decline in foundational visual processes that also affect higher-level cognitive operations like rapid visual processing and scanning. These results align with previous cross-sectional and longitudinal evidence in cognitively healthy older adults demonstrating the relationship between contrast sensitivity and performance on cognitive tests involving visuoperceptual, visuospatial, and visuo-motor integration skills (e.g., visual memory, rapid visual scanning, coding; copying; Skeel et al., 2006; Varadaraj et al., 2021; Swenor et al., 2019). Interestingly, while Swenor and colleagues (2019) found a relationship between contrast sensitivity and digit-symbol test scores (i.e., processing speed) cross-sectionally, they did not find that contrast sensitivity was associated with annual Digit Symbol Test scores over seven years of follow-up assessments, which may reflect that changes in other cognitive domains may be more vulnerable to visual decline over time. In support, Varadaraj and colleagues (2021) found that contrast sensitivity was associated longitudinally with performance in other cognitive domains, like global cognitive function, attention, and even auditory-based tasks of language (naming, phonemic and semantic fluency) and episodic memory (delayed recall on the California Verbal Learning Test). Furthermore, their results remained unchanged following sensitivity analyses to exclude all vision-dependent tasks from each cognitive domain. In the present work, most participants across diagnostic groups did not have severe visual impairments, reducing variance and perhaps weakening the link between contrast sensitivity and other cognitive domains beyond processing speed.

The Sensory-Psychosocial-Cognitive Relationship

Another aim of this dissertation was to determine whether psychosocial function mediates or moderates the relationship between sensory and cognitive function, and whether these relationships differ among cognitively healthy controls and individuals with MCI and AD. As part of Study 2 and other supplementary analyses, we found that 1) psychosocial factors did not mediate, but moderated the relationship between sensory function and cognitive performance, and 2) that this relationship differed across diagnostic groups.

Limited Evidence for Psychosocial Factors Mediating Sensory-Cognitive Relationships

While we observed significant relationships between both sensory measures (speech-in-noise thresholds, contrast sensitivity) and cognitive performance in multiple domains, sensory measures were only significantly related to quality of life and not any other psychosocial variables. This relationship may be due to our measure of quality of life capturing broader aspects of functioning like physical health, energy, family, and finances) may capture the functional impact of sensory difficulties better than symptom-focused psychological or social measures. Given the largely absent relationships between sensory and other psychosocial measures were absent, there was limited evidence to support mediation. This interpretation was further informed by supplementary moderated mediation analyses, not reported in the individual manuscript for Manuscript II. These analyses were used to explore whether psychosocial factors mediated associations between sensory and cognitive function and whether diagnostic group membership moderated any indirect effects. Results indicated that quality of life indirectly mediated the link between contrast sensitivity and processing speed (b = .90, SE = .50, B = .01, 95% CI = 16.58 – 30.63); however, this indirect effect did not differ by diagnostic group. No evidence was found for

quality of life mediating other sensory-cognitive relationships, nor any mediation effects involving other psychosocial variables.

Psychosocial Factors Moderate Sensory-Cognitive Relationships Differently in Cognitively Healthy Controls and Groups with Cognitive Impairment

In analyses comparing CU and MCI participants, positive associations between sensory function and cognitive performance were amplified at low levels of psychosocial function in the MCI group, whereas the inverse pattern was observed for controls, such that positive sensory-cognitive associations were observed at normal or high levels of psychosocial function. One possible explanation is that CU participants with normal or high levels of psychosocial function may have greater cognitive resources to compensate for any sensory difficulties, perhaps reducing the association between sensory function and cognition as psychosocial challenges occur. By contrast, individuals with MCI may have fewer cognitive resources to compensate for sensory difficulties (He et al., 2019), making them more susceptible to the additional effects of social isolation or depressive symptoms on cognitive outcomes. At the same time, the largely preserved sensory and psychosocial functioning in the CU group may have constrained the ability to detect moderation effects at higher levels of sensory and psychosocial burden.

Moderation analyses comparing MCI and AD groups revealed both overlapping and group-specific moderation effects of psychosocial variables on sensory–cognitive associations. In the MCI group, better CS was most strongly associated with faster processing speed and better executive function at lower levels of psychosocial function (high depressive symptoms and social isolation, respectively). A different pattern emerged for social support, where better CDTT performance was associated with faster processing speed at average and high levels of social support (reflecting better psychosocial function). In the AD group, better CS was associated with

faster processing speed and worse executive function at lower levels of psychosocial function (high depressive symptoms and social isolation, respectively). In contrast, better CS was linked to better verbal fluency at low levels of anxiety symptoms. Finally, better CDTT performance was associated with faster processing speed at high levels of social support, but with slower processing speed at low levels of social support.

In both MCI and AD groups, relationships between contrast sensitivity and cognitive performance (processing speed, executive function) were strongest at higher depressive symptoms and social isolation. These similar moderation patterns may reflect comparable levels of psychosocial functioning (e.g., depressive symptoms and social isolation) in MCI and AD participants. However, moderation patterns varied in the AD group: some associations were stronger at better levels of psychosocial function or there were negative sensory-cognitive correlations (e.g., better sensory function corresponding to poorer cognitive performance). Heterogeneity in the AD group could be explained by disease severity and symptom severity as cognitive impairment increases (e.g., apathy, fatigue, anosognosia), which could also impact task performance (e.g., low motivation, poor comprehension) and contribute to inconsistent or inverse associations. Additionally, individuals with AD are likely to receive frequent external support from caregivers, perhaps altering how certain psychosocial factors affect sensory-cognitive relationships. For example, individuals with AD may have regular interactions with caregivers or family members who assist with completion of daily activities. This type of consistent support may buffer impacts of anxiety or social isolation, even in the presence of declining sensory and cognitive function. In fact, in our COMPASS-ND sample, the AD group had the smallest proportion of individuals who live alone and the highest proportion of individuals who were married or in a common-law partnership. While the difference in perceived social support between

MCI and AD individuals did not reach statistical significance in our sample ($p < .06$), supplementary analyses indicated that this relationship got stronger if living circumstances (living alone or not) were not controlled for. This suggests that at least in our sample, caregivers or relatives living with AD participants contribute to their relatively higher perceived social support as compared to those with MCI. As such, the amount and quality of external support may attenuate the strength of sensory-psychosocial-cognitive associations observed in the AD group.

Prior work examining sensory-social-cognitive relationships using moderation analyses has reported mixed results in cognitively healthy older adults. In a cross-sectional study with cognitively healthy participants examining both the mediating and moderating effects of psychosocial function between sensory and cognitive function, multiple social variables (e.g., social engagement, frequency of participation in social activities, social networks, retirement status, living circumstances, social support) weakly mediated or moderated associations between pure-tone hearing and visual acuity and cognitive domains of executive function and memory (Hämäläinen et al., 2019). Another cross-sectional study with nursing home residents aged 50 years and older evaluated sensory function (measured subjectively) as the moderator (Xu et al., 2024). In this study, moderate to severe hearing or vision impairment moderated the relationship between low social engagement and global cognitive function, with the impact of low social engagement on cognitive impairment most profound among residents with self-reported hearing impairment and/or visual impairment. Finally, Sun and colleageus (2021) found that social participation attenuated the negative effect of hearing impairment on global cognitive function (MMSE scores) in cognitively healthy older adults. Other psychosocial variables, such as loneliness, have also been shown to moderate the longitudinal association between visual acuity

and decline in cognitive function (measured by the HRS Telephone Interview for Cognitive Status; Ge et al., 2023).

In comparison to these studies, our work used different sensory variables (speech-in-noise hearing, contrast sensitivity), explored a broader set of cognitive domains (e.g., processing speed and verbal fluency in addition to memory and executive function), and tested psychological variables (anxiety, depression) as potential moderators in our analysis. We also tested diagnostic group as a second-level moderator, consistent with our research aims. Although methodological heterogeneity across studies (e.g., selection of sensory, psychosocial, and cognitive measures) prevents direct comparison of effects, our findings support previous evidence on the combined (synergistic) effects of low sensory and psychosocial function (e.g., Ge et al., 2023; Powell et al., 2022; Xu et al., 2024) on cognitive outcomes. Moreover, our results extend existing literature by demonstrating how psychosocial function *and* diagnostic group jointly influence sensory-cognitive relationships.

A Discussion on Mechanisms Underlying Results

Findings from this dissertation were interpreted within existing frameworks of sensory-cognitive and social-cognitive relationships. These results may shed light on mechanisms through which sensory and psychosocial function affect cognitive performance.

Study 1 demonstrated associations between social participation and cognitive performance on verbal fluency and processing speed. Social participation and engagement with one's social network are believed to enhance cognitive reserve and offer cognitively stimulating opportunities (Berkman et al., 2014; Stern, 2012). Through regular social participation and interactions with others, individuals may have more frequent opportunities to engage in cognitive abilities (i.e., verbal fluency and processing speed) that are routinely recruited in everyday

conversations. Such engagement might provide ongoing cognitive stimulation that supports the integrity of cognitive and neural networks, thereby contributing to cognitive reserve and buffering against cognitive decline (Stern, 2012). Therefore, social participation may offer stimulation or have a protective effect against decline in everyday cognitive processes, particularly for individuals with MCI who are at risk for further cognitive decline.

The moderating role of psychosocial risk factors in Study 2 may help clarify the mechanisms linking sensory loss with cognitive performance. Compared to cognitively healthy controls, the relationship between speech-in-noise performance and verbal fluency was strongest at higher levels of social isolation in participants with MCI. To explain this finding, degraded auditory input due to hearing loss, combined with social isolation, may reduce opportunities to engage in cognitive processes that are associated with verbal fluency (such as word retrieval, phonological storage, and working memory; Andersson, 2002; Classon et al., 2014; Loughrey et al., 2020). Therefore, the combined burden of degraded auditory input with social isolation may reduce cognitive resources available for efficient lexical search and retrieval, whereas preserved hearing may facilitate access to phonological networks and retrieval, reducing cognitive load. These findings align with cognitive load and information degradation hypotheses, suggesting that poor hearing and social isolation jointly tax cognitive processes supporting verbal fluency.

Psychosocial risk factors (social isolation, depressive symptoms) moderated the relationship between contrast sensitivity and cognitive performance (processing speed, executive function) similarly in both MCI and AD groups. Specifically, the vision-cognitive relationship was strongest at high levels of social isolation and depressive symptoms in both groups, which can also be interpreted in the context of the cognitive load and information degradation frameworks. As contrast sensitivity tends to impact activities of daily living and mobility (Cormack et al., 1999),

poor contrast sensitivity may disproportionately affect socially isolated individuals by further limiting their ability to engage in outside activities and interactions with others outside of the home, further reducing cognitive stimulation and slowing the speed of processing information. As with hearing loss, symptoms of depression may influence the visual-cognitive relationship by negatively impacting attentional control and psychomotor processing, which are core components of many cognitive tasks (e.g., processing speed, executive function; Hammar et al., 2022). Therefore, a combination of declining contrast sensitivity and the presence of psychosocial risk factors (i.e., social isolation or depressive symptoms) may jointly limit cognitive resources available for compensation, disrupting efficient cognitive performance. Overall, across both sensory modalities, poorer psychosocial functioning may be associated with greater dependence on preserved sensory function to support cognitive performance, particularly among individuals with cognitive impairment.

Despite robust associations between sensory and cognitive performance across all domains in Study 2, including memory, we found no evidence that psychosocial functioning moderated the link between sensory performance (CDTT and CS) and episodic memory in cognitively healthy controls or, notably, in individuals with MCI and AD. Consistent with our interpretation from Study 1, psychosocial factors may moderate associations between sensory performance and verbal fluency, processing speed, and executive function because these cognitive abilities involve distributed cortical areas that are continuously engaged during everyday social interactions. In contrast, episodic memory is dependent on medial temporal lobe integrity and may therefore be less susceptible to the influence of psychosocial functioning, particularly in individuals with MCI or AD, who are likely to have underlying neuropathology affecting medial temporal structures that support episodic memory.

The Caveat of Directionality in Sensory-Cognitive and Social-Cognitive Relationships

A well-documented challenge in the research assessing risk factors for dementia is clarifying the directionality and the potential for reverse causality (Ghisletta & Lindenberger, 2005; Halahakoon et al., 2019; Levett et al., 2025; Sommerlad et al., 2023; Son & Sung, 2023; Yin et al., 2019). Given that neuropathological changes associated with dementia development can emerge decades before a diagnostic threshold is reached, the presence of a particular characteristic or behaviour prior to a diagnosis may reflect an early manifestation of an underlying disease process rather than a distinct risk factor. Reviews of sensory-cognitive literature have highlighted the issue of reverse causation given the overlap between neuropathological changes associated with dementia and sensory loss (e.g., Levett et al., 2025; Vu et al., 2021). For example, neuropathological changes associated with dementia may lead to central hearing impairment as auditory processing areas overlap anatomically with networks implicated in dementia (Gates et al., 2011; Johnson et al., 2021). Similarly, visual and cognitive impairment share similar microvascular and neuronal changes in the eye and brain (Ikram et al., 2012; Kusne et al., 2017). Moreover, reviews of social-cognitive relationships also propose a bidirectional relationship between psychosocial function and dementia (i.e., poor psychosocial function impairs cognitive performance, which in turn reduces social engagement and well-being) and emphasize the need for longitudinal findings with repeated assessments of psychosocial function and longer-term follow-ups (Sommerlad et al., 2023). Therefore, a major caveat to interpreting our findings is the possibility of bidirectionality in the observed sensory-cognitive and social-cognitive associations (i.e., poor sensory and psychosocial function are not causes but consequences of cognitive decline).

In Study 1, we sought to address this issue by examining whether social participation contributed uniquely to cognitive performance in individuals with MCI, beyond the effects of general cognitive impairment. By including MoCA scores as covariates in our analyses, we concluded that the relationship between social participation and cognitive performance in processing speed and verbal fluency was reliable regardless of the participant's cognitive status. In Study 2, the analysis plan was informed by theoretical frameworks and previous findings proposing that sensory and psychosocial factors contribute to cognitive decline. We partially addressed this issue by assessing patterns within and across diagnostic groups, treating diagnostic group a secondary moderator (e.g., comparing CU to MCI, MCI to AD), and interpreting results cautiously. We emphasized that moderation effects indicate that the strength of the association between sensory and cognitive variables differs across levels of psychosocial function and diagnostic group, but they do not confirm directional or causal pathways.

Clinical Implications for Individuals with Mild Cognitive Impairment

The current work demonstrates the following for individuals with MCI: 1) worse sensory and psychosocial function to cognitively healthy controls; 2) low social participation is associated with poor cognitive performance; and 3) poorer psychosocial function consistently strengthens the link between better sensory function and cognitive performance, suggesting increased reliance on preserved sensory function to support cognition. Both studies highlight a relationship between psychosocial and cognitive function in MCI, who represent a unique at-risk state on the spectrum of cognitive impairment and face emerging changes in sensory, social, and cognitive function. Since individuals with MCI generally maintain functional independence and continue to engage in daily activities, they may be well-positioned to benefit from preventative strategies and interventions targeting sensory and psychosocial function.

Study 1 demonstrated that perceived levels of social participation, compared to other structural and functional measures of psychosocial functioning, was associated with cognitive performance in individuals with MCI. Although people with MCI typically retain communication and functional abilities that support engagement in cognitively stimulating social activities, some barriers can limit their participation. These can include shrinking social networks (e.g., the death or migration of close friends), mobility challenges, lack of suitable activities, lower social efficacy, limited use of technology to support social connectedness, and coexisting decline in physical or sensory health (Zhu et al., 2023). To address this, public health strategies could promote social participation through various approaches, such as organizing social activities, creating accessible spaces and events, promoting face-to-face contact, and facilitating education on the importance of social participation, and exploring technology-based interventions to improve conversational abilities (Fang et al., 2025; Zhu et al., 2023). Such approaches, particularly in social and community centres, may be critically important for individuals with limited social contact (e.g., those living alone or recently retired) or during periods of heightened social isolation (e.g., the COVID-19 pandemic). Furthermore, multicomponent interventions that integrate social interactions with leisure activities (e.g., playing card games or walking together) may provide stimulation by engaging both cognitive processes and social connection with others (Bae et al., 2019; Fang et al., 2025).

The high prevalence of poor hearing and vision in MCI and AD in our sample compared to cognitively healthy controls further underscores the need for systematic sensory assessment and early interventions. If sensory loss is indeed a useful predictor of dementia risk, policy implications should incorporate sensory screening as part of a diagnosis and preventative care pathways (see Dawes et al., 2022; Wittich et al., 2018 as examples of recommendations). Recent

papers have even proposed using hearing tests as "cognitive stress tests" alongside other screening measures in memory clinics (Levett et al., 2025). Furthermore, hearing and vision healthcare professionals should be attentive to signs of cognitive impairment and mental health symptoms in their patients and refer to other services when indicated, supporting a comprehensive model of care for older adults. Finally, rehabilitative interventions should prioritize optimal management of hearing and vision difficulties to support cognitive health and improve quality of life (Dawes et al., 2022; Whitson et al., 2013), particularly in individuals at-risk for further cognitive decline (e.g., those with subjective cognitive concerns or MCI). Prior research indicates that sensory assistive devices (like hearing aids) may alleviate the frequency and severity of neuropsychiatric symptoms (e.g., reduce depressive symptoms), enhance cognitive performance (e.g., Castiglione et al., 2016; Mamo et al., 2018; Whitson et al., 2013), and improve quality of life for individuals with dementia and their caregivers (Dawes et al., 2019; Littlejohn et al., 2022).

Moreover, findings from Study 2 suggest that individuals with MCI may derive the greatest benefit from multi-domain, non-pharmacological strategies that jointly target sensory and psychosocial functioning. Integrating hearing and vision interventions with targeted efforts to reduce social isolation (e.g., group-based community activities) and improve mood (e.g., psychotherapy) may mitigate the compounded effects of sensory and psychosocial difficulties on cognitive function. Examples include group-based sensory rehabilitation programs (e.g., hearing or vision rehabilitation delivered in small groups) that simultaneously improve sensory functioning while promoting social engagement, as well as encouraging the of sensory assistive devices during social interactions (e.g., community events, support groups, and family gatherings), which may increase participation and support cognitive health. Furthermore, modifying social environments to reduce sensory load may promote social participation, such as reduced background noise.

Finally, psychotherapeutic interventions could be adapted to accommodate for sensory limitations, such as providing cognitive-behavioural therapy with visual aids or written summaries.

Limitations

Scope and Extent of Data

The COMPASS-ND dataset includes a wide range of information on psychological well-being and social function, though the psychometric nature of these tests were limited. For example, some measurements of psychosocial variables were not standardized (i.e., part of a previously standardized or validated questionnaire) or were limited to a singular question or item within a questionnaire. Furthermore, social function was assessed using self-report questionnaires completed by participants or their caretakers (in the case of individuals with AD), which may only capture subjective measurements of social function.

Additionally, the COMPASS-ND dataset may not be highly representative of the broader Canadian population. Our sample was relatively homogenous in terms of ethnicity and educational attainment, consisting largely of White, highly educated participants, limiting the generalizability of results. Recruitment bias may also be relevant, as participants were older adults followed in memory clinics with an available study partner, meaning that the current participants in our sample were at least minimally socially integrated. Related to this, although the MCI and AD groups demonstrated lower psychosocial function than cognitively healthy controls, symptom levels were not clinically elevated, which likely reduced variability in psychosocial function and attenuated potential mediation and moderation effects.

Cross-sectional Analyses and Directionality

The cross-sectional and exploratory designs of both studies limited our ability to evaluate causal pathways or determine how associations unfold over time, making it difficult to

disentangle the temporal sequence linking sensory, psychosocial, and cognitive function or exclude reciprocal relationships (see the earlier section in this chapter for more details on the issue of directionality). Associations between social participation and cognitive performance in MCI (Study 1) and three-way interactions between sensory function, psychosocial factors, and diagnostic group on cognitive performance (Study 2) were observed in the current work, though longitudinal research is essential to determine whether sensory loss contributes to cognitive decline through psychosocial mechanisms and to establish directionality and cause-effect in these relationships.

Group Sizes and Power

Both studies aimed to integrate various sensory, psychosocial, and cognitive variables into the statistical models. Although this approach was justified given the exploratory nature of the work, group sizes were relatively modest in relation to the number of predictors and outcomes examined. Particularly in Study 2, the increased model complexity may have reduced statistical power and affected the reliability of findings. Some interaction effects did not reach statistically significant thresholds but showed similar patterns, highlighting the need for replication in larger samples to clarify whether these trends represent true effects rather than sample-specific variability. Importantly, our sample size was constrained further when analyses were stratified by diagnostic group, which may have limited the ability to detect subtle interaction effects and contributed to the inconsistent findings observed in the AD group.

Future Directions

To build on the strengths of this work and address its limitations, future research should consider several factors. First and foremost, to better address questions about directionality and reliability of results, future research with longitudinal COMPASS-ND data should examine how

sensory-social-cognitive trajectories change over time and contribute to risk for cognitive decline. As two-year follow-up assessments for the COMPASS-ND participants have recently been completed, ideas for future analyses include evaluating 1) whether sensory and social status at baseline predict cognitive outcomes and change in diagnostic group (e.g., MCI to AD) at follow-up, and 2) if psychosocial factors mediate or moderate the longitudinal relationship between baseline sensory function and cognitive performance at follow-up.

Second, there are well-established sex- and gender- differences in sensory and psychosocial function (Curran et al., 2020) among older adults, and in associations between sensory-psychosocial factors (e.g., Harada et al., 2008; Mick et al., 2014, 2018), sensory-cognitive factors (e.g., Huang et al., 2020; Ward et al., 2018), and social-cognitive factors (e.g., Hämäläinen et al., 2019; Hwang et al., 2018; Lee et al., 2020; Joyce et al., 2021). While we observed significant differences between men and women on psychosocial function in the CU and MCI groups (e,g., females endorsing poorer psychosocial function than men), we did not further evaluate if the relationship between psychosocial function and cognitive performance differs by sex. Others have suggested that the relationship between social factors and cognitive performance could be slightly more influential in women (Hämäläinen et al., 2019). Furthermore, while we did not evaluate sex differences in hearing and vision and cognitive performance, prior work with the COMPASS-ND sample indicates that hearing loss is associated with cognitive performance most strongly in women than in men in the COMPASS-ND MCI sample (Al-Yawer et al., 2023). Given these patterns, future work with larger and more balanced sex distributions across diagnostic groups is needed to fully examine sensory-psychosocial-cognitive associations in men and women. Such work could explore whether psychosocial

function mediates or moderates sensory-cognitive links by sex, and whether sex-specific pathways vary across levels of cognitive impairment (i.e., diagnostic group).

The selection of sensory and psychosocial variables is another important consideration for future work. Various hearing (e.g., pure-tone thresholds) and visual measures (e.g., visual acuity), not included in Studies 1 and 2, have been associated with cognitive function in cognitively healthy older adults (e.g., (Ge et al., 2023; Hämäläinen et al., 2019; Phillips et al., 2022). Considering other sensory variables, and dual sensory impairment, may help better capture overall sensory functioning in the present sample. Moreover, other psychosocial risk factors that were not assessed in the current work have been strongly linked to cognitive performance cross-sectionally and over time in cognitively healthy older adults, including loneliness (Harrington et al., 2023; Kuiper et al., 2020) and the size and composition of social networks (Perry, McConnell, et al., 2022; Röhr et al., 2020). Comprehensive analysis of *which* psychosocial factors influence sensory-cognitive relationships will be critical for clarifying how specific measures of psychological well-being or social function exacerbate sensory deficits and contribute to cognitive decline.

Furthermore, the COVID-19 pandemic negatively impacted emotional and social well-being in older adults, including those with cognitive impairment and dementia (Hausman et al., 2022; Seckman, 2023; Soysal et al., 2022). Notably, Guimarães and colleagues (2025) found that compared to cognitively healthy older adults, individuals with MCI (especially those who were younger and with better memory function) appeared most vulnerable to the impact of COVID-19. Additional evidence also links social isolation with accelerated decline in cognitive and functional abilities in clinical populations with cognitive impairment (Tsiakiri et al., 2022).Future research should consider how the intensity of psychosocial conditions (e.g., living in the middle

of a pandemic or other major life stressors) and other demographic factors that impact psychosocial function (e.g., socioeconomic status, living in a low-income neighborhood) may affect the sensory-cognitive relationship. Such work may help clarify whether the moderating role of psychosocial function on sensory-cognitive associations differs under conditions of heightened psychosocial stress and which groups may be most affected.

Conclusions

In conclusion, the findings from this dissertation extend the associations between sensory, social, and cognitive function in cognitively unimpaired older adults to clinical groups with (or at risk for) AD. In Study 1, we demonstrated associations between social participation and cognitive performance on verbal fluency and processing speed in individuals with MCI. This suggests that interventions encouraging social participation may be stimulating and helpful in supporting cognitive functions in individuals at-risk for developing AD.

In Study 2, we characterized the sensory and psychosocial profiles of cognitively healthy controls compared to individuals with MCI and early AD, and examined inter-relationships among sensory, psychosocial, and cognitive function in these groups. Further, this study demonstrated that psychosocial function did not mediate but moderated the relationship between hearing and vision and cognitive performance, and that this moderation relationship differed by diagnostic group. Particularly, poor psychosocial function most consistently amplified the sensory-cognitive relationship in participants with cognitive impairment, although sensory-cognitive relationships remained uniformly positive in the MCI group. Together, these findings suggest that individuals with cognitive impairment may be more vulnerable to the compounded effects of emerging sensory (e.g., hearing, vision, and dual sensory impairments) and psychosocial (e.g., reduced social engagement) changes on cognition. These results align with

the information degradation and cognitive load hypotheses, as poor psychosocial function may increase reliance on preserved sensory function to maintain cognitive performance, particularly for individuals with MCI. Collectively, results from the current studies highlight the importance of considering sensory and psychosocial function in clinical practice and the need for targeted interventions addressing these potentially modifiable risk factors for dementia.

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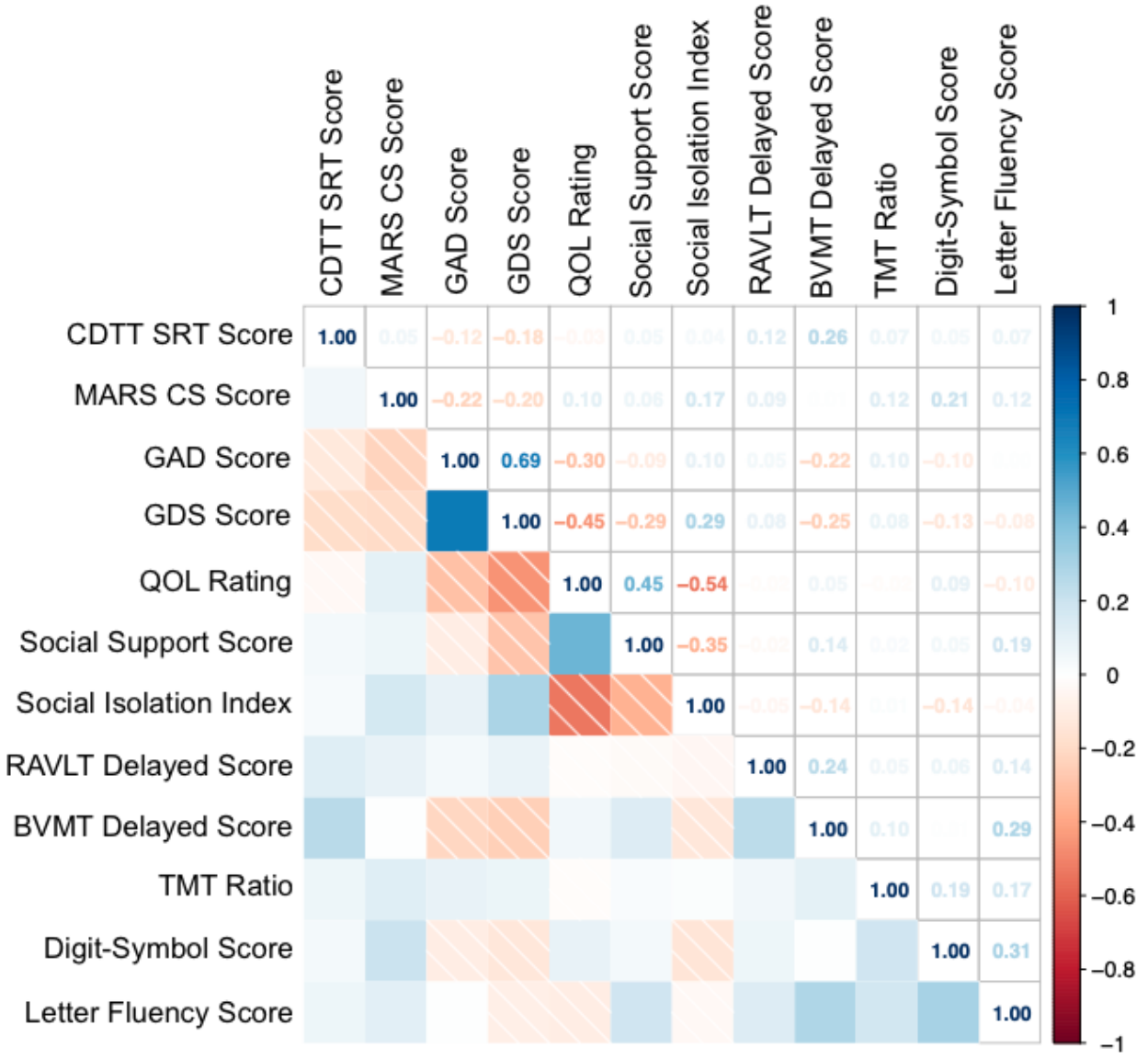
Appendix A: Supplemental Materials for Manuscript I

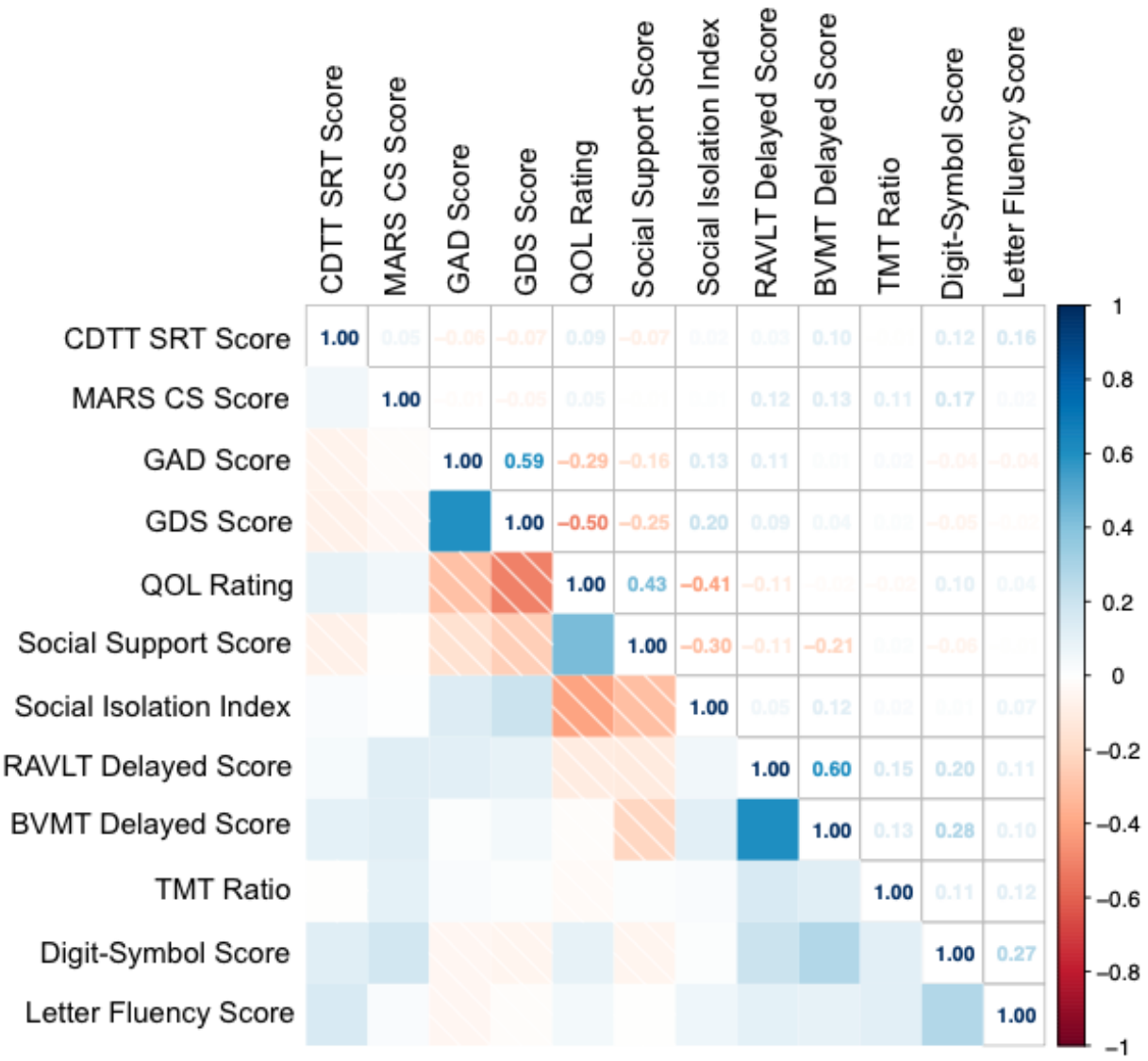
Supplementary Table 1: Demographics and Descriptive Information on Psychosocial Factors by Current Participation Category

Variable	Low (N = 49)	Normal (N = 65)	High (N = 12)
Age	71.1	72.3	70
Education	15.2	15.3	16.8
Sex (%)	35% F	37% F	67% F
Marital Status (%)	80% married or in common-law relationship	80% married or in common-law relationship	83% married or in common-law relationship
Living Circumstances (%)	14% live alone	16% live alone	8% live alone
Geriatric Depression Scale Score (mean)	9	5.28***	5.83*
Geriatric Anxiety Disorder Scale (GAD-7; mean)	5.2	3.71	3.42
Quality of Life	37.47	40.55**	43.67***
Telephone Frequency (N)			
None	2	0	0
Once per week	4	3	0
Twice per week	9	16	3
Three-four times per week	24	26	4
Once or more per day	10	20	5
Time Spent with Others Frequency (N)			
None	8	2	1
Once per week	8	10	2
Twice per week	16	17	2
Three-four times per week	16	29	5
Once or more per day	1	6	2

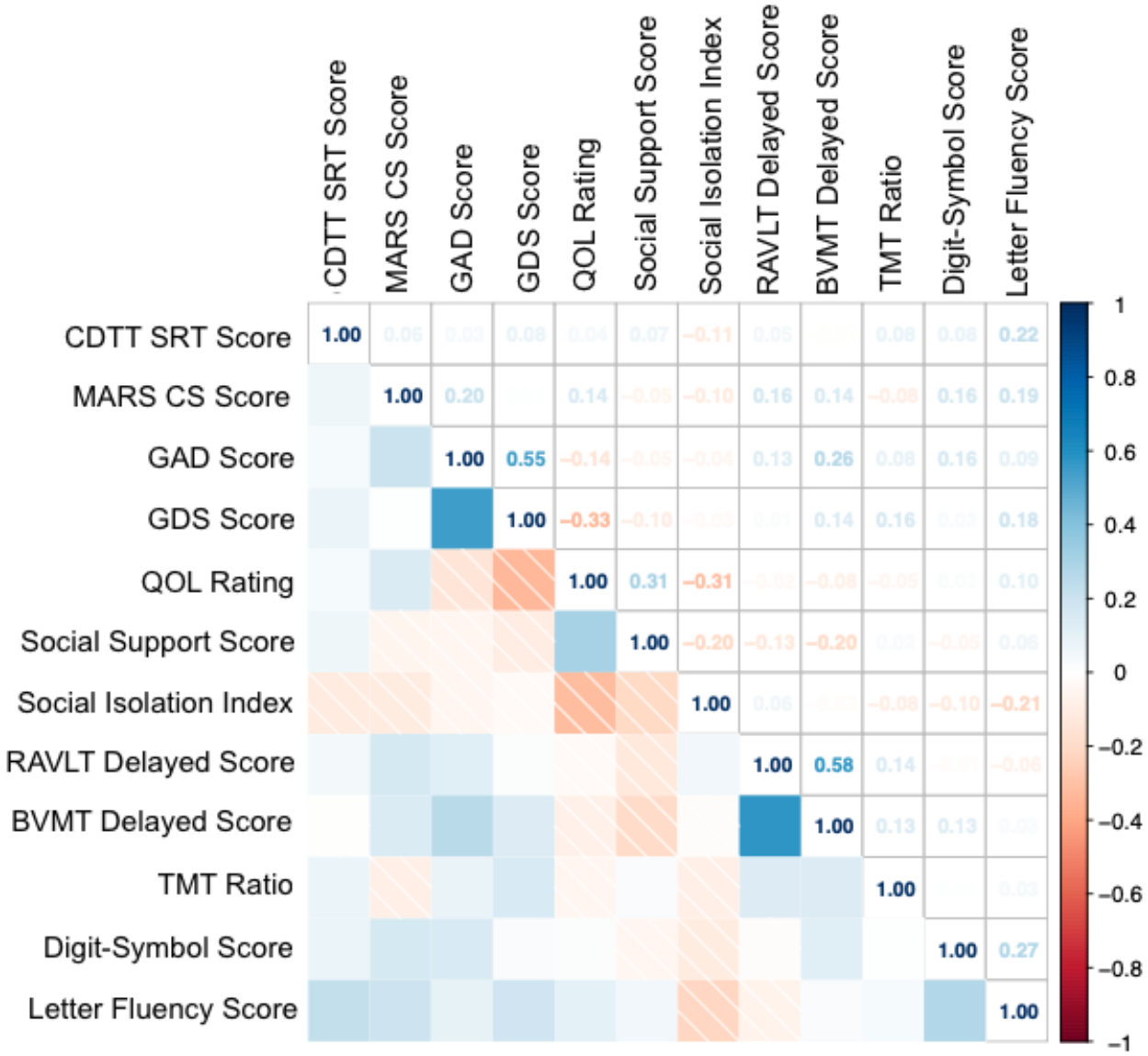
Note. *** $p < .001$, ** $p < .01$, * $p < .05$



Supplementary Figure 1A. Partial correlation matrix of sensory, psychosocial, and cognitive variables in the CU group. Partial correlations (controlling for age and sex) are shown between sensory measures (CDTT, CS), psychosocial variables (GAD, GDS, quality of life, social support, social isolation), and cognitive outcomes (RAVLT and BVMT delayed recall scores, TMT ratio score, Digit-Symbol and Letter Fluency total scores). Positive correlations are shown in blue. Stronger associations are indicated by deeper colour intensity.



Supplementary Figure 1B. Partial correlation matrix of sensory, psychosocial, and cognitive variables in the MCI group. Partial correlations (controlling for age and sex) are shown between sensory measures (CDTT, CS), psychosocial variables (GAD, GDS, quality of life, social support, social isolation), and cognitive outcomes (RAVLT and BVMT delayed recall scores, TMT ratio score, Digit-Symbol and Letter Fluency total scores). Positive correlations are shown in blue. Stronger associations are indicated by deeper colour intensity.



Supplementary Figure 1C. Partial correlation matrix of sensory, psychosocial, and cognitive variables in the AD group. Partial correlations (controlling for age and sex) are shown between sensory measures (CDTT, CS), psychosocial variables (GAD, GDS, quality of life, social support, social isolation), and cognitive outcomes (RAVLT and BVMT delayed recall scores, TMT ratio score, Digit-Symbol and Letter Fluency total scores). Positive correlations are shown in blue. Stronger associations are indicated by deeper colour intensity.

Supplementary Table 1. Moderation Effects of Psychosocial Factors on Sensory-Cognitive Associations

	Analyses Comparing CU and MCI Groups [ab]			
Cognitive Measure	CDTT SRT		CS	
	CU	MCI	CU	MCI
RAVLT				
BVMT				
TMT				
DSST			+ SI*; + GDS^{T}	+ SI* + GDS^{T}
Letter Fluency		+ SI*		

	Analyses Comparing MCI and AD Groups [ab]			
	CDTT SRT		CS	
	MCI	AD	MCI	AD
RAVLT				
BVMT				
TMT			+ SI*	- SI*
DSST	+ SS*	+ SS* - SS*	+ GDS*	+ GDS*
Letter Fluency				+ GAD*

Note. GDS = Geriatric Depression Scale, GAD = Generalized Anxiety Disorder Scale; SI = social isolation; SS = social support; * $p < 0.05$; ^{T} = trend

[a] + indicates statistically significant partial correlation in the positive direction (i.e., **positive** association); - indicates statistically significant partial correlation in the negative direction (i.e., **negative** association).

[b] Green indicates the association is significantly moderated by a psychosocial variable such that the association strongest at lower levels of psychosocial functioning (e.g., more anxiety and depressive symptoms, high social isolation); orange indicates the association is significantly moderated by a psychosocial variable such that the association strongest at higher levels of psychosocial functioning. (e.g., less anxiety and depressive symptoms, low social isolation); pink indicates the association is significantly moderated by a psychosocial variable such that the association was significant at all levels of psychosocial functioning; no colour indicates there is no interaction with any psychosocial variable; no colour indicates there is no interaction with any psychosocial variable.

Supplementary Table 2. Moderation Effects of Social Isolation on the Relationship between CDTT and Verbal Fluency in CU and MCI Groups

Regression Model					
Outcome	B	SE	*t*	*p*	95% CI
Intercept	5.55	18.02	0.31	.76	[-29.86, 40.96]
CDTT SRT	2.72	1.54	1.77	.08	[-0.30, 5.75]
SI Index	7.30	4.15	1.76	.08	[-0.85, 15.49]
Group	16.30	17.10	0.95	.34	[-17.31, 49.91]
CDTT SRT × SI Index	-0.70	0.40	-1.70	.08	[-1.48, 0.07]
CDTT SRT × Group	-2.55	1.67	-1.53	.13	[-5.83, 0.73]
SI Index× Group	-8.46	4.49	-1.89	.06	[-17.27, 0.36]
CDTT SRT × SI Index × Group	0.89*	0.44	2.84	.04	[0.03, 1.76]
Age	-0.05	0.08	-0.63	.53	[-0.22, 0.11]
Sex	-2.09	1.10	-1.91	.06	[-4.24, 0.06]
Education	0.85***	0.19	4.48	<.001	[0.48, 1.23]
Household Income	0.83*	0.40	2.10	.04	[0.05, 1.60]

Conditional Effects of Moderated Moderation						
Moderator Level	Group	B	SE	*t*	*p*	95% CI
Low (16th %ile)	CU	1.51	1.00	1.51	.13	[-0.45, 3.48]
Low (16th %ile)	MCI	0.50	0.41	1.23	.22	[-0.30, 1.31]
Moderate (50th %ile)	CU	0.66	0.78	0.85	.40	[-0.87, 2.18]
Moderate (50th %ile)	MCI	0.73*	0.29	2.57	.01	[0.17, 1.29]
High (84th %ile)	CU	-1.06	1.10	-0.96	.34	[-3.21, 1.10]
High (84th %ile)	MCI	1.20**	0.45	2.64	<.01	[0.31, 2.09]

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, SI = social isolation, *Ref.* = reference condition; controlling for age, sex & education.

Supplementary Table 3. Moderation Effects of Social Isolation on the Relationship between CS and Processing Speed in CU and MCI Groups

Regression Model					
Outcome	B	SE	*t*	*p*	95% CI
Intercept	-15.12	31.14	-0.49	.63	[-76.31, 46.08]
MARS CS	55.95**	16.92	3.31	.001	[22.69, 89.20]
SI Index	19.38	8.92	2.17	.03	[1.86, 36.91]
Group	61.12	32.59	1.88	.06	[-2.92, 125.17]
MARS CS × SI Index	-11.68*	5.10	-2.29	.02	[-21.70, -1.65]
MARS CS × Group	-42.51*	19.31	-2.20	.03	[-79.92, -5.10]
SI Index × Group	-19.17*	9.74	-1.97	.05	[-38.32, -0.02]
MARS CS × SI Index × Group	11.69*	5.64	2.07	.04	[0.62, 22.76]
Age	-0.47***	0.10	-4.87	<.001	[-0.66, -0.28]
Sex	-1.41	1.28	-1.11	.27	[-4.00, 1.09]
Education	0.99***	0.23	4.40	<.001	[0.55, 1.43]
Household Income	0.86	0.46	1.85	.06	[-0.05, 1.77]

Conditional Effects of Moderated Moderation						
Moderator Level	Group	B	SE	*t*	*p*	95% CI
Low (16th %ile)	CU	35.86***	10.41	3.45	<.001	[15.41, 56.32]
Low (16th %ile)	MCI	13.47*	5.68	2.37	.02	[2.31, 24.62]
Moderate (50th %ile)	CU	21.65*	8.69	2.49	.01	[4.57, 38.72]
Moderate (50th %ile)	MCI	13.49**	4.22	3.20	.002	[5.19, 21.78]
High (84th %ile)	CU	-6.81	15.54	-0.44	.66	[-37.35, 23.73]
High (84th %ile)	MCI	13.53*	6.31	2.14	.03	[1.13, 25.94]

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, CS = contrast sensitivity, SI = social isolation, *Ref.* = reference condition; controlling for age, sex & education.

Supplementary Table 4. Moderation Effects of Depressive Symptoms on the Relationship between CS and Processing Speed in CU and MCI Groups

Regression Model					
Outcome	B	SE	*t*	*p*	95% CI
Intercept	27.42	22.29	1.23	.22	[-16.39, 71.23]
MARS CS	31.75**	11.48	2.77	<.01	[9.18, 54.31]
GDS	6.86	4.34	1.58	.11	[-1.66, 15.39]
Group	30.86	22.57	1.37	.17	[-13.50, 75.21]
MARS CS × GDS	-4.26	2.61	-1.63	.10	[-9.39, 0.87]
MARS CS × Group	-23.01	13.17	-1.75	.08	[-48.90, 2.88]
GDS × Group	-8.07	4.52	-1.78	.08	[-16.96, 0.82]
MARS CS × GDS × Group	4.90	2.72	1.80	.07	[-0.45, 10.25]
Age	-0.50***	0.10	-5.09	<.001	[-0.69, -0.30]
Sex	-1.55	1.27	-1.22	.22	[-4.05, 0.91]
Education	0.96***	0.22	4.30	<.001	[0.52, 1.40]
Household Income	0.80	0.44	1.81	.07	[-0.07, 1.67]

Conditional Effects of Moderated Moderation						
Moderator Level	Group	B	SE	*t*	*p*	95% CI
Low (16th %ile)	CU	27.49**	10.01	2.75	<.01	[7.81, 47.16]
Low (16th %ile)	MCI	9.37	6.17	1.52	.13	[-2.75, 21.50]
Moderate (50th %ile)	CU	14.70	9.33	1.58	.12	[-3.63, 33.04]
Moderate (50th %ile)	MCI	11.30*	4.70	2.41	.02	[2.07, 20.52]
High (84th %ile)	CU	-10.86	20.71	-0.52	.60	[-51.55, 29.83]
High (84th %ile)	MCI	15.15**	4.75	3.19	<.01	[5.80, 24.49]

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, GDS = Geriatric Depression Scale scores; isolation, *Ref.* = reference condition; controlling for age, sex & education.

Supplementary Table 5. Moderation Effects of Social Support on the Relationship between CDTT and Processing Speed in MCI and AD Groups

Regression Model					
Outcome	B	SE	*t*	*p*	95% CI
Intercept	60.90**	18.90	3.22	<.01	[23.76, 98.03]
CDTT SRT	0.72	1.71	0.42	.67	[-2.64, 4.08]
Social Support	-0.06	0.19	-0.32	.75	[-0.43, 0.31]
Group	50.86	26.93	1.89	.06	[-2.05, 103.77]
CDTT SRT × Social Support	0.00	0.20	0.08	.94	[-0.09, 0.04]
CDTT SRT × Group	-8.20**	3.96	-2.68	<.01	[-14.20, -2.18]
Social Support × Group	-0.70*	0.31	-2.26	.02	[-1.30, -0.09]
CDTT SRT × Social Support × Group	0.09*	0.03	2.48	.01	[0.02, 0.16]
Age	-0.37***	0.09	-3.99	<.001	[-0.55, -0.18]
Sex	-0.57	1.26	-0.45	.65	[-3.05, 1.92]
Education	0.83***	0.21	3.90	<.001	[0.41, 1.25]
Household Income	0.80	0.45	1.77	.08	[-0.09, 1.69]

Conditional Effects of Moderated Moderation						
Moderator Level	Group	B	SE	*t*	*p*	95% CI
Low (16th %ile)	MCI	0.82	0.51	1.61	.11	[-0.18, 1.82]
Low (16th %ile)	AD	-1.68*	0.78	-2.15	.03	[-3.21, -0.15]
Moderate (50th %ile)	MCI	0.85*	0.34	2.53	.01	[0.19, 1.51]
Moderate (50th %ile)	AD	0.16	0.48	0.34	.73	[-0.78, 1.06]
High (84th %ile)	MCI	0.87	0.44	1.96	.05	[-0.00, 1.74]
High (84th %ile)	AD	1.34*	0.61	2.19	.03	[0.14, 2.53]

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, *Ref.* = reference condition; controlling for age, sex & education.

Supplementary Table 6. Moderation Effects of Anxiety Symptoms on the Relationship between CS and Verbal Fluency in MCI and AD Groups

Regression Model					
Outcome	B	SE	*t*	*p*	95% CI
Intercept	24.69*	11.14	2.22	.03	[2.81, 46.57]
MARS CS	-0.24	4.71	-0.05	.96	[-9.49, 9.02]
GAD	-1.23	1.33	-0.92	.36	[-3.84, 1.38]
Group	-30.20**	11.56	-2.61	<.01	[-52.92, -7.43]
MARS CS × GAD	0.65	0.80	0.81	.42	[-0.92, 2.23]
MARS CS × Group	14.41*	7.22	1.98	.048	[0.12, 28.69]
GAD × Group	6.86*	3.32	2.07	.04	[0.33, 13.85]
MARS CS × GAD × Group	-3.97*	2.02	-1.97	.049	[-7.95, -0.0037]
Age	-0.06	0.08	-0.83	.40	[-0.22, 0.09]
Sex	-3.91***	1.05	-3.71	<.001	[-5.97, -1.84]
Education	0.99***	0.18	5.56	<.001	[0.64, 1.34]
Household Income	1.36***	0.37	3.65	<.001	[0.63, 2.10]

Conditional Effects of Moderated Moderation						
Moderator Level	Group	B	SE	*t*	*p*	95% CI
Low (16th %ile)	MCI	-0.24	4.71	-0.05	.96	[-9.50, 9.02]
Low (16th %ile)	AD	14.17*	5.64	2.51	.01	[3.09, 25.27]
Moderate (50th %ile)	MCI	1.07	3.86	0.28	.78	[-6.52, 8.66]
Moderate (50th %ile)	AD	7.52	4.73	1.59	.11	[-1.76, 16.81]
High (84th %ile)	MCI	4.33	4.38	0.99	.32	[-4.27, 12.93]
High (84th %ile)	AD	-9.09	10.90	-0.83	.41	[-30.52, 12.34]

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, GAD = General Anxiety Disorder - 7 score, *Ref.* = reference condition; controlling for age, sex & education.

Supplementary Table 7. Moderation Effects of Depressive Symptoms on the Relationship between CS and Processing Speed in MCI and AD Groups

Regression Model					
Outcome	B	SE	*t*	*p*	95% CI
Intercept	42.39**	15.17	2.79	<.01	[12.58, 72.19]
MARS CS	11.23	7.04	1.59	.11	[-2.61, 25.07]
GDS	-1.12	1.35	-0.83	.40	[-3.77, 1.52]
Group	27.78	19.32	1.44	.15	[-10.20, 65.73]
MARS CS × GDS	0.62	0.81	0.76	.45	[-0.97, 2.12]
MARS CS × Group	-27.55*	12.09	-2.28	.02	[-51.31, -3.80]
GDS × Group	-5.99*	2.76	-2.17	.03	[-11.42, -0.57]
MARS CS × GDS × Group	3.87*	1.72	2.25	.03	[0.50, 7.25]
Age	-0.34***	0.09	-3.63	<.001	[-0.52, -0.16]
Sex	-0.78	1.25	-0.63	.53	[-3.23, 0.67]
Education	0.93***	0.21	4.38	<.001	[0.51, 1.34]
Household Income	0.81	0.45	1.83	.07	[-0.06, 1.69]

Conditional Effects of Moderated Moderation						
Moderator Level	Group	B	SE	*t*	*p*	95% CI
Low (16th %ile)	MCI	10.47	5.83	2.04	.07	[-0.20, 23.93]
Low (16th %ile)	AD	-7.35	7.57	-0.97	.33	[-22.23, 7.53]
Moderate (50th %ile)	MCI	14.94***	4.32	3.34	<.001	[6.45, 23.43]
Moderate (50th %ile)	AD	10.60	5.53	1.92	.06	[-0.26, 21.45]
High (84th %ile)	MCI	18.03***	5.39	3.46	<.001	[7.44, 28.63]
High (84th %ile)	AD	33.03**	9.98	3.31	<.01	[13.42, 52.64]

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, GDS = Geriatric Depression Scale score, *Ref.* = reference condition; controlling for age, sex & education.

Supplementary Table 8. Moderation Effects of Social Isolation on the Relationship between Vision and Executive Function in MCI and AD Groups

Regression Model					
Outcome	B	SE	*t*	*p*	95% CI
Intercept	-2.94	1.71	-1.72	.09	[-6.30, 0.42]
MARS CS	0.07	0.88	0.08	.93	[-1.68, 1.82]
SI Index	-0.29	0.39	-0.75	.45	[-1.05, 0.47]
Group	-2.43	2.23	-1.09	.28	[-6.87, 1.95]
MARS CS × SI Index	0.18	0.24	0.77	.44	[-0.28, 0.64]
MARS CS × Group	1.50	1.40	1.07	.29	[-1.25, 4.23]
SI Index × Group	1.06	0.58	1.83	.07	[-0.08, 2.19]
MARS CS × SI Index × Group	-0.77*	0.37	-2.08	.04	[-1.49, -0.04]
Age	-0.01	0.08	-1.39	.17	[-0.03, 0.01]
Sex	0.18	0.12	1.52	.13	[-0.05, 0.41]
Education	0.06*	0.02	2.79	.02	[0.02, 0.09]
Household Income	-0.07	0.04	-1.65	.10	[-0.16, 0.01]

Conditional Effects of Moderated Moderation						
Moderator Level	Group	B	SE	*t*	*p*	95% CI
Low (16th %ile)	MCI	0.41	0.53	0.78	.44	[-0.63, 1.46]
Low (16th %ile)	AD	0.47	0.67	0.70	.48	[-0.85, 1.79]
Moderate (50th %ile)	MCI	0.63	0.41	1.55	.12	[-0.17, 1.43]
Moderate (50th %ile)	AD	-0.22	0.53	-0.42	.67	[-1.26, 0.81]
High (84th %ile)	MCI	1.31*	0.61	1.96	.04	[0.16, 2.23]
High (84th %ile)	AD	-1.54*	0.75	-2.05	.04	[-3.02, -0.06]

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; B = unstandardized beta coefficient, SE = standard error, SI = social isolation, *Ref.* = reference condition; controlling for age, sex & education.