Cognitive Function and Decline Among Older Adults:
The Roles of Sensory Loss and Psychosocial Factors

by

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Dissertation submitted in partial fulfillment of
the requirements for the degree of
Doctor of Philosophy in Nursing
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ABSTRACT

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Abstract

In the context of rapid global aging, cognitive decline among older adults has become a major public health and social issue. A better understanding of the risk factors for cognitive decline is important for developing interventions to preserve cognitive function among older adults. Knowledge gaps still exist in understanding the impact of sensory loss (i.e., hearing loss and vision loss) and psychosocial factors (i.e., social support and loneliness) on cognitive function and cognitive decline. This dissertation aims to fill these knowledge gaps by (1) examining the relationship between psychosocial factors and cognitive function in a unique population: community-dwelling Chinese older adults in the United States (U.S.); (2) understanding the longitudinal relationship between sensory loss and cognitive decline among community-dwelling older adults in the United States; and (3) exploring the mechanisms that accelerate or decelerate cognitive decline by examining the inter-relationships between sensory loss, psychosocial factors, and cognitive decline. The primary study conducted for this dissertation used structural equational modeling (SEM) to model the potential moderation or mediation effect of psychosocial factors on the relationship between sensory loss and cognitive decline over time. Findings from this dissertation deepen our understanding of the important roles that social support, loneliness, and sensory loss can play in cognitive function and decline among community-dwelling older adults. Findings from this dissertation also highlight the importance of adequately addressing the physical and psychological challenges encountered by older adults. Subsequent recommendations are provided to health providers and policy makers to help better preserve and promote cognitive health among older adults using a more holistic approach.

Dedication

To mentors, colleagues, family, and friends whose endless support made this work possible.

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Acknowledgements

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1. Introduction and Background

1.1 Problem: Aging and Cognitive Decline

The aging of the world's population is a growing concern (United Nations, 2017). From 2017 to 2050, the number of adults aged 60 and above is projected to expand by 200% and reach 2.1 billion, representing about 21% of the global population (He, Goodkind, & Kowal, 2016; United Nations, 2017). In the United States, the number of older adults aged 65 years and above is projected to double between 2012 and 2050, yielding about 83.7 million older adults (Ortman, Velkoff, & Hogan, 2014). The aging of the population requires that policy makers and researchers pay close attention to the health and well-being of older adults in the nation.

With an increasingly aging population, cognitive decline among older adults has posed severe challenges to the society and older adults' daily lives (Deary et al., 2009). Cognitive decline is an important aspect of human aging that differs in extent between individuals (Deary et al., 2009; Levy, 1994). The term *cognitive decline* reflects a continuum of changes in cognitive performance, which can be within the spectrum of normal aging or can exceed expected decline and reflect a pathological process (Harada, Love, & Triebel, 2013). Age-related cognitive decline involves deterioration in several domains of cognition including memory, executive function, processing speed, and reasoning (Deary et al., 2009; Harada et al., 2013; Levy, 1994). If an individual's cognitive decline crosses a threshold, in which the person has cognitive impairment in one or more cognitive domains but preserved functional independence, this level of deterioration is called mild cognitive impairment (MCI) (Kane et al., 2017; Petersen, 2004; Petersen et al., 2014). This decline can progress until the individual's cognitive impairment interferes with instrumental activities of daily living (IADLs) or activities of daily living (ADLs) and prevent the individual from living independently. In this case, the individual would likely to be diagnosed as having Alzheimer’s disease or a related dementia (ADRD) (Kane et al., 2017). Different stages of cognitive decline and cognitive impairment are shown in Figure 1.

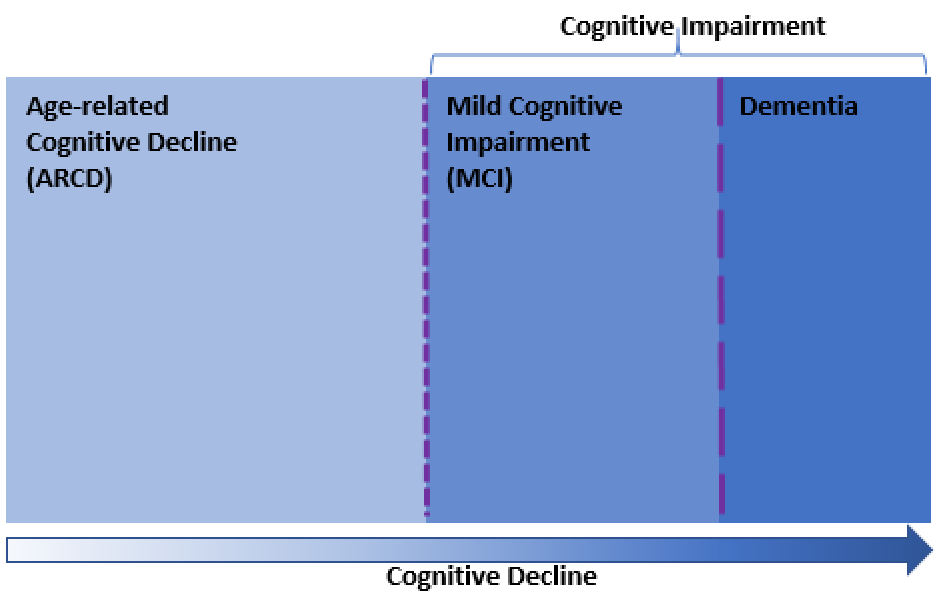

Figure 1: Graphic for stages of cognitive decline.

By definition, age-related cognitive decline and MCI do not cause functional impairment, but they still can present challenges in older adults' daily lives by increasing the likelihood of falls (Herman, Mirelman, Giladi, Schweiger, & Hausdorff, 2010; Mirelman et al., 2012), neuropsychiatric symptoms such as apathy, depression, or irritability (Apostolova & Cummings, 2008), and diminishing quality of life (Pusswald et al., 2015). Accelerated cognitive decline has been found to be associated with an increased chance of MCI. Older adults with MCI are subject to a higher risk of progressive deteriorating cognitive function. Although estimates vary across studies, the annual conversion rate of MCI to dementia ranges from 4.9% to 9.6% (Cooper, Sommerlad, Lyketsos, & Livingston, 2015; Manly et al., 2008; Mitchell & Shiri‐Feshki, 2009; Tschanz et al., 2006), underscoring the importance of cognitive decline and related disorders as a public health issue (Alzheimer's Association, 2018; World Health Organization, 2012).

Implementing strategies to prevent cognitive decline and dementia through reduction of risk factors can potentially reduce cognitive decline and dementia incidence (Barnes & Yaffe, 2011; Lin, Yang, Fillit, Cohen, & Neumann, 2014). Previous intervention studies and systematic reviews have suggested that interventions that increase physical exercise (Miller, Taler, Davidson, & Messier, 2012; Tarazona-Santabalbina et al., 2016), cognitive activity (Ge, Zhu, Wu, & McConnell, 2018; Spector et al., 2003), social engagement, and social support (Coll-Planas et al., 2017; Fried et al., 2004; Heaven et al., 2013; Myhre, Mehl, & Glisky, 2016) can contribute to the optimization and promotion of cognitive function among older adults (Plassman, Williams, Burke, Holsinger, & Benjamin, 2010; Williams & Kemper, 2010). For example, Ngandu et al. (2015) conducted a randomized controlled trial (RCT) using a 2 year multi-domain intervention (diet, exercise, cognitive training, vascular risk monitoring) among 1190 Finnish older adults aged 60-67 years (intervention n = 591, control n = 599) and found that the multi-domain intervention could maintain or improve cognitive function in this elderly population. The results demonstrate the potential for intervening successfully to improve cognitive function among older adults, even in later life. However, knowledge gaps still exist regarding how and why these interventions can actually benefit cognitive function among older adults. Therefore, it is widely agreed that more research is needed to understand the mechanisms of cognitive decline and the factors that contribute to its individual differences (Brayne, 2007; Deary et al., 2009; Petersen et al., 2014; Plassman et al., 2010). The National Institute of Health (NIH) has promoted research initiatives to emphasize the importance of identifying the demographic, biological, and psychosocial factors that can help people maintain or enhance their cognitive health as they grow older, which has become a major public health goal for the United States (Hendrie et al., 2006; Lin et al., 2014).

Understanding and addressing the risk factors for cognitive decline can potentially promote cognitive health and decelerate cognitive decline (Baumgart et al., 2015). Understanding the associations and the underlying mechanisms between the targeted risk factors and cognitive decline lays a foundation for designing practical interventions. Therefore, I propose to broaden and deepen the understanding of the risk factors of cognitive decline by examining the relationship of cognitive function with sensory loss and psychosocial factors, namely, hearing loss, vision loss, social support, and loneliness.

A recent review paper published in *The Lancet* summarized the potential protective factors against cognitive decline (Livingston et al., 2017). Among these factors, promising research has been conducted to understand, for example, diabetes as a risk factor for faster rate of cognitive decline, and many studies have examined the underlying mechanisms explaining this association (Arvanitakis, Wilson, Bienias, Evans, & Bennett, 2004; Biessels, Staekenborg, Brunner, Brayne, & Scheltens, 2006; Kodl & Seaquist, 2008; Saedi, Gheini, Faiz, & Arami, 2016). However, limited research has been done to understand other important physical health concerns among older adults as risk factors for accelerated cognitive decline, such as hearing loss, which is projected to be twice as prevalent as diabetes among older adults by 2025 (Cederroth, Canlon, & Langguth, 2013). Given this high prevalence, it is important to gain a better understanding of sensory loss as a risk factor for cognitive decline because it has the potential for an even greater impact on prevention of cognitive decline.

Sensory loss, insufficient social support, and loneliness are three important concerns in older adults' lives. Empirical evidence summarized in multiple systematic reviews has identified them as potential independent risk factors for cognitive decline among older adults (Cacioppo & Hawkley, 2009; Lin et al., 2013; Plassman et al., 2010; Reyes-Ortiz et al., 2005). Previous literature has suggested several theoretical hypotheses about the potential inter-relationships between sensory loss, social support, loneliness, and cognitive decline (Dawes et al., 2015; Pichora-Fuller, Mick, & Reed, 2015; Whitson et al., 2018). These inter-relationships need to be understood given their potential implications to explain the underlying mechanisms connecting hearing loss and cognitive decline (Whitson et al., 2018). Specifically, it has been hypothesized that social support and loneliness may act as moderators and mediators for the associations between sensory loss and cognitive decline (Fortunato et al., 2016; Fulton, Lister, Bush, Edwards, & Andel, 2015; Pichora-Fuller et al., 2015; Wayne & Johnsrude, 2015; Whitson et al., 2018). However, little research has been conducted to explore these important relationships and inconsistent evidence has been generated (Dawes et al., 2015; Yamada et al., 2016).

In summary, knowledge gaps still exist in understanding the inter-relationships between sensory loss, social support, loneliness, and cognitive decline. In the following sections of this chapter, I will discuss the importance of understanding each of these domains as a risk factor for cognitive decline and explain why understanding the inter-relationships as underlying mechanisms to accelerate/decelerate cognitive decline is of particular interest.

1.2 Sensory Loss

1.2.1 Prevalence and Significance

Both hearing and vision loss disproportionally affect the elderly population (Lin, Thorpe, Gordon-Salant, & Ferrucci, 2011; Varma, Vajaranant, Burkemper, & et al., 2016). Among different types of sensory loss, hearing and vision loss are highly prevalent and have a prominent impact on older adults' lives (Rooth, 2017). Empirical evidence has demonstrated associations between hearing or vision loss and mental/physical health outcomes including depression (West, 2017; Zhang et al., 2013), lower quality of life (QOL) (Brown, 1999; Polku et al., 2018), higher likelihood of falls (Hong, Mitchell, Burlutsky, Samarawickrama, & Wang, 2014; Lin & Ferrucci, 2012), and increased mortality (Fisher et al., 2014; McGuinness, Karahalios, Finger, Guymer, & Simpson, 2017). Previous studies have also found that older adults with sensory loss have lower availability of social support and a higher chance of feeling lonely (Dawes et al., 2015; Mick, Parfyonov, Wittich, Phillips, & Pichora-Fuller, 2018; Weinstein & Ventry, 1982).

Hearing loss is the third most common chronic condition in older adults, and thus represents a major public health issue in the United States (Fisher et al., 2014). Approximately 48 million people in the United States reported some degree of hearing loss based on data from the 2001–2008 cycles of the National Health and Nutritional Examination Surveys (NHANES) (Lin, Niparko, & Ferrucci, 2011; Lin, Thorpe, et al., 2011). The prevalence of hearing loss is highly associated with age. Approximately one third of adults older than 65 years experience a disabling hearing loss (World Health Organization, 2018). Several cohort studies have demonstrated that hearing loss of 25 dB or more affects about 60% of older adults aged 71 to 80 years, and more than 80% of older adults aged 80 and above (Gates, Cooper, Kannel, & Miller, 1990; Lin, Thorpe, et al., 2011; Van Eyken, Van Camp, & Van Laer, 2007; Walling & Dickson, 2012).

In terms of vision loss, using the criterion of visual acuity (VA) worse than 20/40 but better than 20/200 (blindness) to define visual impairment, approximately 3.22 million persons in the United States were visually impaired in 2015 (Varma et al., 2016). This number is projected to reach 6.95 million in 2050, representing a 115.8% increase (Varma et al., 2016). The prevalence of vision loss is also highly associated with age. Varma and colleagues reported that in 2015, 50% of those who were visually impaired are aged 80 and above, followed by those aged 70 - 79 years (24.2%), and then by those aged 60 - 69 years (16.1%). The proportions taken by these age groups were projected to be even higher in 2050 (Varma et al., 2016).

1.2.2 Contributors to Age-related Hearing and Vision Loss

The risk of hearing loss increases significantly with age. Age-related hearing loss can be caused by many factors, including environmental exposure to excessive noise, viral or bacterial infections, cardiovascular disease or stroke, brain trauma, tumors, genetic predisposition, and certain medicines, (Agrawal, Platz, & Niparko, 2009; Davis et al., 2016; HealthinAging, 2016; NIDCD, 2016). Older adults with hearing loss can experience difficulties including inability to hear well in noisy environments (speech-in-noise), having trouble hearing sounds of higher pitches (e.g. voices of women and children), and mishearing and misunderstanding (Dybala, 2017; Moore et al., 2014). The gold-standard of measuring hearing loss is the pure-tone threshold test, which measures the level of hearing loss in a quiet environment (Gates, Murphy, Rees, & Fraher, 2003; Lichtenstein, Bess, & Logan, 1988).

The risk of vision loss is also significantly associated with age (Varma et al., 2016). Age-related vision loss can be attributed to the physiological changes that occur within the eye as a person ages, genetic predisposition, or age-related eye diseases including age-related macular degeneration (AMD), glaucoma, cataract, and diabetic retinopathy (Chader & Taylor, 2013; Quillen, 1999). Almost every measure of visual function declines as people grow older. Visual functions that decline include but are not limited to visual acuity, sensitivity of the visual field, contrast sensitivity, visual processing speeds, tear production, and dark adaptation (Owsley, 2011; Salvi, Akhtar, & Currie, 2006; Sharma & Hindman, 2014; Welp et al., 2016).

1.2.3 Evidence on Hearing and Vision Loss as Risk Factors for Cognitive Decline

Empirical evidence has suggested an association between sensory loss and cognitive function and decline (Whitson et al., 2018). The two paragraphs below synthesize the findings from previous literature regarding hearing and vision loss.

Research on the association between hearing loss and cognitive function/decline or dementia has produced inconsistent results. The vast majority of the evidence shows a significant positive association of hearing loss with lower cognitive function and increased risk of cognitive impairment (Lindenberger & Baltes, 1994; Loughrey, Kelly, Kelley, Brennan, & Lawlor, 2018; Panza, Solfrizzi, & Logroscino, 2015). Importantly, longitudinal studies have demonstrated that individuals with hearing loss are likely to have a faster rate of decline in global cognitive function and a higher likelihood of developing cognitive impairment and dementia (Lin, Metter, et al., 2011; Lin et al., 2013; Livingston et al., 2017; Yuan, Sun, Sang, Pham, & Kong, 2018). However, contradictory evidence also exists. Hong, Mitchell, Burlutsky, Liew, and Wang (2016) found that baseline hearing loss was not associated with the extent of cognitive decline over 5-, 10-, and 15-year periods. Similarly, Anstey, Luszcz, and Sanchez (2001) found that 2-year decline in hearing was not associated with memory decline in older adults. Also, Reyes-Ortiz et al. (2005) found no significant associations between hearing loss and cognitive function over a 7-year follow-up period. These inconsistent epidemiologic findings may be due to a variety of reasons, including different measures of hearing loss (e.g., self-reported or objectively measured hearing loss), various measures of cognitive function (e.g., Mini Mental State Examination (MMSE), Digit Symbol Substitution Test (DSST)), different length of follow-up, and different ways of defining "decline". Given this inconsistency, a recent systematic review and meta-analysis was conducted to further understand the relationship from a population perspective. The meta-analysis found significant associations between hearing loss and cognitive impairment among both cross-sectional (OR = 2.00, 95% CI [1.39-2.89]) and prospective cohort studies (OR = 1.22, 95% CI [1.09-1.36]). However, as the authors pointed out, the mechanisms that connect hearing loss and cognitive decline are still not well understood (Loughrey et al., 2018).

As for vision, previous studies have indicated associations between reduced visual acuity and poor cognitive function (Baker et al., 2009; Bowen et al., 2016; Chen, Bhattacharya, & Pershing, 2017; Clemons, Rankin, & McBee, 2006; Ong et al., 2012;

Pham, Kifley, Mitchell, & Wang, 2006; Rait et al., 2005; Reyes-Ortiz et al., 2005; Spierer, Fischer, Barak, & Belkin, 2016; Woo et al., 2012). Although the study findings were mostly consistent, Reyes-Ortiz et al. (2005) measured near and distant vision separately and found that only near vision was associated with a decline in cognitive function over a period of 7 years. These studies, with the exception of Reyes-Ortiz et al. (2005), had similar limitations in that they were cross-sectional, or used a single indicator of change in cognitive function between two measurements as the dependent variable, rather than modeling the longitudinal trajectory of cognitive decline over time using three or more times of measurements. Importantly, these studies were inconsistent in how they represented cognitive function. Some studies used a single measure of working memory (Chen et al., 2017; Ong et al., 2012), whereas others used a brief screening tool (e.g., MMSE) (e.g.,(Clemons et al., 2006) to represent cognitive function.

Despite the increasing evidence that hearing and vision loss can each be associated with cognitive function, there are limitations across all previous studies. In order to better delineate the relationship between one modality of sensory loss and cognitive function, researchers need to consider controlling for the effect of the other modality of sensory loss given the potential correlation between hearing and vision loss (Chen et al., 2017). However, all the previous studies on the association between sensory loss and cognitive function, except a very recent one published in *JAMA* (Chen et al., 2017), failed to adjust for the potential confounding effects of one modality of sensory loss on the other. Additionally, vision and hearing loss tend to co-occur among older adults (Whitson et al., 2018), yet very few studies have been conducted to understand the effect of dual sensory loss of both hearing and vision on cognitive decline over time (Maharani, Dawes, Nazroo, Tampubolon, & Pendleton, 2019; Yamada et al., 2016). Moreover, *APOE* ε4 has been widely acknowledged to be an important risk factor for cognitive decline (Livingston et al., 2017; Plassman et al., 2010). However, all of the previous studies but one (Baker et al., 2009) on the relationship between sensory loss and cognitive function failed to consider and adjust *APOE* ε4 as a covariate. Last but not least, the mechanisms that link sensory loss and cognitive function have not been tested.

In summary, evidence suggests that hearing and vision loss can each be an important risk factor for cognitive decline. However, knowledge gaps still exist. Future studies are still needed to: 1) understand the underlying mechanism for the relationship between sensory loss and cognitive decline; 2) understand the longitudinal individual association between each modality of sensory loss and cognitive decline using objective measures; 3) understand the longitudinal associations between dual sensory loss and cognitive decline. I will conduct my dissertation studies to address these knowledge gaps.

1.3 Social Support

Social support is defined as perceived supportive resources from a person's social engagement or social network (Cohen & Syme, 1985). Social support can be categorized as emotional support, informational support, companionship, and instrumental support (Cohen & Wills, 1985). Lack of sufficient social support has been found to be related to physical and mental health outcomes including depression, cardiovascular disease, and higher mortality rates (Compare et al., 2013; Schwarzer & Rieckmann, 2002; West, 2017).

In most cases, social support implies a positive meaning. However, social scientists have proposed and studied the concept of negative social support. *Negative social support* is defined as perceived negative social exchanges such as conflict, rejection, criticism, and other burden related to social ties (Chen & Feeley, 2014; Rook, 1990). Negative social support was also sometimes called "social strain" (Chen & Feeley, 2014). In previous studies, the term "social support" generally refers to "positive social support" unless otherwise specified.

Less research attention has been allocated to negative social support (i.e., social strain) than positive support. According to the solidarity-conflict model, support and strain can coexist among close relationships (Bengtson, Giarrusso, Mabry, & Silverstein, 2002). Therefore, some experts have recommended studying both positive and negative social support at the same time. However, the "stress-buffering hypothesis" (which we will describe in detail in the following section) is only used to explain the protective effect of positive social support.

1.3.1 Theory and Evidence for Social Support as a Protective Factor for Cognitive Function

The association between social support and cognitive function has been examined among various populations (Barnes, De Leon, Wilson, Bienias, & Evans, 2004; Chen & Feeley, 2014; Yeh & Liu, 2003). Higher levels of social support have been associated with better cognitive function (Chen & Feeley, 2014; Seeman, Lusignolo, Albert, & Berkman, 2001b; Sims et al., 2014; Yeh & Liu, 2003; Zuelsdorff et al., 2013), less cognitive decline over time (Barnes et al., 2004; Dickinson, Potter, Hybels, McQuoid, & Steffens, 2011; Seeman et al., 2001b; Windsor, Gerstorf, Pearson, Ryan, & Anstey, 2014), and reduced risk for incident dementia (Fratiglioni, Paillard-Borg, & Winblad, 2004). Unfortunately, the mechanisms through which social support is associated with better cognitive health remain uncertain.

One prominent theory explaining the protective effect of social support on cognitive function is the stress-buffering hypothesis. In this theory, social support helps to preserve cognitive function through buffering the pathological effects of stressful events and bolstering efficient coping (Cohen & Syme, 1985; Thoits, 2011). In turn there is less chance of developing stress-related problems, such as depression, cardiovascular disease, that may increase the rate of cognitive decline (Chen & Feeley, 2014; Compare et al., 2013; West, 2017). When encountering the same stressor, people with a higher level of social support would tend to experience less detrimental impact on cognitive function than people who have a lower level of social support. In this case, social support would moderate the relationship between the stressor and cognitive decline.

Even though there has been abundant research conducted to understand social support as an independent protective factor against cognitive decline, efforts devoted to understanding social support as a moderator for the relationship between a stressor and cognitive decline are minimal. To my knowledge, only one study has been conducted to examine the stress-buffering effect of social support on cognitive function. Zuelsdorff et al. (2013) conducted a study with 623 participants in the United States aged 40 to 65 years to understand if social support would "buffer" (moderate) the associations between stressful life events and cognitive function among middle-aged adults with a family history of Alzheimer's disease. The results indicated that even though social support and stressful life events were independently associated with cognitive function, there was no significant interaction between social support and stressful life events, indicating no significant moderation effect of social support on the relationship between stressful life events and cognitive function. Despite focusing on a different stressor, Zuelsdorff's study provides a foundation for examining the moderating effect of social support on the associations between stressful life events and cognitive function.

1.4 Loneliness

Loneliness is defined as a state in which the individual perceives their relationships to be insufficiently fulfilling or of poor-quality (Cacioppo & Hawkley, 2009; Chen & Feeley, 2014; Courtin & Knapp, 2017; Coyle & Dugan, 2012; Nicholson Jr, 2009; Nicholson, 2012). Loneliness is sometimes called perceived social isolation and can threaten the well-being of older adults (Cornwell & Waite, 2009; DiNapoli, Wu, & Scogin, 2014). Loneliness has been associated with elevated risk of depression (Gonyea, Curley, Melekis, Levine, & Lee, 2018; Ong, Uchino, & Wethington, 2016), increased systolic and diastolic blood pressure (Petitte et al., 2015; Tomaka, Thompson, & Palacios, 2006), and higher risk of cardiovascular disease and mortality (Steptoe, Shankar, Demakakos, & Wardle, 2013; Uchino, 2006).

1.4.1 Differentiation between Loneliness and Social Support

Loneliness and social support reflect related but distinct perspectives of social relationships (Tomaka et al., 2006; Wang, Mann, Lloyd-Evans, Ma, & Johnson, 2018). *Loneliness* describes the perceived deficient quality or quantity of social interactions, while *social support* reflects the positive content or perceptions of supportive resources from a person's social relationships. Therefore, loneliness is not the negative counterpart of social support but describes an individual's social relationship from an emotional perspective (Wang, Mann, et al., 2018). Previous studies used diverse instruments to measure loneliness (Chen & Feeley, 2014; Cornwell & Waite, 2009; Courtin & Knapp, 2017; Coyle & Dugan, 2012; Donovan et al., 2017; Fratiglioni et al., 2004).

1.4.2 Theory and Evidence on Loneliness as a Risk Factor for Cognitive Decline

Epidemiologic studies have demonstrated associations between a higher level of loneliness and lower cognitive function (Cacioppo & Hawkley, 2009; Conroy, Golden, Jeffares, O'Neill, & McGee, 2010; Luanaigh & Lawlor, 2008; O'luanaigh et al., 2012; Shankar, Hamer, McMunn, & Steptoe, 2013), faster cognitive decline over time (Buchman et al., 2010; Donovan et al., 2017), and increased likelihood of dementia (Livingston et al., 2017; Wilson et al., 2007). Based on the evidence, the UK National Institute of Health and Care Excellence (NICE) and the US National Institutes of Health (NIH) identified loneliness as a potential risk factor for dementia (Livingston et al., 2017).

Despite the increasing evidence of an association between loneliness and cognitive function, the mechanisms that connect loneliness and cognitive function are still not clear. People who experience loneliness may have less exposure to healthy social interactions. Being distant from a socially-engaged lifestyle can result in fewer exposures to stimulating cognitive activities (e.g., engaged lifestyle, leisure activities), which can contribute to preserving better cognitive function among older adults (Cacioppo, Norris, Decety, Monteleone, & Nusbaum, 2008; Fratiglioni et al., 2004; Hultsch, Hertzog, Small, & Dixon, 1999; Wang, Karp, Winblad, & Fratiglioni, 2002).

1.5 Conceptual model

In this dissertation, we will systematically examine the inter-relationships between sensory loss, social support, loneliness, and cognitive function by conducting secondary analyses of data from three studies: the Population Study of Chinese Elderly in Chicago (PINE), the Health and Retirement Study (HRS), and Aging, Demographics, and Memory Study (ADAMS). It is important to examine and understand the inter-relationships because new insights can be gained about (1) the relationship between psychosocial factors and cognitive function among a culturally unique population - U.S. Chinese older adults; (2) the mechanisms connecting the relationship between sensory loss and cognitive decline, and (3) the potential to develop interventions to prevent cognitive decline by intervening with the corresponding risk factors.

1.5.1 Conceptual Model for the Relationship between Sensory Loss, Social Support and Cognitive Function

Based on the "stress-buffering" hypothesis of social support, we propose that social support may buffer the negative effect of sensory loss on cognitive decline by bolstering coping strategies (Cohen & Syme, 1985; Thoits, 2011).

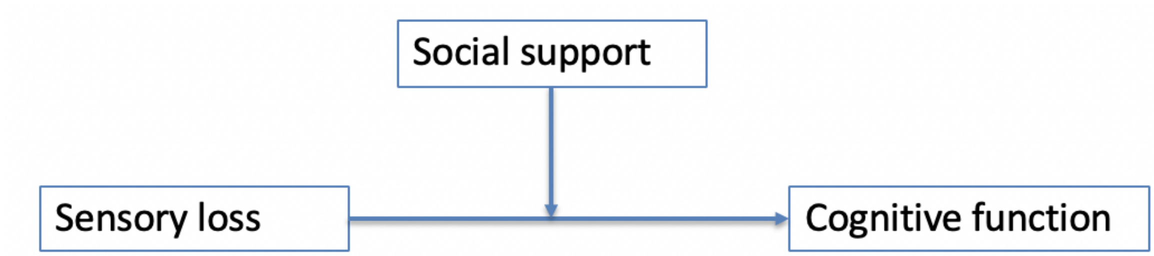

Figure 2: Path illustration: social support as the moderator.

Sensory loss is a chronic stressor that can cause ongoing, long-term functional limitations and difficulties for individuals as they attempt to engage in day-to-day activities (Pearlin, Menaghan, Lieberman, & Mullan, 1981; West, 2017). Older adults with sensory loss face daily life challenges in mobility (e.g., driving), activity (e.g., capacity to attend group fitness class), and communication (e.g., engage in pastimes with friends) (Bittner, Edwards, & George, 2010; Brennan & Bally, 2007; Mick, Kawachi, & Lin, 2014). As a result, older adults with sensory loss need to continuously manage, cope, and adapt to their physical limitations (Bittner et al., 2010; Brennan & Bally, 2007). Under such circumstances, extra assistive social resources are helpful and may diminish or even prevent the negative effects of sensory loss (Pearlin et al., 1981; West, 2017).

Specifically, older adults with a higher level of social support are likely to cope better with sensory loss (Cohen & Syme, 1985; Cohen & Wills, 1985; Mick et al., 2014; Thoits, 1986) because of their greater access to emotional support (e.g., encouragement and comfort), companionship, instrumental assistance (e.g., transportation to a community center, financial support, assistance with obtaining hearing and vision aids), and information support (e.g., emphasizing the significance of wearing hearing and vision aids, or learning about different options to support sensory function). These supportive resources can buffer the impact of sensory loss on cognitive function by reducing negative emotional reactions (West, 2017) and by reducing the harmful impact of decreased social interactions (Mick et al., 2014). In contrast, those with a lower level of social support may not have these supportive resources. Therefore, older adults with sensory loss and low social support may be more vulnerable to cognitive decline. In other words, the association between sensory loss and cognitive function may differ based on different levels of social support. This function played by social support corresponds to the moderation effect as defined in Baron and Kenny (1986) (Figure 2).

1.5.2 Conceptual Model for the Relationship between Sensory Loss, Loneliness, and Cognitive Function

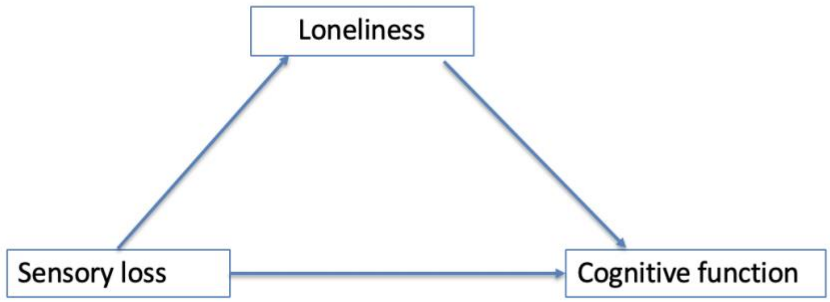

Figure 3: Path illustration: loneliness as the mediator.

Sensory loss has been widely hypothesized to cause cognitive decline through a pathway of loneliness (Fulton et al., 2015; Hong et al., 2016; Lin, 2011; Lin, Metter, et al., 2011; Lin et al., 2013; Spierer et al., 2016; Yamada et al., 2016) (Figure 3). Older adults with sensory loss are likely to encounter difficulties in communication with families and friends. Therefore, sensory-impaired older adults' social relationships can be harmed by miscommunications and misunderstandings (Crews & Campbell, 2004; Guthrie, Declercq, Finne-Soveri, Fries, & Hirdes, 2016; Mick et al., 2014). Consequently, older adults with sensory loss may experience a progressively shrinking number of social interactions. Moreover, older adults with sensory loss may feel negative emotions due to functional and communication difficulties (Heine & Browning, 2004) and have a tendency to passively or intentionally withdraw from social interactions (Mick et al., 2014). The decreased amounts of social interactions can result in less exposure to cognitive stimuli and which has been associated with worse cognitive function (DiNapoli et al., 2014; Fratiglioni et al., 2004; Hultsch et al., 1999; Stern, 2006; Wang et al., 2002; Wilson et al., 2007). Therefore, there can be a cascade between sensory loss, loneliness, and cognitive decline. In other words, loneliness may perform as a mediating factor (Baron & Kenny, 1986) between sensory loss and cognitive function.

1.5.3 Conceptual Model for the Inter-relationships between Sensory Loss, Loneliness, and Cognitive Function

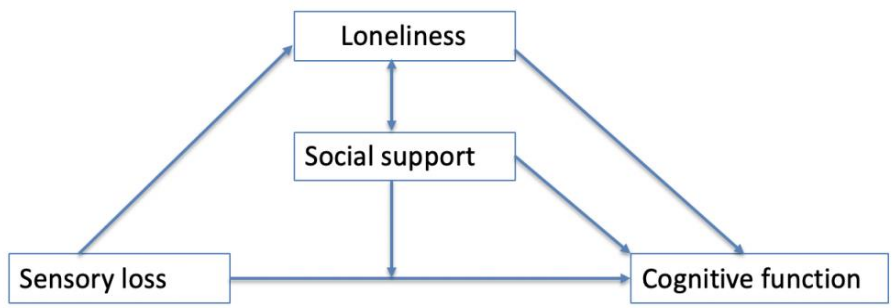

Figure 4: Conceptual model for the Inter-relationships between Sensory Loss, Loneliness, and Cognitive Function.

Based on the theories and empirical literature described above, we propose the conceptual model in Figure 4.

1.6 Purpose Statement and Aims

The purpose of this dissertation is to broaden and deepen our understanding of the roles of two categories of potential risk factors for decline in cognitive function among older adults: sensory loss and psychosocial factors. Specifically, based on our constructed conceptual model, we will conduct the following three studies.

1.6.1 Chapter 2

In Chapter 2, we will examine the path between social support and cognitive function in our conceptual model. This path is an important part of our conceptual model and several studies have been conducted to understand this relationship (Seeman et al., 2001b; Sims et al., 2014; Yeh & Liu, 2003). Yet, no research attention has been allocated to understand this relationship among Chinese older adults residing in the United States. The dramatic changes in their cultural-social environment post immigration made U.S. Chinese older adults particularly at risk of insufficient social support (Chen, Simon, Chang, Zhen, & Dong, 2014). Despite the fast increase in the number of U.S. Chinese older adults, research on cognitive function among this population was scarce due to a lack of culturally competent cognitive measures (Chang & Dong, 2014a). Therefore, it is important to understand the relationship between social support, social strain, and cognitive function among this group of older adults.

The specific aims of this study are:

1. To examine the associations between social support, social strain (i.e., negative social support), and global cognitive function as well as across specific cognitive

domains (i.e., episodic memory, working memory, and executive function) in a cross-sectional study of community-dwelling U.S. Chinese older adults; and

2. To explore the various sources of social support and social strain (i.e., negative social support) in relation to global cognitive function and specific cognitive domains.

1.6.2 Chapter 3

Increasing evidence suggests that hearing and vision loss can each be independently associated with cognitive function and cognitive decline (Baker et al., 2009; Bowen et al., 2016; Chen et al., 2017; Clemons et al., 2006; Lin, Metter, et al., 2011; Lin et al., 2013; Livingston et al., 2017; Ong et al., 2012; Pham et al., 2006; Rait et al., 2005; Reyes-Ortiz et al., 2005; Spierer et al., 2016; Woo et al., 2012; Yuan et al., 2018). However, knowledge gaps still exist, and future studies are still needed to 1) examine the effects of objectively measured hearing and vision loss on cognitive decline; 2) understand the longitudinal association between vision loss and cognitive decline; and 3) understand the longitudinal association between dual sensory loss and cognitive decline. Chapter 3 will be conducted to address these knowledge gaps.

The specific aims of this study are:

1. To examine the associations between hearing loss and cognitive decline, and vision loss and cognitive decline, as people grow older; and

2. To examine the associations between dual sensory loss and cognitive decline as people grow older.

1.6.3 Chapter 4

Different categories of risk factors for cognitive decline may be inter-related and may alter each other's relationship with cognitive function and cognitive decline (West, 2017; Whitson et al., 2018; Yamada et al., 2016). Sensory loss has been hypothesized to be associated with cognitive decline through the pathway of loneliness (Fulton et al., 2015; Hong et al., 2016; Lin, 2011; Lin, Metter, et al., 2011; Lin et al., 2013; Spierer et al., 2016; Yamada et al., 2016). On the other hand, sensory loss is a chronic stressor that can cause ongoing function limitations and difficulties for older adults in their daily activities (Pearlin et al., 1981). According to the stress-buffering hypothesis, social support can buffer the harmful impact of sensory loss on health outcomes, including cognitive function (West, 2017; Zuelsdorff et al., 2013). However, to my knowledge, no studies have been conducted to test these hypotheses. Therefore, in Chapter 4, we aim to 1) gain a better understanding of the underlying mechanisms connecting the relationship between sensory loss and cognitive decline and 2) examine the stress-buffering hypothesis of social support in the relationship between sensory loss and cognitive decline over time.

The specific aims of this study are:

1. To examine if loneliness mediates the associations between sensory loss (i.e., hearing or vision loss) and future cognitive decline as people grow older;

2. To examine if social support moderates the associations between sensory loss (i.e., hearing or vision loss) and future cognitive decline as people grow older;

3. To explore if loneliness mediates the association between dual sensory loss (i.e., both hearing and vision loss) and future cognitive decline as people grow older; and

4. To explore if social support moderates the association between dual sensory loss (i.e., both hearing and vision loss) and future cognitive decline as people grow older.

1.6.4 Chapter 5

In Chapter 5 we will synthesize and discuss key findings from the three studies conducted in my dissertation. We will also discuss implications of our findings for future research and practice.

2. Social Support, Social Strain, and Cognitive Function Among Community-Dwelling U.S. Chinese Older Adults

2.1 Background

The population of U.S. Chinese older adults aged 65 and above has increased dramatically by 55% in the past decade, far exceeding the population growth rate of 15% among general U.S. older adults (U.S. Census Bureau, 2010). Despite this dramatic increase, research on cognitive aging of U.S. Chinese older adults was limited due to methodological barriers such as a lack of linguistically and culturally sensitive instruments, and difficulties in recruitment (Chang & Dong, 2014b). Cognitive function is crucial to older adults as it is closely associated with physical function, psychological health, and quality of life (Rosano et al., 2004; Saraçlı et al., 2015). Having a better understanding of cognitive function among the increasing U.S. Chinese older adults has become a prominent issue for researchers, policy makers, and healthcare providers.

An older adult’s cognitive function is affected by psychosocial factors such as social support and social strain (Chen & Feeley, 2014; Tun, Miller-Martinez, Lachman, & Seeman, 2013; Yeh & Liu, 2003; Zunzunegui, Alvarado, Del Ser, & Otero, 2003). *Social support* is defined as perceived supportive resources from a person’s social engagement or social network, whereas *social strain* is conceptualized as perceived negative social exchanges such as conflict, rejection, criticism, and support failure (Chen & Feeley, 2014). Previous studies about social support and social strain on cognitive function have reported mixed findings (Chen & Feeley, 2014; Seeman, Lusignolo, Albert, & Berkman, 2001a; Sims et al., 2014; Tun et al., 2013; Yeh & Liu, 2003; Zunzunegui et al., 2003). Within these context, theoretical mechanism underlying the association between social support/strain and cognitive function or other health outcomes is largely inconclusive (Antonucci, Akiyama, & Lansford, 1998; Cohen & Syme, 1985; Lazarus & Folkman, 1984; Windsor et al., 2014). According to the solidarity-conflict model, support and strain are not competing or antagonistic concepts but can coexist among close relationships (Bengtson et al., 2002). Although empirical evidence was inconclusive, potential correlations (Okabayashi, Liang, Krause, Akiyama, & Sugisawa, 2004) or interactions (Tun et al., 2013) between sources of social support/strain may further complicate the picture.

Understanding the relationship between social support, social strain and cognitive function among U.S. Chinese older adults is critical. The uniqueness of this population is shaped by the interplay of race, culture, and immigration (Chen et al., 2014). As an ethnic minority, many Chinese older adults have high expectation of support from their adult children because of financial constrains (Chinese Health, 2011; Wu et al., 2005) and cultural preference (Chen et al., 2014). However, with the substantial social, cultural, and financial changes after immigration, the children's generation may not hold on to these traditional Chinese cultural norms and fail to meet the older adults' needs (Dong et al., 2010). Also, family was traditionally ranked of the highest importance in the Chinese older adults' life (Chi & Chou, 2001). Yet, given the insufficient receipt of support from children and other family members, U.S. Chinese older adults have to seek more support from friends (Dong et al., 2010). Despite these challenges faced by the U.S. Chinese older adults, we have limited knowledge about the relationship between social support, social strain, and cognitive function among this population.

Building upon previous studies, we formulated our study hypotheses: 1) higher levels of social support would have a positive association with cognitive outcomes; and higher levels of social strain would have a negative association with cognitive outcomes. 2) support from a spouse would be the source that most significantly associated with cognitive outcomes. Although U.S. Chinese older adults can be heterogeneous based on their origin and cultural background, this study is unique because we used the data from the PINE study, which is the largest population-based study (N=3,159) and has the best representativeness of U.S. Chinese in the Western world. We believe the current study contributes to understanding the potential cross-cultural disparities in the relationship between social support/strain with cognitive function. It also helps to better understand the comparative importance of each source of social support in regards of reserving/deteriorating cognitive function.

2.2 Methods

2.2.1 Population and Settings

This study used data from the Population Study of Chinese Elderly in Chicago (PINE). The purpose of the PINE study was to examine the relationship between key cultural determinants, health and wellbeing among community-dwelling U.S. Chinese older adults (Dong, Wong, & Simon, 2014). Built on a community-based participatory research (CBPR) approach, the PINE team designed and implemented culturally and linguistically sensitive community recruitment strategies to recruit from community centers, social service agencies, and senior apartments (Simon, Chang, Rajan, Welch, & Dong, 2014). Out of 3,542 eligible older adults approached, 3,159 agreed to participate in the study.

2.2.2 Measures

2.2.2.1 Dependent variables

Cognitive function. Cognitive function was assessed by the following. The Chinese Mini Mental Status Exam (C-MMSE) is a modified version of (MMSE) and has been validated for use with Chinese aging populations (range 0-30) (Chiu, Lee, Chung, & Kwong, 1994). Episodic memory was assessed with the composite score of immediate recall and delayed recall of the East-Boston Memory Test (EBMT) (range 0-24). Executive function was assessed with the 11-item Symbol Digit Modalities Test (range 0-80). Working memory was assessed with the Digit Span Backwards test. Based on all five tests, a global cognitive function score was calculated using z-transformation and then averaging the transformed z score across the five tests (Chang & Dong, 2014b); higher scores indicate higher cognitive function.

2.2.2.2 Independent variables

Social support. Social support was measured by the Health and Retirement study (HRS) social support scale (Chen et al., 2014). For each source of social support (spouse, other family members, and friends), participants were asked "How often can you open up to if you need to talk about your worries" and "How often can you rely on for help if you have a problem?". The response options ranged from 1 (hardly ever) to 3 (often). Social support was calculated as the average of all the six items, and each source of social support was calculated separately by the average of the two items within each source (Cronbach's alpha 0.73) (Chen & Feeley, 2014).

Social strain. The social strain scale was also drawn from HRS (Chen et al., 2014). Social strain was measured by asking the participants to report the frequency of being "criticized" or "having too many demands" made by the spouse, other family members and friends. Responses ranged from 1 (hardly ever) to 3 (often), with a higher value represented a higher level of social strain. Social strain was calculated as the average of the six items, and each source of social strain was calculated separately by the average of the two items within each source (Cronbach's alpha 0.63) (Chen & Feeley, 2014).

2.2.2.3 Covariates

Demographics. Demographics included age, gender, education, marital status, personal annual income, length of residence in the community, and living arrangement.

Acculturation. Acculturation was measured using the 12-item short acculturation scale (range 12-60) developed by Marin and colleagues (Marin, Sabogal, Marin, Otero-Sabogal, & Perez-Stable, 1987) with higher score representing a higher acculturative level (Cronbach's alpha 0.88).

Depression. Depression was evaluated using the 9-item Patient Health Questionnaire (PHQ-9) (range 0– 27) (American Psychiatric Association, 1994); a higher score represented a higher level of depression (Cronbach's alpha 0.82).

Medical conditions. Self-reported medical conditions included diabetes, hypertension, hypercholesterolemia, stroke, cardiac disease, cancer (sum of the disease conditions, range 0-6).

Physical function. Physical function was measured by ADL (range 4-18, Cronbach's alpha 0.92) and IADL (range 0-8, Cronbach's alpha 0.90), with higher scores indicating worsening physical function in both scales (Dong, Chang, & Simon, 2014).

2.2.2.4 Data Analysis

A series of unadjusted linear regression analyses were used to examine the association between the independent variables and the dependent variables. Next, each of the linear regression analyses was repeated and adjusted for covariates, which were selected based on their bivariate associations with cognitive function. Pearson correlation coefficients, variance inflation factor (VIF < 10.0) and tolerance (tolerance > .01) diagnostic methods were used to screen for multicollinearity among variables included in the models. Potential interactions between overall and different sources of social support/strain were also screened. The non-directional statistical tests were conducted with p-value at 0.05, and standardized regression coefficients were used to describe the results. All analyses were performed using SAS 9.3 (SAS Institute Inc., Cary, NC).

2.3 Results

2.3.1 Participants

Among the 3,159 participants, 58.9% were female. The mean age was 72.8 (range 60-105) (see Table 1). Social support score ranged from 2 to 18 (M = 11.95). Social strain measure ranged from 3 to18 (M = 6.12). Global cognitive function (the z score) ranged from -2.8 to 2.0 (M = -0.002). Other information related to social support, social strain, and cognitive outcomes are also displayed in table 1.

< Table 1>

2.3.2 Social Support and Social Strain

There were no significant interactions found between overall or any source of social support and strain. No multicollinearity was found in the models. Based on the fully adjusted models, U.S. older adults who received more overall social support tended to preserve better global cognitive function (β = .11, *SE* = .02, $p < .001$), episodic memory (β = .11, *SE* = .03, $p < .001$), working memory (β = .18, *SE* = .08, $p < .05$) and executive function (β = 1.44, *SE* =.37, $p < .001$). Older adults who had more overall social strain also prone to have better global cognitive function (β = .23, *SE* = .05, $p < .001$), episodic memory (β = .27, *SE* = .07, $p < .001$), working memory (β = .34, *SE* = .17, $p< .05$) and executive function (β = 2.75, *SE* = .85, $p < .01$) (see Table2).

< Table2>

2.3.3 Social Support and Social Strain from Spouse, Family Members and Friends

Again, we found no significant interactions and no multicollinearity issue over the process of analyses. Based on the fully adjusted models, older adults those who received higher levels of support from friends had higher global cognitive function (β = .04, *SE* = .02, $p < .05$). Those who received higher levels of support from friends (β = .05, *SE* = .02, $p < .05$) and who received higher levels of strain from spouse (β = .11, *SE* = .04, *p*

< .01) reported higher score of episodic memory. Older adults who had higher level of support from friends (β = .71, SE = .29, p < .05), higher level of strain from spouse (β = 1.28, SE = .49, p < .01), and higher level of strain from friends (β = 3.59, SE = 1.17, p < .01) had higher score of executive function (see Table3). None of the sources of social support/strain was significantly associated with working memory (p > .05).

<Table 3>

2.4 Discussion

We found no significant interactions between overall or any source of social support and social strain. Higher levels of social support and social strain had significant associations with higher levels of cognitive outcomes (i.e., global cognitive function, episodic memory, working memory, executive function). However, findings related to sources of social support and social strain were mixed. Specifically, strain from spouse and support from friends were significantly associated with global cognitive function, episodic memory, and executive function. Strain from friends was significantly associated with executive function. Support or strain from family members had no significant associations with any of the cognitive outcomes, regardless of adjusting for covariates or not.

Surprisingly, our study found that higher social strain was associated with higher levels of global cognitive function as well as each of the specific cognitive domains. These findings were in contrast to our hypothesis that higher social strain would be associated with lower cognitive function (Chen & Feeley, 2014; Tun et al., 2013). The unexpected findings may partially be explained by the following reasons. (1) U.S. Chinese older adults may have unique features of appraisals comparing to previously studied populations. Reporting social strain may reflect a socially engaged life-style (Windsor et al., 2014). Influenced by the traditional Chinese culture and norm, the U.S. Chinese older adults view their active engagement in the family as indications of self-value (Wu et al., 2005). Consequently, U.S. Chinese older adults are likely to have more positive evaluations of their social strain. (2) The co-existence of social support and social strain. A previous study found that U.S. Chinese older adults who perceive higher social support also tend to perceive higher social strain (Chen et al., 2014). This finding along with ours are consistent with the theoretical underpinning of the solidarity-conflict model (Bengtson et al., 2002).

One of the important contributions of our study is of categorizing and accounting for different sources of social support and strain. Our study partially supported our hypothesis and found that higher level of support from friends and higher level of strain from spouse showed strong associations with higher global cognitive function. These findings were consistent with Chen and colleagues' findings (Chen & Feeley, 2014), which also indicated a significant relationship with support from friends and strain from spouse in the Health and Retirement Study. It is possible that both studies recruited community-dwelling older adults, where frequent interactions with friends are an important component of their social life. Having more support from friends may indicate a lifestyle involving more out-of-home and intellectually stimulating activities (Windsor et al., 2014) that could be beneficial for the preservation of cognitive function (Fratiglioni et al., 2004; Tilvis et al., 2004).

Another important contribution of the study is that we have expanded our understanding of social support and social strain in relationship with different cognitive domains. This process is important given the role of specific cognitive domains in disease diagnosis (Román et al., 1993). Without considering sources of social support/strain, we found significant associations between overall social support/strain with all three specific cognitive domains. However, the associations were attenuated after the sources of social support/strain (i.e., spouse, family members, and friends) were taken into consideration. Specifically, higher strain from spouse and from friends, as well as higher support from friends had significant associations with higher executive function. The basis was unclear as previous studies were scarce and the results varied (Sims et al., 2014; Windsor et al., 2014). One possibility may be that the measurement of executive function is more sensitive to capture the age-related declines as compared to measurements of other cognitive domains (Johnson, Lui, & Yaffe, 2007; Windsor et al., 2014). This sensitivity may be especially important in our sample of community-dwelling U.S. Chinese older adults, among whom 42% were between 60 and 70 years old and tended to have intact cognitive function. Our findings suggested that social exchanges with friends were critical in preserving older adults' abilities in planning, organizing, and implementing tasks. These findings furthered our understanding of the benefit of a socially engaged lifestyle.

The findings of this study should be interpreted in the context of several limitations. The study participants were recruited from the greater Chicago area. The generalizability of these findings to Chinese older adults living in other regions of the U.S. might be limited. However, the findings are still important given the representativeness of the current study sampling to the greater Chicago area (Simon et al., 2014), and this is by far the largest study targeting Chinese older adults in the Western world (Dong, Wong, et al., 2014). In addition, the current study only measured and analyzed emotional support but has not taken other aspects of support, such as financial and instrumental support into consideration. Future studies should also examine the potential contributions of other aspects of social support to cognitive outcomes. Further, the cross-sectional study design of the current study limits our understanding of the temporal relationship between social support and cognitive function. Future longitudinal studies will be helpful in understanding of the variations of associations between social support/strain and cognitive function over time.

This study has important implications for researchers, policy makers, and healthcare providers. With the recent 2015 White House Conference on Aging announcement that combating dementia is a high priority, new preventive policies and programs that help promote healthy brain are highly needed (The White House Office of the Press Secretary, 2015a). This study contributes to the understanding of the potential cross-cultural disparities in terms of social support/strain and cognitive function. It also warrants further exploration on the insignificant results on the association between social support from spouse and other family members and cognitive functioning within this population. Qualitative analysis should be conducted to capture the essence of support/strain from friends and understand why they play such important roles in the U.S. Chinese older adults' lives. Future studies are also needed to explore social support/strain as predictors of cognitive decline over time. Local community services organizations should encourage older adults to be more involved in community activities and peer supported social groups. Policies and programs targeting U.S. Chinese older adults should also be designed with appreciations of the culture valued by this specific population.

In sum, this study demonstrates that both social support and social strain have significant associations with global cognitive function, as well as consistently across cognitive outcomes. However, the findings with respect to sources of social support and social strain were mixed. The findings in this study highlight the importance of integrating support from spouse and friends into policy and program developments. Future studies should be conducted to better understand the mechanism through which social support/strain have an impact on cognitive function in this unique cultural context.

Note: Chapter 2 has been published in the Journals of Gerontology: Series A.

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The full paper can be found via link:
https://academic.oup.com/biomedgerontology/article/72/suppl_1/S16/3859670

Table 1: PINE Study Participant Characteristics (N = 3,159).

Variable name	N (Percentage)	Mean± SD (range)
Age		72.8±8.3 (60-105)
60-69	1,324 (42.0)	
70-79	1,163 (36.8)	
80 and over	672 (21.2)	
Gender		
Male	1,297 (41.1)	
Female	1,862 (58.9)	
Marital status		
Married	2,237 (71.3)	
Separated or Divorced	131 (4.2)	
Widowed	769 (24.5)	
Income		
US$0- US$9,999	2,658 (85.1)	
US$10,000- US$19,999	378 (12.1)	
US$20,000 and over	87 (2.8)	
Education		8.7±5.1 (0-26)
0	195 (6.2)	
1-6	1,179 (37.6)	
7-12	1,103 (35.1)	
13-16	576 (18.3)	
17 and over	87 (2.8)	
Length of residence in the community		12.1±11.0 (0.1-80.0)
0-10	1,811 (57.5)	
11-20	740 (23.5)	
21-30	388 (12.3)	
31 and more	210 (6.7)	
Living arrangement		1.9±1.9 (0-10)
Living alone	679 (21.5)	
Not alone	2,479 (78.5)	
Acculturation		15.3±5.1 (12-60)
Medical conditions		1.4±1.2 (0-5)
Depression		2.7±4.1 (0-27)
Social support		11.9±3.8 (2-18)
From spouse		3.7±2.5 (0-6)
From family members		4.8±1.3 (2-6)
From friends		3.3±1.9 (0-6)
Social strain		6.1±1.8 (3-18)

From spouse	1.8±1.4 (0-6)
From family members	2.2±0.6 (2-6)
From friends	2.1±0.4 (2-6)
Global cognitive score	-0.002±0.9 (-2.8-2.0)
Episodic memory	-0.005±1.0 (-2.7-1.3)
Working memory: DB	0.0±1.0 (-2.1-2.9)
Executive function: SDMT	0.0±1.0 (-2.4-4.2)

Notes: C-MMSE = Chinese Mini-Mental State Exam; DB = Digit Span Backwards; SDMT = Symbol Digit Modalities Test.
Each cognitive test is the *z*-score

Table 2: Regression analysis of the associations between social support, social strain and cognitive outcomes (N = 3,159).

	Global cognitive function		Episodic memory		Working memory		Executive function	
	Estimate R^2=0.11	Adj. R^2=0.51	estimate R^2=0.08	Adj. R^2=0.36	estimate R^2=0.06	Adj. R^2=0.32	estimate R^2=0.10	Adj. R^2=0.46
Social support	0.31 (0.02)***	0.11 (0.02)***	0.31 (0.03)***	0.11 (0.03)***	0.66 (0.07)***	0.18 (0.08)*	4.55 (0.39)***	1.44 (0.37)***
Social strain	0.48 (0.05)***	0.23 (0.05)***	0.47 (0.06)***	0.27 (0.07)***	0.99 (0.15)***	0.34 (0.17)*	5.92 (0.83)***	2.75 (0.85)**

Note. *$p<.05$, ** $p<.01$, *** $p<.001$
Adj. = estimates adjusted for covariates (age, gender, education, marital status, income, length of residence in community, living arrangement, acculturation, depression, medical conditions, ADL, IADL)

Table 3: Estimates of multiple regression models: social support and social strain from different sources (N = 3,159).

	Global cognitive function		Episodic memory		Working memory		Executive function	
	estimate	Adj.	estimate	Adj.	estimate	Adj.	estimate	Adj.
	R^2=0.11	R^2=0.48	R^2=0.08	R^2=0.33	R^2=0.06	R^2=0.30	R^2=0.09	R^2=0.43
Support from spouse	0.08 (0.02)***	0.03 (0.02)	0.07 (0.02)***	0.03 (0.03)	0.19 (0.05)***	0.10 (0.08)	0.90 (0.29)**	-0.01 (0.37)
Support from family members	-0.03 (0.03)	0.02 (0.02)	-0.02 (0.03)	0.02 (0.03)	-0.12 (0.08)	0.05 (0.07)	-0.33 (0.43)	0.38 (0.35)
Support from friends	0.17 (0.02)***	0.04 (0.02)*	0.18 (0.03)***	0.05 (0.02)*	0.34 (0.07)***	0.06 (0.06)	2.47 (0.35)***	0.71 (0.29)*
Strain from spouse	0.22 (0.03)***	0.10 (0.03)**	0.21 (0.04)***	0.11 (0.04)**	0.50 (0.10)***	0.19 (0.10)	3.22 (0.53)***	1.28 (0.49)**
Strain from family members	0.11 (0.06)	0.08 (0.05)	0.13 (0.07)	0.10 (0.06)	0.06 (0.17)	0.04 (0.15)	0.17 (0.96)	-0.07 (0.78)
Strain from friends	0.17 (0.09)	0.10 (0.07)	0.22 (0.11)*	0.10 (0.10)	0.16 (0.26)	0.12 (0.24)	2.05 (1.37)	3.59 (1.17)**

Note. *p<.05, ** p<.01, *** p<.001
Adj. = estimates adjusted for covariates (age, gender, education, marital status, income, length of residence in community, living arrangement, acculturation, depression, medical conditions, ADL, IADL)

3. Associations between Hearing Loss, Vision Loss, and Dual Sensory Loss and Cognitive Decline: Findings from the ADAMS Study

3.1 Introduction

As a result of the general trend of global aging, cognitive impairment and Alzheimer's disease and related dementia (ADRD) among older adults has become a major public health and social issue (Deary et al., 2009; Prince et al., 2017; World Health Organization, 2012). Decreased cognitive function, ranging from mild cognitive impairment (MCI) to ADRD, presents severe challenges for older adults' daily lives (Apostolova & Cummings, 2008; Herman et al., 2010; Mirelman et al., 2012; Pusswald et al., 2015). ADRD is projected to affect a population of more than 152 million globally by the year 2050 (Prince, Bryce, & Ferri, 2018; World Health Organization, 2019). Multiple countries have identified preventing ADRD as an important public health priority, including the United States. In 2015, the White House Conference on Aging has announced that combating ADRD is a high priority, indicating the need for programs that can help prevent cognitive decline in the populations at risk (The White House Office of the Press Secretary, 2015b). Identifying and understanding risk factors for cognitive decline will contribute to developing effective intervention programs to better preserve cognitive function in the aging population.

Hearing loss and vision loss have each drawn increasing research attention as risk factors for cognitive decline and ADRD. Hearing loss and vision loss are significant public health issues with projected heightened prevalence among older adults in the next few decades (Lin, Thorpe, et al., 2011; Varma et al., 2016). Among older adults aged above 70, more than 60% of them are affected by hearing loss (Gates et al., 1990; Lin, Thorpe, et al., 2011; Van Eyken et al., 2007; Walling & Dickson, 2012), and about 40% are affected by vision loss (Bourne et al., 2017; Stevens et al., 2013). Accumulating evidence suggests that both hearing and vision loss can be independently associated with cognitive decline (Baker et al., 2009; Bowen et al., 2016; Chen et al., 2017; Clemons et al., 2006; Deal et al., 2016; Lin, Metter, et al., 2011; Lin et al., 2013; Livingston et al., 2017; Maharani et al., 2019; Ong et al., 2012; Pham et al., 2006; Rait et al., 2005; Reyes-Ortiz et al., 2005; Spierer et al., 2016; Woo et al., 2012; Yuan et al., 2018; Zheng et al., 2018). Importantly, longitudinal studies have demonstrated that individuals with decreased hearing or vision were likely to have a faster rate of decline in global cognitive function and a higher likelihood of developing cognitive impairment (Lin et al., 2013; Livingston et al., 2017; Ong et al., 2012; Pham et al., 2006; Reyes-Ortiz et al., 2005; Yuan et al., 2018; Zheng et al., 2018).

However, knowledge gaps still exist. Despite the accumulating evidence, most of the prior evidence is from cross-sectional studies. There have been far fewer longitudinal studies on the relationship between sensory loss and cognitive function, and the findings have been highly inconsistent. Some longitudinal studies have found significant associations between sensory loss and cognitive decline (Alattar et al., 2019; Deal et al., 2015; Lin et al., 2013; Maharani et al., 2019; Reyes-Ortiz et al., 2005), but others have not (Deal et al., 2016; Hong et al., 2016; Lin et al., 2004; Maharani et al., 2019; Reyes-Ortiz et al., 2005). The inconsistencies in previous study findings are related to differences in ways of measuring sensory loss (subjective or objective), measures of cognitive function, and lengths of follow-up. Additionally, the prevalence of dual sensory loss can be as high as 22.5% among older adults aged more than 70 (Brennan, Su, & Horowitz, 2006; Fuller, Mudie, Siordia, Swenor, & Friedman, 2018). These older adults face even more challenges in their daily lives due to their extended functional limitations (Brennan, Horowitz, & Su, 2005; Cosh et al., 2018; Heine & Browning, 2015; Simning, Fox, Barnett, Sorensen, & Conwell, 2018). However, very few longitudinal studies have been conducted to examine the association between having dual sensory loss (i.e., both hearing and vision) and cognitive decline (Lin et al., 2004; Yamada et al., 2016). Therefore, studies are still needed to further understand the longitudinal relationship between sensory loss and cognitive decline over time using national data with robust measures.

To better understand the roles of hearing and vision loss as risk factors for cognitive decline, this study aims to 1) examine the associations between hearing loss and cognitive decline, and vision loss and cognitive decline, as people grow older; and 2) examine the associations between dual sensory loss and cognitive decline as people grow older.

3.2 Methods

3.2.1 Parent Study Overview and Data Source

This is a longitudinal study using data from Health and Retirement Study (HRS) and its supplement: The Aging, Demographics, and Memory Study (ADAMS).

The Health and Retirement Study (HRS) is a population-based, nationally representative epidemiological survey of U.S. adults aged 50 years and older. The HRS was sponsored by the National Institute on Aging and was conducted by the University of Michigan. HRS is an ongoing longitudinal study. Participants were first interviewed in 1992 and every two years thereafter.

The Aging, Demographics, and Memory Study (ADAMS) is a supplement to the HRS and was also funded by the NIA. ADAMS is a population-based study of dementia among older adults aged 70 or older (Plassman et al., 2007). Four waves of data collection (waves A, B, C, D) occurred during the following time periods: Aug 2001- Dec 2003, Nov 2002 - Mar 2005, Jun 2006 - May 2008, and Jan 2008 - Dec 2009. A total of 1,170 participants aged 70 and older from the HRS study were targeted for the wave A data collection and 856 of them (56%) successfully completed the assessment. In Wave C, ADAMS started objectively measuring hearing and vision loss.

This current study used data merged from HRS and ADAMS. We used one wave of hearing and vision data objectively measured in ADAMS Wave C (N = 315), and five waves of cognitive function data measured from HRS in 2006, 2008, 2010, 2012, and 2014. Among the 315 older adults with measured sensory status in ADAMS Wave C, 304 had cognitive function data available from the HRS 2006 wave, therefore, the sample size for the current study is 304. The study was approved by the Duke University IRB.

3.2.2 Measures

Cognitive function. Cognitive function was measured using the HRS Telephone Interview for Cognitive Status (TICS), a brief cognitive status measure. Cognitive function was assessed in every wave (every two years) of HRS (since 1992). The HRS TICS included immediate and delayed free-recall (range 0 - 20), serial 7 subtraction (range 0 - 5), counting backward tests (range 0 - 2), orientation to time (range 0 - 4), object naming (range 0 - 2), president/vice president naming (range 0 - 2) (Ofstedal, Fisher, & Herzog, 2005). Immediate free-recall was measured by the interviewer reading a list of 10 nouns to the respondent, and then asking the respondent to recall as many words as possible from the list in any order. Delayed recall was assessed by asking the respondent to recall the nouns previously presented as part of the immediate recall task after approximately 5 minutes of asking other survey questions. The serial 7 subtraction was conducted by asking the respondent to subtract 7 from 100 and continue subtracting 7 from each subsequent number for a total of five trials. The counting backward test was conducted by asking the respondents to count backwards for 10 continuous numbers beginning with the number 20. The orientation to time test was conducted by asking the respondents to report "today's date", including the month, day, year, and day of week. The object naming test was conducted by asking the respondent the following two questions: "What do you usually use to cut paper?" and "What do you call the kind of prickly plant that grows in the desert?". The president/vice president naming was conducted by asking the respondent to name the current President and Vice President of the United States. A total cognitive function score was calculated by summing the score for all items (range: 0 - 35).

Hearing Loss. Hearing loss was measured by administering the Pure Tone Thresholds test (The ADAMS Study, 2013). Pure Tone Thresholds test is the gold standard for evaluating hearing loss. In ADAMS, pure tone stimuli were presented at 0.5, 1, 2, and 4 kHz at both 25 and 40 dB to the right and the left ear individually. If a participant could hear 25 or 40 dB at certain Hz level, then the response was documented yes, otherwise was no (The ADAMS Study, 2013). Levels of hearing loss severity were defined based on American Speech-Language Hearing Association guidelines and previous literature (Clark, 1981; Lin, Thorpe, et al., 2011). We categorized participants as having (1) normal hearing if the better ear could hear 25 dB at all or some of the frequencies; (2) mild loss if the better ear could not hear 25 dB at any frequency but could hear 40 dB at some or all frequencies; (3) moderate/severe loss if the better ear could not hear 40 dB at any frequencies. Based on these criteria, we dichotomized our sample to (1) having hearing loss and (2) no hearing loss. This dichotomization led to a balanced sample size.

Vision Loss: Vision loss was measured by using a pocket Snellen card (The ADAMS Study, 2013). Vision loss was defined as having a best-corrected binocular vision worse than 20/40. This cut-point has been widely used in other studies of vision loss, including large-scale population-based surveys (Gopinath et al., 2013; Kahn et al., 1977; Lin et al., 2004; Reyes-Ortiz et al., 2005; Tielsch, Sommer, Witt, Katz, & Royall, 1990; West et al., 1997). This cut-point has also been used in screening for issuing driver’s license (West et al., 1997).

Dual Sensory Loss: Dual sensory loss was defined as having both hearing and vision loss.

Covariates: Covariates selected were characteristics found in prior studies to have been associated with sensory loss and cognitive decline (Lin et al., 2004; Plassman et al., 2007). These characteristics included demographics, socioeconomic status, health status, lifestyle factors, and risk genes. Demographic variables included age (measured in years), sex (0 = female, 1 = male), and ethnicity (1 = white, 2 = black, and 3 = other race). Socioeconomic factors included education (0 = "<=12 years", 1 = "> 12 years"), marital status (0 = single, 1 = married, 2 = divorced or separated, and 3 = widowed), living arrangement (0 = not living alone, 1 = living alone), and household income (in quartiles). Health factors included number of reported chronic conditions, and depression. Specifically, number of chronic health conditions was measured by summing positive responses to items asking about doctor-diagnosed history of high blood pressure, diabetes, cancer, chronic lung disease, heart problems, stroke, psychiatric problems, and arthritis (range 0-8) (Steffick, 2000). Depression was measured by the Shortened Center for Epidemiologic Studies - Depression Scale (CES-D) (range 0 - 8), and the total score of CES-D was used as a continuous variable in the initial models. Lifestyle factors included smoking (current smoker or not) and exercise (any rigorous exercise or not). Genetic risk for Alzheimer's disease was represented by *APOE* ε4 genotype (*APOE ε4* carrier or not).

3.2.3 Statistical Analysis

The longitudinal data analyses were performed using the cognitive function data collected in 2006, 2008, 2010, 2012, and 2014 of the Health and Retirement Study.

Descriptive statistics were used to describe the study sample. Descriptive analysis was also used to ensure the assumptions of the statistical tests that we used were met as well as helping to examine the generalizability of results (as applicable). Mixed effect models were performed to investigate the association between sensory loss at baseline and cognitive function changes in the following waves. Little's (1988) test for missing completely at random (MCAR) was performed and demonstrated that in our sample, data were not missing completely at random. Expected maximization imputation was implemented to accommodate the issue of non-MCAR.

We estimated three sets of linear mixed models for hearing loss, vision loss, and dual sensory loss each as the independent variable of interest (McLean, Sanders, & Stroup, 1991). For each set of models, unconditional modeling was first applied to test between-subjects' variation. After ensuring that there was significant variance at both the within- and between-subjects level, the effects of sensory loss on cognitive function were estimated by linear mixed modeling with covariates adjusted. We used linear mixed models and modeled with age to estimate the effects of baseline sensory loss on the decline of cognitive function as people aged.

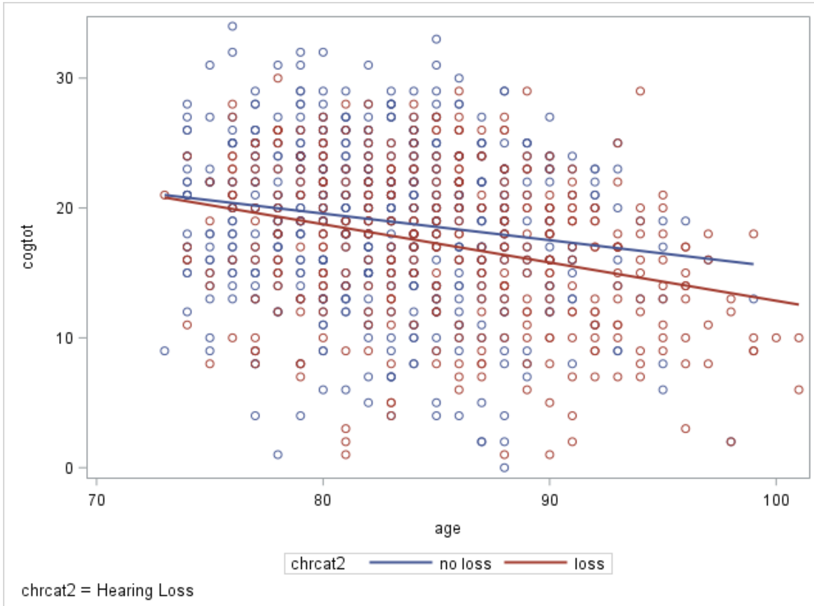


Figure 5: Change in cognitive function as people age based on different hearing loss status.

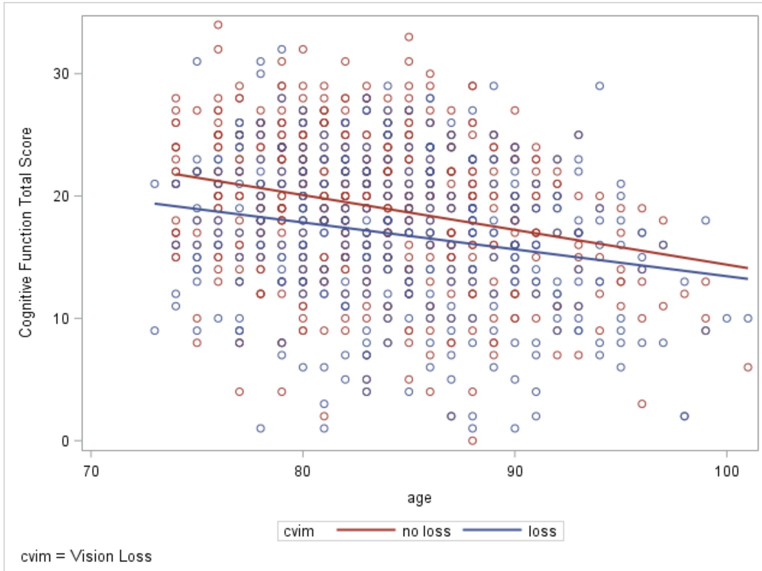


Figure 6: Change in cognitive function as people age based on different vision loss status.

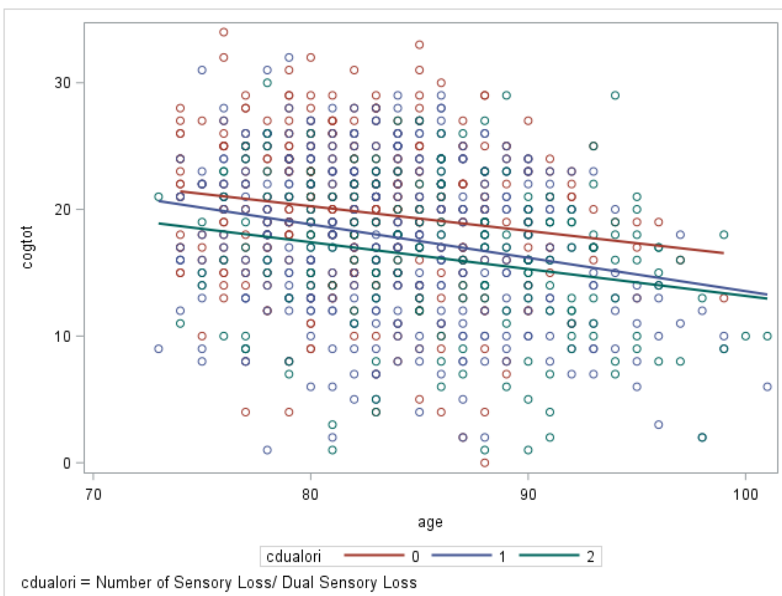


Figure 7: Change in cognitive function as people age based on number of sensory loss.

We applied a rigorous method to select our covariates to be included in the final models. Specifically, for each set of models, we first entered the sensory loss variable and all candidate covariates to the model. Then, we only included the covariates that had a significant association with our outcome variable (i.e., cognitive function) in our final models. Education level, race, survey wave (time), household income, number of physical conditions, and physical exercise consistently had significant associations with cognitive function ($p < .05$) for hearing loss, vision loss, and dual sensory loss, each as the predictor of interest. All the data analyses were carried out with SAS 9.4 (SAS Institute, Cary, NC).

3.3 Results

Table 4 presents baseline characteristics of subjects. Among 304 participants, 151 (49.67%) had normal hearing and 92 (30.26%) had hearing loss; 177 (58.22%) had normal vision and 115 (37.83%) had vision loss. Dual sensory loss was present in 41 (13.49%) participants. The mean age was 82 (mean 81.6, SE 5.64) years, and 159 (52%) were women. The average years of formal education was 11.2 (SE 4.08) with a range of 0 – 17 years.

Table 4: Descriptive statistics for Chapter 3 (data from HRS 2006 or ADAMS Wave C) (N = 304).

	N = 304 (%) or Mean ± SD	Range
age	81.55 ± 5.64	73 - 100
Gender		
Male (1)	145 (47.70)	
Female (0)	159 (52.30)	
Race		
White 1	245 (80.59)	
Black 2	51 (16.78)	
Other 3	8 (2.63)	
Education		0 - 17
<-12 yrs. (1)	196 (64.47)	
>12 yrs. (3)	108 (35.53)	
Annual household income (Mean of each quartile)		
Higher quartile	83,299.30 (63401.01)	40,380.00 -460,800.00
Second quartile	31,558.77 (4939.79)	23,492.00 -39,600.00
Third quartile	17,972.40 (3338.83)	12,960.00-23,232.00
Lower quartile	9,281.91 (2462.54)	0 – 12,904.00
Chronic conditions	2.47 ± 1.45	0 -7
Physical exercise		
Yes	71 (23.36)	
No	233 (76.64)	
Cognition	19.13 ± 5.64	2 -32
Hearing loss		
No loss	151 (49.67)	
Loss	92 (30.26)	
Not assessed/Don't know/Refused	61 (20.07)	
Vision loss		
No loss	177 (58.22)	
Loss	115 (37.83)	
Not assessed/Don't know/Refused	12 (3.95)	

Dual sensory loss	
No loss	102 (33.55)
One loss	98 (32.24)
Two loss	41 (13.49)
Not assessed/Don't know/Refused	63 (20.72)

In the final adjusted multivariate models (see Table 5), older adults with hearing loss had a significantly faster rate of cognitive decline as they grew older. Compared with those with normal hearing, older adults with hearing loss declined 0.18 more points in cognitive function as they grew one-year older (β = -0.18, *p* = .02). Older adults with vision loss did not have a significantly faster rate of cognitive decline. Compared to those with normal vision, older adults with vision loss declined 0.04 more points in cognitive function as they grew one-year older (β = -0.04, *p* = .58), but this difference was not significant. Older adults who had dual sensory loss had a significantly faster rate of cognitive decline. Compared with those with no sensory loss, older adults with dual sensory loss declined 0.23 more points in cognitive function as they grew one-year older (β = -0.23, *p* = .03). Older adults with only one type of sensory loss declined 0.02 more points in cognitive function than those without sensory loss (i.e., vision or hearing loss) (β = -0.02, *p* = .78), but this difference was not significant.

Table 5: Longitudinal cognitive decline for participants with sensory loss compared with participants without sensory loss of the HRS and ADAMS study (N = 304).

	Hearing loss			Vision loss			Dual sensory loss		
Predictors	Estimate ± SE		*p*	Estimate ± SE		*p*	Estimate ± SE		*p*
Intercept	23.38	0.78	< .001	23.95	0.74	< .001	24.15	0.76	< .001
Age	-0.27	0.06	< .001	-0.17	0.07	.01	-0.11	0.08	.17
wave	-0.88	0.14	< .001	-0.83	0.14	< .001	-0.88	0.14	< .001
Hearing loss	-0.63	0.57	0.27	-0.77	0.57	.17			
Hearing loss*age	-0.18	0.07	0.02						
Vision loss	-0.93	0.55	0.10	-0.90	0.56	.11			
Vision loss*age				-0.04	0.07	.58			
One loss							-1.11	0.60	0.07
Two losses							-1.26	0.79	0.11
One loss*age							-0.02	0.08	.78
Two losses*age							-0.23	0.10	.03
College education or higher	3.64	0.59	< .001	3.67	0.59	< .001	3.62	0.59	< .001
Black	-3.92	0.74	< .001	-3.88	0.74	<.001	-3.95	0.73	< .001
Other races	-3.69	1.62	.02	-3.90	1.62	.02	-3.92	1.62	.02
Second quartile of household income	0.59	0.41	.15	0.59	0.41	.14	0.62	0.41	.13
Third quartile of household income	1.34	0.46	.003	1.31	0.46	.004	1.37	0.46	.003
Fourth quartile of household income	1.60	0.48	< .001	1.59	0.48	.001	1.64	0.48	< .001
Number of chronic conditions	-0.34	0.15	.02	-0.35	0.15	.02	-0.36	0.15	0.01
Exercise	0.78	0.30	.009	0.78	0.30	.009	0.78	0.30	.008

3.4 Discussion

Our study found that among older adults in the U.S. aged 73-100 years old, hearing loss was associated with a faster rate of cognitive decline as people grow older; older adults with dual sensory loss had a significantly faster rate of cognitive decline than older adults with normal sensory function or than those with only one type of sensory loss. These associations remained significant after adjusting for covariates. No significant associations was found between vision loss and cognitive decline. Our study contributes to the understanding of the longitudinal associations between vision loss, hearing loss, dual sensory loss, and cognitive decline by using objectively measured sensory loss in a national sample of older adults in the U.S.

Our finding that older adults with hearing loss had faster rate of cognitive decline as they grew one year older is consistent with several previous publications (Alattar et al., 2019; Deal et al., 2015; Lin et al., 2013; Maharani et al., 2019). For example, Deal et al. (2015) conducted a longitudinal analysis of data from 253 older adults in Washington County, Maryland, and found that those with hearing loss had a faster rate of cognitive decline compared to those without hearing impairment over a 20-year follow-up. Lin et al. (2013) studied 1984 older adults who were followed up for 6 years from the Health ABC study, and found that older adults with hearing loss had accelerated cognitive decline compared to those with normal hearing.

However, contradictory evidence has also been reported (Deal et al., 2016; Hong et al., 2016; Lin et al., 2004; Maharani et al., 2019; Reyes-Ortiz et al., 2005). In a study published by Deal et al. (2016), no significant association between hearing loss and rates of domain-specific cognitive decline during 7 years of follow-up was observed. Hong et al. (2016) found that the presence of baseline hearing loss was not associated with the extent of cognitive decline over 5-, 10-, and 15-year periods. Similarly, Reyes-Ortiz and colleagues studied 3,050 non-institutionalized Mexican Americans aged 65 and older residing in southwestern United States (2005) and found no significant association between hearing loss and cognitive decline over a 7-year follow-up period. These inconsistent findings may be related to the use of different measures of cognitive function in the different studies. The inconsistent findings may also be related to the different lengths of follow-up among the studies. Our study used longitudinal data collected over 8 years, but the follow-up periods in the related literature varied between 6 to 20 years (Alattar et al., 2019; Deal et al., 2016; Deal et al., 2015; Hong et al., 2016; Lin et al., 2013; Maharani et al., 2019; Reyes-Ortiz et al., 2005). Additionally, different studies applied different measures of hearing loss. For example, Maharani et al.'s study used self-reported hearing loss and found no significant longitudinal association with cognitive decline (2019). Our study used objectively measured hearing loss using the gold-standard pure tone threshold test. Additionally, different studies used different approaches to model cognitive decline. We used linear mixed models and modeled with age to understand the rate of cognitive decline for each year of older age, while some other studies used "change in cognitive function" to represent cognitive decline and used regressions (Hong et al., 2016; Lin et al., 2004).

The mechanism underlying the association between hearing loss and cognitive decline is largely unknown (Fortunato et al., 2016; Wayne & Johnsrude, 2015; Whitson et al., 2018). The most often mentioned potential mechanisms included social isolation or loneliness, depression, sensory-deprivation, variations in cognitive load, changes in brain structures, and common causes including examples such as aging and cardiovascular diseases (Baltes & Lindenberger, 1997; Fortunato et al., 2016; Fulton et al., 2015; Lin et al., 2013; Oster & Claude, 1976; Pichora-Fuller et al., 2015). Despite these many proposed hypotheses, researchers are still unsure if a causal relationship between sensory loss and cognitive decline exists, and if so, which mechanism plays a more prominent role in that relationship. It is beyond the scope of our current study to examine the potential mechanism connecting the relationship between sensory loss and cognitive decline. Future studies that aim to understand the mechanism using non-auditory measures of cognition are warranted (Wayne & Johnsrude, 2015).

As for vision loss, we did not find a significant association between having vision loss and the rate of cognitive decline. Previous studies that focused on the association between vision loss and cognitive function have been mostly based on cross-sectional data. Multiple cross-sectional studies have suggested associations between reduced visual acuity and poor cognitive function (Baker et al., 2009; Bowen et al., 2016; Chen et al., 2017; Clemons et al., 2006; Ong et al., 2012; Pham et al., 2006; Rait et al., 2005; Spierer et al., 2016; Woo et al., 2012). However, only a very limited number of studies have examined the relationship between vision loss and rate of cognitive decline using longitudinal data, and these studies produced inconsistent findings (Reyes-Ortiz et al., 2005; Zheng et al., 2018). Zheng and colleagues conducted a longitudinal population-based study of older adults with a sample size of 2520, and found that older adults with worsening vision had a stronger association with cognitive decline (Zheng et al., 2018). Reyes-Ortiz and colleagues (2005) measured near and distant visions separately and found that distant vision loss was not associated with a decline in cognitive function over a period of 7 years among older Mexican Americans. Our non-significant findings regarding the association between vision loss and the rate of cognitive decline may be related to the fact that the ADAMS data did not specify the time and reason of vision loss. The onset of vision loss might have been at a younger age, which may blur the association between vision loss and cognitive decline during the age range of our sample. Additionally, during the course of the study's follow-up period, participants may have started wearing glasses or had cataract surgeries, which may have contributed to the lack of association between vision loss and cognitive decline.

Our study found that older adults with dual sensory loss had a faster rate of cognitive decline than those with no sensory loss. Our findings were consistent with previous studies (Lin et al., 2004; Maharani et al., 2019; Yamada et al., 2016). Yamada and colleagues (Yamada et al., 2016) examined the association between dual sensory loss and one-year change in cognitive performance using a sample of 1,989 nursing home residents in Europe, and found that older adults with dual sensory loss were at increased risk for a greater cognitive decline compared to those with normal sensory functions. Similar to our findings, Yamada and colleagues also found no greater cognitive decline among those with single sensory loss than those without any sensory loss. However, Yamada's study used "change in cognitive function", rather than modeling a trajectory of cognitive change, to represent cognitive decline. In addition, Yamada's study did not investigate the relationship between each individual type of sensory loss and cognitive decline. Our findings suggest the need for understanding the longitudinal relationships between each specific type of sensory loss and cognitive decline given the differentiated associations found. Another study conducted by Maharani and colleagues (2019) examined the longitudinal association between dual sensory loss and cognitive decline using nationally-representative data in the United

States, and found a significant association between dual sensory loss and increased rate of cognitive decline. However, this study was limited in that the sensory loss was measured by self-report, rather than objective measures of sensory function.

Our study has the following limitations. First, we could not use the averaged pure tone threshold to define hearing impairment in our study because only 4 frequencies were tested at 2 different dB levels. However, the cut-point of hearing impairment we have chosen in the current study was consistent with the common standard used in the literature (Chou, Dana, Bougatsos, Fleming, & Beil, 2011; Clark, 1981; Lin, Thorpe, et al., 2011). Second, the measure of cognitive function in HRS was conducted through a mixture of telephone and face-to-face interviews. Therefore, hearing function may affect older adults' performance on the cognitive test, especially for those that were conducted over the phone. This may explain part of the association between hearing loss and cognitive decline. Moreover, older adults with hearing loss may also have a lower likelihood of completing TICS. However, the HRS team has done rigorous work to ensure that the telephone interview had the same validity as if the interview was conducted face-to-face (Herzog & Rodgers, 1999). Third, older adults' vision and hearing status are subject to changes as they age, yet we only used one time point of measured hearing and vision loss data in the current study, as relatively few individuals had multiple measurement time points due to the study design. Fourth, for both hearing and vision loss, we did not have data for age of onset and possible etiology of the sensory loss. Future studies with this information may be able to better delineate the relationship between sensory loss and cognitive decline among older adults.

This study has several strengths. The data is a sub-sample retrieved from a nationally representative population-based study. We used objectively measured sensory loss for our analyses. The analysis was based on longitudinal data of cognitive function measured over 8 years, which strengthened our ability to detect the association between sensory loss and cognitive decline as people grow older.

3.5 Conclusion

This prospective study of older Americans demonstrated associations between sensory loss and faster rate of cognitive decline as people grow older. Our findings contribute to the growing body of evidence suggesting that sensory loss is a potential risk factor for cognitive decline. Further research is needed to determine if intervening on sensory loss at an earlier stage would help slow down or even prevent future cognitive decline. Health care providers should pay attention to proactively screening hearing and vision loss among older adults, which may contribute to preserving optimal cognitive function in later life.

4. Longitudinal Inter-relationships between Sensory Loss, Social Support, Loneliness, and Cognition

4.1 Introduction

A global population of more than 152 million is projected to be affected by dementia by the year 2050 (Prince et al., 2018; World Health Organization, 2019). Dementia is more likely to happen to older adults with accelerated cognitive decline (Cooper et al., 2015; Tschanz et al., 2006). Identifying and understanding the risk factors for cognitive decline will contribute to developing effective intervention programs to better preserve cognitive function among the aged population. Among the potential risk factors for cognitive decline, hearing loss and vision loss are two that are of high prevalence among older adults (Lin, Thorpe, et al., 2011; Varma et al., 2016). Many cross-sectional and longitudinal studies have found that both hearing and vision loss can be independently associated with cognitive decline (Baker et al., 2009; Bowen et al., 2016; Chen et al., 2017; Clemons et al., 2006; Deal et al., 2016; Lin, Metter, et al., 2011; Lin et al., 2013; Livingston et al., 2017; Maharani et al., 2019; Ong et al., 2012; Pham et al., 2006; Rait et al., 2005; Reyes-Ortiz et al., 2005; Spierer et al., 2016; Woo et al., 2012; Yuan et al., 2018; Zheng et al., 2018). Dual sensory loss has been found to be a risk factor for cognitive decline as well (Lin et al., 2004; Maharani et al., 2019; Yamada et al., 2016).

Psychosocial factors, including social support and loneliness, play important roles in older adult's daily lives and can impact older adults' health outcomes (Courtin & Knapp, 2017; Coyle & Dugan, 2012; Thoits, 2011). Social support and loneliness are two related, yet distinct concepts. *Social support* is defined as perceived supportive resources from a person's social engagement or social network (Cohen & Syme, 1985), while *loneliness* is defined as the negative experience of perceived social isolation even when being with family or friends (Cacioppo, Hawkley, Norman, & Berntson, 2011; House, 2001; Weiss, 1973). Although these two concepts are likely to be correlated, these definitions underscore the fact that older adults who have abundant social support may still feel lonely (Wang, Mann, et al., 2018).

Studies have suggested that loneliness and social support may connect or alter the relationship between sensory loss and cognitive function (Fulton et al., 2015; Lin, Ferrucci, et al., 2011; Lin, Metter, et al., 2011; West, 2017). Specifically, understanding the mechanisms connecting sensory loss and cognitive function has been acknowledged as a priority for future research regarding sensory loss (Whitson et al., 2018), and loneliness has been widely hypothesized to be a potential mediator between sensory loss and cognitive function (Fulton et al., 2015; Lin, Ferrucci, et al., 2011; Lin, Metter, et al., 2011). However, empirical evidence on this relationship is scarce. To our knowledge, only one cross-sectional study and no longitudinal studies have been conducted to test this relationship (Dawes et al., 2015). Further studies using longitudinal data are warranted. Also, to our knowledge, no studies have been conducted to test the role of social support in the relationship between sensory loss and cognitive decline. Hearing loss and vision loss are potentially stressful because they are physical impairments that impact functioning across multiple domains of daily life (Bittner et al., 2010; Brennan & Bally, 2007; Dalton et al., 2003; Mick et al., 2014; Pearlin et al., 1981). Studies have started treating hearing and vision loss as stressors in the stress buffering hypothesis paradigm for other important health outcomes, such as depressive symptoms (West, 2017). The stress buffering hypothesis suggests that social support can moderate the relationship between a chronic physical stressor and negative health outcomes by preventing an individual from perceiving a potential stressor as stressful or by reducing negative reactions to an actual stressor (Cohen & Wills, 1985). Moreover, considerable evidence suggests that social support is a resource to help individuals cope with stressors more effectively by encouraging positive strategies and health behaviors (Milner, Krnjacki, Butterworth, & LaMontagne, 2016; Thoits, 2011). One study has been conducted to test the moderation effect of social support on the relationship between sensory loss and depression among older adults (West, 2017). To the authors' knowledge, no studies have been carried out to test this potential moderation effect for a different yet important health outcome – decline in cognitive function.

Therefore, this study aims to better understand the inter-relationships between sensory loss, changes in cognitive function, and psychosocial factors including loneliness and social support. Specifically, we aim to examine (1) if loneliness mediates the associations between sensory loss (i.e., hearing or vision loss) and future cognitive decline as people grow older; (2) if social support moderates the associations between sensory loss (i.e., hearing or vision loss) and future cognitive decline as people grow older. We also have a secondary goal to explore these research questions in terms of dual sensory loss.

4.2 Conceptual model

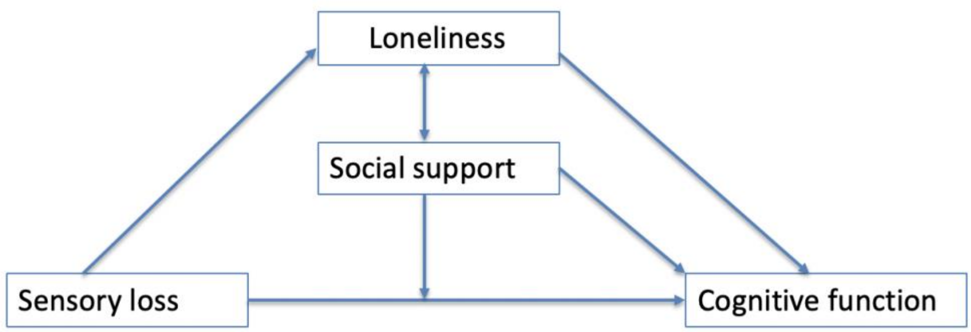


Figure 8: Conceptual model.

The conceptual model for the study was built based on theories and empirical evidence. We hypothesized that loneliness would act as a mediator and social support would act as a moderator for the relationship between sensory loss and cognitive decline. We modeled correlation for loneliness and social support in our conceptual model based on the literature (Wang, Mann, et al., 2018). Structural equational modeling enables us to test this conceptual model (Figure 8).

4.3 Methods

4.3.1 Parent Study Overview and Data Source

As described in section 3.2.1 (page 50 - 51), this is a longitudinal study using data from the Health and Retirement Study (HRS) and its supplement: The Aging, Demographics, and Memory Study (ADAMS) (Plassman et al., 2007); both are population-based, nationally representative epidemiological surveys of older adults in the United States. Data from the HRS and ADAMS can be merged using household and participant IDs. Hearing and vision loss were initially objectively measured in ADAMS Wave C (N = 315). In our current study, we use one wave of hearing and vision data from ADAMS Wave C, one wave social support and loneliness data from HRS, and five waves of cognitive function data measured in HRS in 2006, 2008, 2010, 2012, and 2014. The study was approved by the Duke University IRB.

4.3.2 Measures

The measures and coding of cognitive function, hearing loss, vision loss, dual sensory loss, and adjusted covariates have been described in detail in section 3.2.2 (page 51 – 54). In summary, cognitive function was measured by the HRS TICS in years 2006, 2008, 2010, 2012, and 2014 (Ofstedal et al., 2005). Hearing loss was objectively measured by the Pure Tone Threshold test (The ADAMS Study, 2013) (0 = no hearing loss: can hear 25dB at 0.5 - 4 kHz , 1 = hearing loss: cannot hear 25dB at 0.5 - 4 kHz). Vision loss was objectively measured by the pocket Snellen card (The ADAMS Study, 2013) (0 = the visual acuity of the better-seeing eye was better than 20/40, 1 = the visual acuity of the better-seeing eye was worse than 20/40). Dual sensory loss, in this current study, is operationally defined as the “number of modalities of sensory loss” (0 = no sensory loss, 1 = one modality of sensory loss, 2 = dual sensory loss). Covariates included in our models were chosen based on the literature and on their significant statistical association with our outcome variable (i.e., cognitive function) (Lin et al., 2004; Plassman et al., 2007). These covariates included age (in years), education level (0 = “<=12 years”, 1 = “> 12 years”), race (1 = white, 2 = black, 3 = other race), survey wave (time), household income (in quartiles), number of physical conditions (range 0 - 8), and physical exercise (0 = no, 1 = yes).

Social support. Social support was measured by the HRS social support scale. For each source of social support (spouse, other family members, and friends), participants were asked “How much do your [spouse, other family members, friends] really understand the way you feel about things?”, “How often can you open up to [spouse, other family members, friends] if you need to talk about your worries”, and “How often can you rely on [spouse, other family members, friends] for help if you have a problem?". The response options ranged from 1 (a lot) to 4 (not at all). Social support was reverse coded and then was calculated as the average of the twelve items, with a higher score indicating a higher level of social support. In our sample, the Cronbach's alpha for the social support scale is 0.80.

Loneliness: Loneliness was measured by the 3-item loneliness scale. Participants were asked "How much of the time do you feel you lack companionship?", "How much of the time do you feel left out?", "How much of the time do you feel isolated from others?" The response options ranged from 1 (Often) to 3 (Hardly ever or never). Loneliness was reverse coded and was calculated as the average score of the three items, with a higher score representing a higher level of loneliness. This scale has been used in large-scale population telephone surveys and has good reliability (Hughes, Waite, Hawkley, & Cacioppo, 2004). In our sample, the Cronbach's alpha for the loneliness is 0.80.

4.3.3 Statistical Analysis

Descriptive statistics were computed for sample characteristics. The initial sample consisted of 232 patients. Hearing and vision data were objectively measured from Wave C of the ADAMS study (N = 315). Social support and loneliness were measured by the HRS self-administered leave-behind psychosocial questionnaire, and only 232 of the 315 participants of ADAMS wave C had the social support, loneliness, and cognition data available. Therefore, the sample size for this study was 232. We conducted Little (1988)'s test for missing completely at random (MCAR) and found that data were not missing completely at random in our sample. Therefore, we implemented expected maximization imputation to accommodate the issue of non-MCAR.

The longitudinal mediation effects of loneliness and the moderation effects of social support on the relationship between sensory loss and cognitive function were examined using the two-step longitudinal parallel-process (LPP), one type of structural equation modeling (SEM) (Hooke et al., 2018; Sousa, Kwok, Schmiege, & West, 2014). Both moderation and mediation effects were estimated in the same SEM model. The effects of both hearing loss and vision loss were also estimated in the same model to account for the potential confounding effect of each modality of sensory loss to the other (Chen et al., 2017). In the first step, the intercept and slope of the longitudinal variable, cognitive function, was estimated by using multilevel modeling with SAS Proc Mixed. The intercept of cognitive function represents the average status of cognitive function at age 81 (mean age). The slope represents the rate of change in cognitive function as people age one year. By modeling the intercept and slope of cognitive function separately, LPP allows us to explore the relationships between sensory loss, social support, loneliness and cognitive function cross-sectionally as well as longitudinally. At the same time, since we used 1-wave of data for sensory loss, social support, and loneliness, the predicted values of each of these variables were produced by using SAS Proc Logistic and Proc Genmod. This approach controlled for the effects of sociodemographic variables and time-varying covariates in the SEM. The longitudinal moderation effects of social support on the relationship between sensory loss and cognitive function were examined by computing two interaction terms of hearing loss*social support and vision loss*social support.

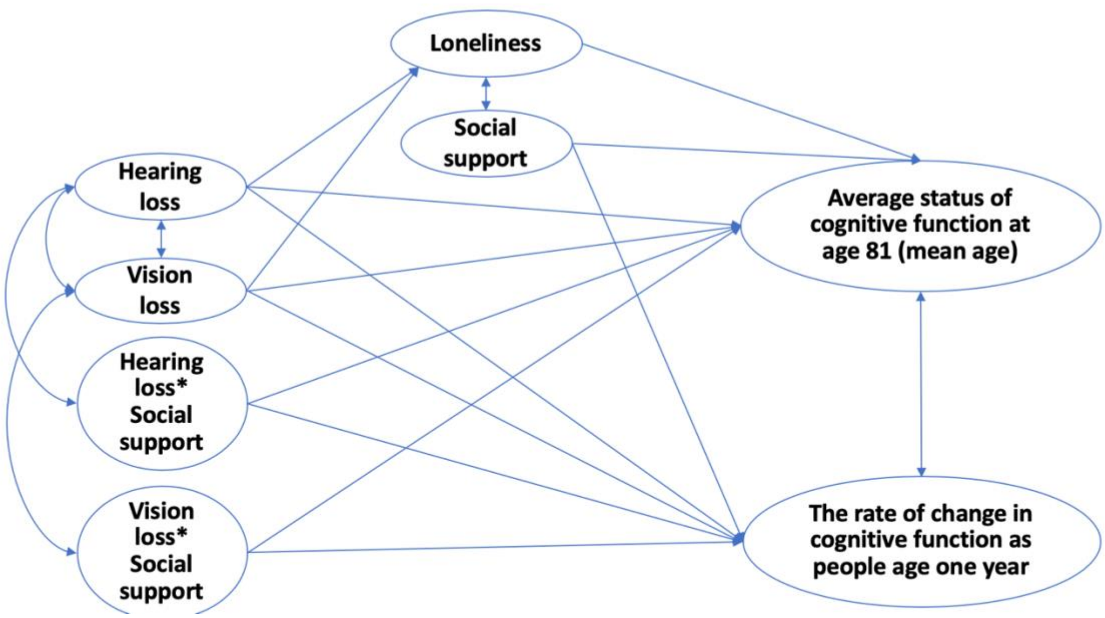


Figure 9: Initial SEM estimated for single modality sensory loss.

In the second step, structural equation modeling was employed to test the longitudinal mediation effects of loneliness on the relationship between sensory loss and cognitive function using IBM SPSS Amos. In the same model, we also added the interaction terms between each modality of sensory loss and social support to examine the moderation effect of social support. Given that the variables of dual sensory loss and single sensory losses were highly correlated, we decided not to incorporate dual sensory loss and single modality sensory loss modalities in the same model. Therefore, we estimated two SEMs: one for single sensory loss modalities and one for dual sensory loss.

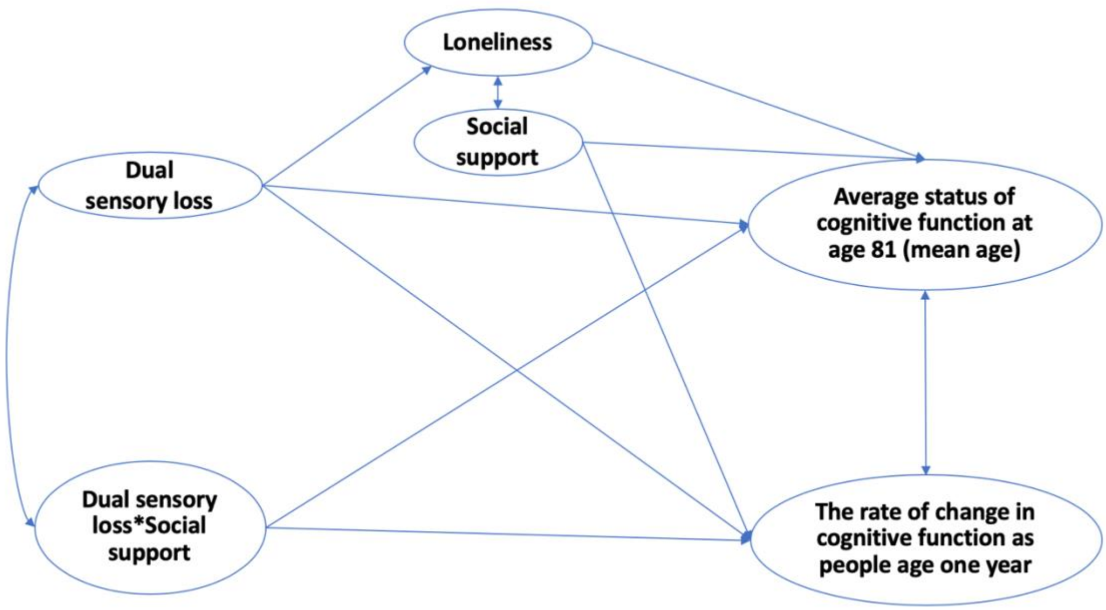


Figure 10: Initial SEM estimated for dual sensory losses.

Specifically, we first fit a full SEM model (Figures 9 and 10) based on our conceptual model (Figure 8). To achieve the most parsimonious model, the model fit was evaluated using the following model-fit indices: Chi-square of the estimated model (χ^2), goodness of fit index (GFI), normed fit index (NFI), incremental fit index (IFI), relative fit index (RFI), comparative fit index (CFI), and root mean square error of approximation (RMSEA). A nonsignificant Chi-square value ($p > .05$) suggests a good overall model fit to the data. For GFI, NFI, IFI, RFI, and CFI, values larger than .90 indicate that the model provides a good fit to the data, whereas the RMSEA value should be below .06. The fit indices and their criteria are commonly recommended in the literature.

4.4 Results

4.4.1 Descriptive Statistics

Characteristics of the sample are shown in Table 6. In our sample, there were more females (51.7%) than males, more white participants (80.6%) than other race, and more participants who had 12 years or less of education (61.2%) than those who had more than 12 years. In a total sample of 232 older adults in our sample, the average age was 80.87 ± 5.27 and their average cognition score was 19.78 ± 5.38. The average number of chronic conditions among our sample was 2.35 ± 1.41. Regarding the psychosocial factors, the average level of social support among the older adults was 3.19 ± 0.51, and the average level of loneliness was 1.51 ± 0.52. 50.86% of the older adults did not have hearing loss, but 74 (31.9%) of them had hearing loss. As for vision loss, 149 (64.22%) of the older adults did not have vision loss, but 78 (33.62%) had vision loss. Eighty-seven (37.5) participants had no sensory loss, 73 (31.34%) had one type of sensory loss, and 31 (13.36%) had dual sensory loss.

Table 6: Descriptive statistics for Chapter 4 (N = 232).

	N = 232 (%) or Mean ± SD	Range
age	80.87 ± 5.27	73 - 97
Gender		
Male (1)	112 (48.28)	
Female (0)	120 (51.72)	
Race		
White 1	187 (80.60)	
Black 2	38 (16.38)	
Other 3	7 (3.02)	
Education		0 - 17
<-12 yrs. (1)	142 (61.21)	
>12 yrs. (3)	90 (38.79)	
Annual household income (Mean of each quartile)		
Higher quartile	81,899.48 (48826.46)	40,380.00 -260,016.00
Second quartile	32,006.56 (4996.92)	23,492.00 -39,600.00
Third quartile	18,219.25 (3314.49)	12,960.00-23,232.00
Lower quartile	9,552.39 (2443.16)	2,400.00 -12,828.00
Chronic conditions	2.35 ± 1.41	0 - 6
Physical exercise		
Yes	58 (25)	
No	174 (75)	
Cognition	19.78 ± 5.38	2 -32
Social support	3.19 (0.51)	1.83 - 4.00
Loneliness	1.51 (0.52)	1.00 – 3.00
Hearing loss		
No loss	118 (50.86)	
Loss	74 (31.90)	
Not assessed/Don't know/Refused	40 (17.24)	
Vision loss		
No loss	149 (64.22)	

Loss	78 (33.62)
Not assessed/Don't know/Refused	5 (2.16)
Dual sensory loss	
No loss	87 (37.50)
One loss	73 (31.47)
Two loss	31 (13.36)
Not assessed/Don't know/Refused	41 (17.67)

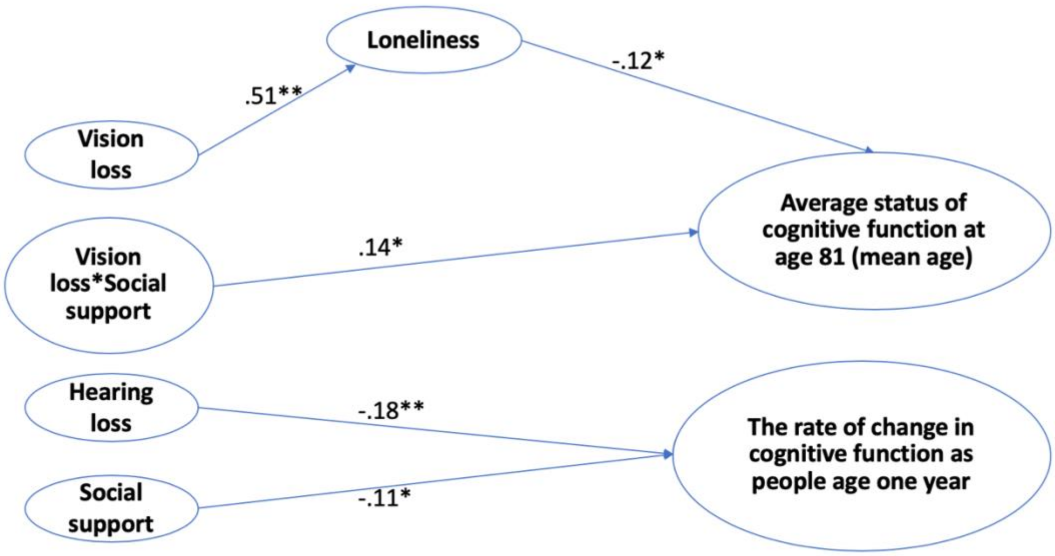
4.4.2 Longitudinal SEM Results for Single Modality Sensory Losses

The initial model fit indices for the longitudinal model (Figure 9) to examine the mediation effect of loneliness and the moderation effects of social support were not all satisfactory ($\chi^2(7) = 43.18$, $p < .001$; GFI = .96, NFI = .99, IFI = .99, RFI = .95, CFI = .99; and RMSEA = .15). These indices indicated that the model needed further improvement.

To obtain a parsimonious, best-fit model, the initial model was modified by removing non-significant paths and adding significant paths based on statistical modification indices produced by IBM SPSS Amos as well as on theoretical interpretability. A final model was reached as shown in Figure 11 in which all the standardized estimates of path coefficients were significant or marginally significant at the $\alpha = .05$ level by 1-tailed tests. The model fit indices for the final model improved and all were satisfactory ($\chi^2(9) = 2.763$, $p = .97$; GFI = .99, NFI = .99, IFI = 1.00, RFI = .99, CFI = 1.00; and RMSEA = .00).

We did not find a significant mediation effect of loneliness on cognitive decline (Figure 11). We observed that older adults with hearing loss have a significantly faster rate of decline in cognitive function as they get older ($\beta = -.18$, $p < .01$), as evidenced by the rate of change in cognition as the older adults aged one year (the slope of cognition). However, the path coefficient from hearing loss to the average status of cognitive function at age 81 was not significant at the $\alpha = .05$ level (not shown in the diagram). Similarly, the path coefficient from hearing loss to loneliness was not significant either ($p > .05$), indicating no significant mediation effect of loneliness on the relationship between hearing loss and cognitive function. Regarding vision loss, at the average age of 81 (age variable centered at its mean age of 81), those who had vision loss experienced more severe loneliness ($\beta = .51$, $p < .01$). In addition, older adults who experienced more severe loneliness were found to have a lower level cognitive function at age 81. This relationship was marginally significant ($\beta = -.12$, $p = .057$). At the same time, the path coefficient from vision loss to the average status of cognitive function at age 81 (mean age of the sample) was not significant, demonstrating a full mediation effect of loneliness on the relationship between vision loss and the average status of cognitive function at age 81. However, there was no mediation effect of loneliness on the relationship between vision loss and the rate of change in cognitive function as the older adults aged one year ($p > .05$).

Regarding the moderation effects of social support, older adults who had a higher level of social support tended to have a faster rate of cognitive decline as they aged. This relationship was marginally significant (β = -.11, p = .057). This counterintuitive finding may indicate that those older adults whose cognitive function declined faster needed and perceived more social support than those whose cognitive function declined more slowly. The path coefficients were not significant for the associations between the interaction term of hearing loss*social support and either the average status of cognitive function at age 81 or the rate of change in cognitive function as people aged 1 year (not shown in the diagram). These results suggest no significant moderation effect of social support on the relationship between hearing loss and cognitive function. The path coefficient was significant for the association between the interaction term of vision loss*social support and average status of cognitive function at age 81 (β = .14, p < .05). This result indicates a significant moderation effect of social support on the relationship between vision loss and cognitive function.



- 1-tailed tests, * $p < .05$, ** $p < .01$
- The model fit indices for the final model improved and all were satisfactory $\chi 2(7) = 9.54$, p = .482; GFI = .99, NFI = .99, IFI = 1.00, RFI = .99, CFI = 1.00; and RMSEA = .00
- The error terms and correlational paths are omitted

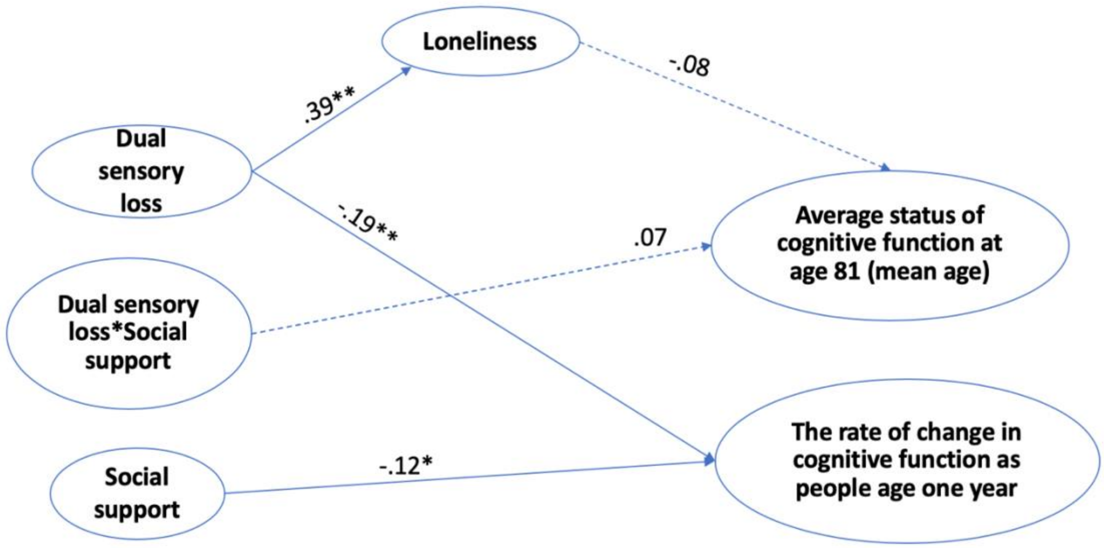
Figure 11: Path coefficient estimates from the most parsimonious model for single modality sensory loss.

4.4.3 Longitudinal SEM Results for Dual Sensory Loss

The initial model fit indices for the longitudinal model (Figure 10) to examine the mediation effects of loneliness and the moderation effects of social support were not all satisfactory ($\chi^2(3) = 12.54$, $p < .01$; GFI = .98, NFI = .99, IFI = .99, RFI = .96, CFI = .99; and RMSEA = .12). These indices indicated that the model needed further improvement.

We used the same approach as in the model for single modality sensory loss to obtain a parsimonious, best-fit model for dual sensory loss. A final model was reached as shown in Figure 12 in which the model remained interpretable and the fit indices were mostly satisfactory ($\chi 2(6) = 13.16$, $p = .04$; GFI = .98, NFI = .99, IFI = .99, RFI = .98, CFI = .99; and RMSEA = .07).

Significant associations were found between dual sensory loss and rate of cognitive decline as the older adults age ($\beta = -.19$, $p < .01$). With an increase in the number of modalities of sensory losses, cognitive function declined faster. No significant mediation effects of loneliness nor moderation effects of social support were found for the relationship between dual sensory loss and cognitive function (neither the average status of cognitive function at age 81 nor rate of cognitive decline). Similar to what we have found in the model for single modality of sensory loss, older adults with more social support had a faster rate of decline in cognitive function ($\beta = -.12$, $p < .05$).



- 1-tailed tests, * *p* < .05, ***p* < .01
- The model fit indices for the final model improved and almost satisfactory $\chi2(6) = 13.16$, p = .04; GFI = .98, NFI = .99, IFI = .99, RFI = .98, CFI = .99; and RMSEA = .07
- The error terms and correlational paths are omitted

Figure 12: Path coefficient estimates from the most parsimonious model for dual sensory loss.

4.5 Discussion

Our study examined longitudinal data from a national sample of older adults in the U.S. to examine the potential mediation effect of loneliness, and the potential moderation effect of social support, on the relationship between sensory loss and cognitive decline. Although, we found that loneliness mediated the association between vision loss and the average cognitive status at age 81 among older adults, we did not find that loneliness mediated the association between sensory loss and cognitive decline. We also found that social support moderated the association between vision loss and the average cognitive status at age 81, but we did not find any evidence of social support moderating the effects of sensory loss on the rate of cognitive decline.

Our study found a significant association between vision loss and greater loneliness. Older adults with vision loss may be lonely due to their limited physical mobility and their increased difficulty of communicating with others (e.g., more difficulty in interpreting visual cues during face-to-face conversations, replying emails, and texting). Our finding is consistent with previous studies (Alma et al., 2011; Mick et al., 2018). Alma et al. (2011) found that the prevalence of loneliness among the visually impaired elderly (n = 173) was higher compared with the reference group (n = 258). Mick et al. (2018) conducted a cross-sectional study using data collected from 21,241 participants of the Canadian Longitudinal Study on Aging (CLSA) and found that older adults with vision loss were more likely to feel lonely. However, this study also found that older adults with hearing loss were more likely to have loneliness, which was not found in our study. This inconsistency might be related to factors including different samples and different measures used. The participants in the study by Mick et al. (2018) were 45 – 89 years old and 80.6% of them were below age 70, whereas all the participants in our sample were 73 and above. As for the measures, Mick et al. (2018) used self-reported sensory loss, whereas we used objectively measured sensory loss. Mick et al. (2018) also used one-item loneliness instrument, with no validity or reliability information reported. Future studies on the relationship between sensory loss and loneliness should consider using objectively measured sensory loss and robust loneliness instruments.

Our study found significant association between severity of loneliness and the average cognitive status at age 81. This finding is consistent with previous evidence on the association between loneliness and cognitive function (Cacioppo & Hawkley, 2009; Conroy et al., 2010; Luanaigh & Lawlor, 2008; O'luanaigh et al., 2012; Shankar et al., 2013). We did not find a significant association between loneliness severity and rate of cognitive decline. This finding is contradictory to the findings from previous longitudinal studies that have examined the longitudinal relationship between loneliness and rate of cognitive decline. Donovan et al. (2017), studied 8,382 older adults aged 65 and above from the HRS study and found that loneliness at baseline predicted accelerated cognitive decline over 12 years. Zhong, Chen, Tu, and Conwell (2017) studied 14,199 Chinese older adults aged 65 years and above from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) and found that severe loneliness predicted faster cognitive decline at subsequent waves. The discrepancies between our findings and previous ones may be because that we also included sensory loss and social support in our model, which turned out to be significant predictors of cognitive decline in our analysis.

The findings from our study suggest that loneliness may mediate the association between vision loss and the average cognitive status among older adults; however, we did not find a significant mediation effect of loneliness for the relationship between hearing loss and rate of cognitive decline. The hypothesis that loneliness may be a mediator for the association between hearing loss and cognitive function or decline has been widely proposed (Fulton et al., 2015; Lin, Ferrucci, et al., 2011; Lin, Metter, et al., 2011). To our knowledge, only one previous study has been conducted to test this hypothesis. Dawes et al. (2015) tested loneliness as a mediator for the relationship between hearing loss and cognitive function using the cross-sectional Biobank data from the United Kingdom (N= 164,770, age range 40-69) and found a partial mediation effect of loneliness for the relationship between hearing loss and cognitive function. Gaining a better understanding of the mechanisms that connect the relationship between sensory loss and cognitive function or cognitive decline will promote the development of interventions to help preserve cognitive function among older adults. Future studies are warranted to better understand the potential mechanisms underlying the associations between sensory loss and cognitive function or cognitive decline.

Although we found significant moderation effect of social support on the relationship between vision loss and the average cognitive status at age 81, we did not find a moderation effect on cognitive decline. Our findings thus partially supported the stress-buffering hypothesis (Cohen & Syme, 1985; Thoits, 2011; West, 2017). As sensory loss draws increasing research attention, more researchers are trying to understand it as a chronic physical stressor (Mick et al., 2014; West, 2017). However, to our knowledge, no studies have been conducted to understand the inter-relationships between social support, sensory loss, and cognitive function or cognitive decline based on the stress-buffering hypothesis. The only previous study that has explored the stress-buffering hypothesis in the paradigm of sensory loss and mental health outcomes only studied hearing loss, but not vision loss, and focused on depressive symptoms as the health outcome, rather than cognitive function (West, 2017). West (2017) supported the stress-buffering hypothesis by finding a significant moderation effect of social support on the relationship between hearing loss and depression using the data from the HRS. On the other hand, only one study has examined the stress-buffering effect of social support on cognitive function. Zuelsdorff et al. (2013) conducted a study with 623 participants aged 40 to 65 in the United States to understand if social support would "buffer" (moderate) the associations between stressful life events and cognitive function among middle-aged adults with a family history of Alzheimer's disease. The results indicated that even though social support and stressful life events were each independently associated with cognitive function, there was no significant interaction between social support and stressful life events. However, the study of Zuelsdorff et al. (2013) had several limitations including the cross-sectional study approach and using a "stressful experiences" instrument with a very low internal consistency (Cronbach's alpha = 0.36). Also, Zuelsdorff et al.'s study findings had limited comparability with our study because their study was conducted among participants aged 40 - 65, which is younger than the group of participants in our sample.

We decided to test social support only as a moderator but not as a mediator based on both theoretical and empirical considerations. Previously hypothesized underlying mechanisms that connect sensory loss and cognitive function (Fulton et al., 2015; Lin, Ferrucci, et al., 2011; Lin, Metter, et al., 2011) provided strong theoretical reasons for us to conduct mediation analysis for loneliness (Baron & Kenny, 1986). We tested loneliness as a potential mediator of the relationship between sensory loss and cognitive function based on these prior studies. However, social support lacked a similarly strong foundation for us to test social support as a potential mediator. Empirically, the evidence for testing social support as a mediator between life stressors and health outcomes was not strong. As mentioned before, only one prior study has been conducted to examine the inter-relationships between sensory loss (i.e., hearing loss), social support, and health outcome (i.e., depressive symptoms) (West, 2017). This study tested social support as both a moderator and mediator. However, only a significant moderation effect for social support was found. When we reviewed related literature using the stress-buffering hypothesis to examine the inter-relationships between life stressors, social support, and health outcomes, we found that more studies have examined social support as a moderator only (Cruza-Guet, Spokane, Caskie, Brown, & Szapocznik, 2008; Gellert et al., 2018; Wilcox, 1981), rather than as both a moderator and mediator (Schumacher, Dodd, & Paul, 1993). Also, all but one (Schumacher et al., 1993) of the reviewed articles testing social support as a moderator have found a significant moderation effect. Therefore, based on both the theory and evidence, as well as the scarcity of prior studies aiming to understand of the inter-relationships between sensory loss, social support, and cognitive function, the rationale was only strong enough for us to test social support as a moderator but not as a mediator.

We found that the level of social support was negatively associated with the rate of cognitive decline. This finding was surprising and was contradictory to the findings of previous studies. Barnes et al. (2004) studied 6,102 community-dwelling non-Hispanic African Americans and whites from the Chicago Health and Aging Project, and found that higher number of social networks and higher level of social engagement were associated with a reduced rate of cognitive decline. Seeman et al. (2001b) studied 1,189 older adults from the MacArthur Studies of Successful Aging and found that greater baseline emotional support was also a significant predictor of better cognitive function at the 7.5-year follow-up. Béland, Zunzunegui, Alvarado, Otero, and del Ser (2005) studied 1,571 community-dwelling elderly aged 65 or older living in suburban Madrid and found that engagement with family delayed the decline in cognitive function. However, even though these studies all examined the longitudinal relationship between some sort of social resource and the rate of cognitive decline, each study used a different measure of the psychosocial factor of interest. Therefore, the implications of the findings from these studies for our study are limited. In our case, even though we used longitudinal data for our analysis, SEM cannot prove causal relationships. Therefore, our finding may suggest that older adults with a faster rate of cognitive decline need a higher level of social support.

As a secondary aim, we conducted exploratory analysis for dual sensory loss. We explored the mediation effect of loneliness and moderation effect of social support on the relationship between sensory loss and cognitive function. The only significant relationships found were between dual sensory loss and loneliness, and between dual sensory loss and rate of cognitive decline. Our findings suggest that older adults who have more types of sensory loss have both more severe loneliness and a faster rate of cognitive decline. This finding was consistent with the findings from our previous chapter.

Our study has some limitations. First, in our exploratory analysis of dual sensory loss, we did not differentiate between vision loss and hearing loss, but just coded our sensory loss variable as "number of sensory losses". Based on our findings, the relationships between sensory loss and cognitive function are different for different types of sensory loss. Therefore, future studies of dual sensory loss should bear this difference in mind. Second, we did not have information about the time of onset of sensory loss, which limits our understanding of how length of time living with sensory loss and adaptation to sensory loss may influence its relationship to cognitive decline. Third, we only had five waves of cognitive function information collected over 8 years, and 197 participants in our sample have had at least three waves of cognitive function measured. future studies with a longer follow-up period of time may be better able to delineate the relationship between sensory loss, psychosocial factors, and cognitive decline. Fourth, we only had baseline information for sensory loss, social support, and loneliness. Future studies may consider using longitudinal data for sensory loss, social support, and loneliness to better delineate the effects of these factors as they vary with time.

4.6 Conclusion

Our study examines the inter-relationships between sensory loss, social support, loneliness, and cognitive decline using longitudinal data. We used objectively measured sensory loss, and we used a cognitive function measure that has been widely used in national representative surveys. The measures of loneliness and social support used in our study have also been widely used and have demonstrated satisfactory reliability and validity. Our findings suggest that vision and hearing loss each has a different pattern of associations with cognitive decline, and social support and loneliness can moderate or mediate the relationship between sensory loss and cognitive function, but not decline. Future studies that seek to understand the inter-relationships between sensory loss, psychosocial factors, and cognitive decline should consider using longer follow-up period with multiple waves of sensory loss and psychosocial factors measured.

5. Conclusion

5.1 Introduction

This dissertation aims to understand the roles that two major categories of potential risk factors, psychosocial factors and sensory loss, play on cognitive function and decline among community-dwelling older adults. It is important to examine the relationship between sensory loss, psychosocial factors, and cognitive decline; given the general trend of global aging and the increasing research interest in preventing cognitive decline and dementia (Livingston et al., 2017; Prince et al., 2018; World Health Organization, 2019).

The introductory chapter (Chapter 1) lays the foundation for the whole dissertation. A literature review was integrated into the introduction chapter. Chapter 1 articulated the importance of understanding the risk factors for cognitive decline, and Chapter 1 also provided detailed conceptualizations for each variable of interest. A synthesis of the empirical studies based on the literature review was also provided to describe the current evidence and to define the knowledge gaps.

Overall, this dissertation offers important insights. First, the relationship between social support and cognitive function can vary in different cultural settings. Second, older adults with hearing loss and dual sensory loss are likely to have a faster rate of subsequent cognitive decline. Third, increasing social support and reducing loneliness may potentially benefit cognitive function but not decelerate cognitive decline among older adults with sensory loss. Findings from the dissertation contribute to filling the research gaps in understanding the risk factors for cognitive decline. A summary of the specific and relevant findings in each chapter are highlighted below, followed by recommendations for future research, practice, and policy.

5.2 Social Support, Social Strain, and Cognitive Function among Community-dwelling U.S. Chinese Older Adults

In the first data-based study in this dissertation, we conducted a cross-sectional study to examine the relationship between social support, social strain (also known as negative social support), and cognitive function among U.S. Chinese older adults.

Chapter 2 inspired the development of the subsequent chapters. Despite the existing evidence on the relationship between social support and cognitive function, it remains unclear why and how social support affects cognitive function. The stress-buffering hypothesis has been widely mentioned in studies of social support and cognitive function. However, no studies have tested if social support can actually "buffer" the impact from life stressors on cognitive function among older adults. Therefore, in Chapter 4, we tested the relationship between sensory loss and cognitive decline in the context of the stress-buffering hypothesis. Given the limitations of this chapter as a cross-sectional study, the author realized the need to take one step further in Chapter 4 to examine the longitudinal relationship between psychosocial factors and cognitive decline among older adults. The collaboration with PINE study provided a solid foundation for the author to start and finish the remaining studies in this dissertation.

5.3 Associations between Hearing Loss, Vision Loss, and Dual Sensory Loss and Cognitive Decline: Findings from the ADAMS Study

In Chapter 3, we employed multilevel modeling to test the longitudinal association between sensory loss (i.e., hearing loss, vision loss, and dual sensory loss) and cognitive decline among older adults in the United States using data from HRS. We found that older adults with hearing loss and those with dual sensory loss had faster rates of cognitive decline than those without sensory loss, and the effect size for the association between dual sensory loss and rate of cognitive decline was larger than the effect size for the association between hearing loss alone and cognitive decline. In this chapter, we hoped to first clarify the associations between sensory loss and cognitive decline before testing the moderation or mediation effects from two important psychosocial factors – social support and loneliness.

Our study found no significant association between vision loss and rate of cognitive decline. Although this finding was surprising, we continued to examine the potential existence of indirect associations by exploring the mediation effect of loneliness in the subsequent chapter (Zhao, Lynch Jr, & Chen, 2010).

5.4 Longitudinal Inter-relationships between Sensory Loss, Social Support, Loneliness, and Cognition

In Chapter 4, we tested our entire conceptual model by employing a structural equational modeling (SEM) approach. The findings from this chapter contribute to the understanding of the mechanisms underlying the association between sensory loss and cognitive function, which has been proposed as a research priority for prospective studies of sensory loss (Whitson et al., 2018).

Our findings suggest inter-relationships between sensory loss, psychosocial factors, and cognitive function or cognitive decline. Future studies, interventions, or policy decisions concerning older adults with sensory loss should keep in mind the potential influence of psychosocial factors. Our findings also suggest that vision loss and hearing loss each interact with different types of psychosocial factors in different ways. Future studies should pay attention to conceptualize their psychosocial factors of interest carefully and apply robust measurement approaches to facilitate greater understanding of these relationships.

5.5 The Utilization of Different Measures of Cognitive Function between Chapter 2 and Chapters 3 and 4

The PINE study used a battery of five cognitive tests, including the Chinese Mini-Mental Status Examination (C-MMSE), Immediate and Delayed East Boston Memory Test (EBMT), Symbol Digit Modalities Test (SDMT), and Digit Span Backwards Test (DSBT). Given that cognitive function domains were measured using five individual tests, a composite z score of the five tests was used to assess the global cognitive function. Using a z score to combine scores measured from two or more different cognitive function scales reduces measurement error and has been utilized in previous publications (Agrawal et al., 2009; Chang & Dong, 2014a; Wilson et al., 2002).

In Chapters 3 and 4, we used the HRS version of the modified Telephone Interview for Cognitive Status (TICS) (Brandt, Spencer, & Folstein, 1988; Ofstedal et al., 2005; Welsh, Breitner, & Magruder-Habib, 1993), which is a measure of global cognitive function that was modeled after MMSE. TICS is one test and uses its total sum score to represent global cognitive function.

Because these analyses were dependent on the use of secondary data, the use of different cognitive function measures across different chapters is subject to the availability of data in the parent study. Even though we used different measures of cognitive function in different chapters, the outcome variable across the chapters is consistent (cognitive function). Although we are not able to directly compare results from each study because of different study designs and approaches to measuring social support and cognition, each of the chapters provides distinctive but complementary insights into the relationship between psychosocial factors, sensory loss, and cognitive function that can be used to inform future studies, particularly in the area of how psychological factors influence cognition.

5.6 The Selection of Covariates in Chapters 2, 3, and 4

The selection of covariates in each of the data-based chapters was based on theory and prior research (Heinze, Wallisch, & Dunkler, 2018). We intended to include the factors that have been shown to have associations with cognitive function or cognitive decline. Therefore, in each of the data-based chapters, we controlled for demographic and socioeconomic factors (e.g., age, education, and income), health factors (e.g., depression, number of medical conditions, and physical function). In Chapter 2, we also included the factors that were population specific, including length of residence in the community and acculturation. Both length of residence in the community (Clarke et al., 2012) and acculturation (Tang, Chi, Zhang, & Dong, 2018) have been found to be associated with cognitive function among older adults. In Chapters 3 and 4, beyond using theory to guide our selection of covariates, we also used a statistical approach to assist our selection. In the initial list of potential covariates for

Chapter 3 and 4, we also included gender, marital status, living arrangement, depression, smoking, and *Apoe ε4.* Because of the much smaller sample sizes in Chapters 3 and 4 than in Chapter 2, we sought to carefully limit the number of variables in the models (VanVoorhis & Morgan, 2007). Therefore, we only included the variables that had significant associations with cognitive function in the current sample in the final models.

Because my purpose is not to compare the results from the three data-based chapters, having different covariates included in Chapter 2 and Chapters 3 and 4 was not a particular concern.

5.7 The Counter-intuitive Findings in Chapters 2 and 4

In Chapter 2, we found counter-intuitive results for the associations between social strain or sources of social strain (negative social support) and cognitive function among U.S. Chinese older adults. We discussed the potential reasons for these counter-intuitive findings in Chapter 2's discussion section.

In Chapter 4, we found counter-intuitive results regarding the associations between social support and the rate of cognitive decline among older adults in the U.S. These findings may be because older adults who have faster cognitive decline need and perceive more social support from their social ties.

findings were unlikely to be related to the measurement errors. The instruments of social support (Walen & Lachman, 2000)and loneliness (Hughes et al., 2004) have demonstrated good content validities (Hughes et al., 2004; Walen & Lachman, 2000) and have shown satisfactory reliabilities in the samples used in each chapter.

5.8 Studying Different Populations in Different Chapters

We studied Chinese older adults (age > 60 years) in the U.S. in Chapter 2 and we studied the general U.S. older adult population (mostly Caucasians) in Chapters 3 and 4.

The relationship between social support and cognitive function has been widely studied in the general U.S. older adult population (Dickinson et al., 2011; Seeman et al., 2001b; Sims et al., 2014; Tun et al., 2013; Windsor et al., 2014). Therefore, we chose to study this relationship among the U.S. Chinese older adults based on my research interest and the lack of prior studies. Examining this relationship among the U.S. Chinese older adults is also of significance given the fast increase in the size of this population as well as their unique social environment post immigration (Chen et al., 2014).

Despite the fact that different populations were studied, we tried to maintain the consistency across the three data-based chapters by using similar constructs and instruments. We consistently used “perceived social support” as one of our key variables of interest across the chapters. The measures of social support in the PINE study was also drawn from HRS (Chen et al., 2014).

To my knowledge, there are no published cross-validation studies of the perceived social support and the UCLA 3-item loneliness instruments among U.S. Chinese older adults. However, these carefully translated instruments have shown adequate psychometric properties among the U.S. Chinese older adult population, and have been frequently used in previous publications (Chao, Katigbak, Zhang, & Dong, 2018; Chen et al., 2014; Dong & Liu, 2017; Tang, Chi, & Dong, 2017; Wang, Kong, Sun, & Dong, 2018). Future studies may consider conducting cross-validation studies of these instruments to provide stronger support for using these instruments among the U.S. Chinese older adults.

5.9 The Scope of the Dissertation

In this dissertation, we only studied two psychosocial factors: social support and loneliness. Meanwhile, we only studied two modalities of sensory loss: hearing loss and vision loss. The scope of this dissertation was established based on the author's research interests and the significance of these factors (Cacioppo & Hawkley, 2009; Cohen & Wills, 1985; Crews & Campbell, 2004; Lin et al., 2013). Future studies may consider examining the relationships between cognitive function and other psychosocial factors or other modalities of sensory loss.

5.10 EM Imputation

We chose to use EM imputation for Chapters 3 and 4. There is no clear threshold in the percentage of missing data that would prevent us from using EM. EM is appropriate to be used under the circumstance of missing not completely at random but the missing mechanism is ignorable (i.e., missing at random) (Allison, 2009), which is the case for our data. When missing at random (MAR), both EM imputation and multiple imputation (MI) are stable and produce approximately unbiased estimates (Allison, 2009). However, EM imputation has many advantages compared with MI. First, EM imputation is easy to implement. Many software packages are readily available to implement EM imputation. Second, unlike MI, the EM algorithm is based on the observed data log likelihood and does not need simulations (Dong & Peng, 2013). However, EM imputation has a prominent disadvantage in that it does not produce standard error (SE) estimates. Therefore, if the research primarily aims to generate confidence intervals of the estimated parameters, EM imputation cannot be used (Allison, 2009; Dong & Peng, 2013). Otherwise, EM imputation has been preferred over MI, especially for use in mixed models (Dong & Peng, 2013).

5.11 Limitations

This dissertation is subject to several limitations.

First, because it is a secondary data analysis, we can only conduct our analysis with the data available in the dataset. For example, in Chapter 3 and Chapter 4, we only had information for the Pure Tone Threshold, and we had insufficient information to calculate the Pure Tone Average (PTA) Score. However, we coded hearing loss in a robust manner using a standard that was both clinically meaningful and widely used in the literature (Clark, 1981; Gopinath et al., 2013; Lin, Thorpe, et al., 2011).

Second, in Chapters 3 and 4, we only coded vision loss as "vision loss (1) or not (0)" in our analyses. We did not include "blindness" as a separate level of vision loss.. One previous prevalence study of vision loss coded to also include the level of "blindness" (Varma et al., 2016). But most studies have not (Chen et al., 2017; Lin et al., 2004; Reyes-Ortiz et al., 2005). The author of this dissertation may consider including the level of "blindness" in future studies of vision loss, which may provide more insights into the relationship between vision loss and cognitive decline.

Third, in Chapter 3 and 4, we only had five waves of cognitive function measured over an 8-year follow-up. One study that examined the relationship between hearing loss and cognitive decline using data from a study with 20-year follow-up modeled a quadratic relationship between age and cognitive decline (Maharani et al., 2019). With the data we had, we did not observe a quadratic relationship in our analysis. Therefore, we modeled a linear relationship between sensory loss and cognitive decline, as most other studies on sensory loss and cognitive function have done (Lin, 2011; Lin & Ferrucci, 2012; Lin, Ferrucci, et al., 2011; Lin, Metter, et al., 2011; Lin, Thorpe, et al., 2011; Lin et al., 2013; Lin et al., 2004; Reyes-Ortiz et al., 2005). With a longer follow-up period, we may be able to observe a curvilinear relationship that may help us further improve our model.

Fourth, we should be cautious when attempting to generalize our study findings. The HRS and ADAMS study are nationally representative. However, in our analysis, we decided not to use weights for several reasons. First, we started using the data from ADAMS wave C. ADAMS wave A was nationally representative as of 2001, but the ADAMS wave C sample is not representative anymore due to which individuals were followed based on study design and loss to follow up. Second, ADAMS Wave C weights (CCOHORTWT) seems to be the most appropriate weight variable for our studies. However, the ADAMS data user guide specifically mentions that use of this weight variable is not recommended (Heeringa et al., 2009).

5.12 Implications for Research

The findings from this study highlight a few points for future studies to consider.

Future studies that examine the effects of several psychosocial factors simultaneously should carefully differentiate the conceptualization of each of these variables. It is not uncommon to see studies use different psychosocial terms interchangeably. In addition, beyond careful conceptualizations, researchers should be cautious in correctly modeling the potential associations between different psychosocial terms.

In the case of sensory loss, future studies should bear in mind the clinical implications of different severities of sensory loss for older adults. Based on our findings, future studies of dual sensory loss should preferably take different kinds of sensory loss into consideration, not just “numbers of sensory loss”, given that different types of sensory loss may have different relationships with cognitive function/decline.

Our study contributes to the understanding of the mechanisms that connect sensory loss and cognitive decline. However, much more research is still needed to test the hypothesized mechanisms (Fulton et al., 2015; Whitson et al., 2018). Our findings supported the point of view that sensory loss can be a chronic life stressor. There is merit in testing the impact of sensory loss on other health outcomes in the paradigm of the stress-buffering hypothesis of social support.

To achieve the ultimate goal of preventing cognitive decline and dementia, studies that intervene on sensory loss to prevent or delay cognitive decline are on the horizon. To the author’s knowledge, there are two early-stage studies that aim to prevent cognitive decline through promoting healthy behavioral adaptations to hearing loss. Pilot studies have shown high acceptability by the study participants and have shown satisfactory intervention efficacy (Deal et al., 2017; Deal et al., 2018).

Future researchers should consider the potential racial differences in the relationship between sensory loss and cognitive decline, and how psychosocial factors interact with the relationship. Potential racial disparities in sensory loss is another topic that has been prioritized (Whitson et al., 2018). Future studies should also examine the relationship between cognitive function and other facets of sensory loss, e.g., visual contrast sensitivity, smell, touch, etc.

Future studies should consider including the *Apoe ε4* allele as a potential covariate to be controlled. The *Apoe ε4* information was available in the ADAMS data. We initially planned to adjust for it in our model. However, when we tested the association between *Apoe ε4* and cognitive function in Chapter 3, we found no significant association between the two. Therefore, we decided not to include *Apoe ε4* as a covariate in our final models. The insignificant association may be attributed to that the ADAMS Wave C sample is composed of older adults who were not previously diagnosed with dementia. Though we did not include *Apoe ε4* in our models, we acknowledge that *Apoe ε4* is an important genetic factor to be considered in research of cognitive function and decline. Previous studies of sensory loss and cognitive function/decline have rarely controlled for the effect of *Apoe ε4* (Alattar et al., 2019).

Future studies should carefully consider the appropriateness of controlling for *Apoe ε4* in their models should they have the information available.

5.13 Implications for Practice and Policy

Preserving adequate sensory and cognitive function allows older adults to live an independent life. Healthcare practitioners and family members should closely observe the changes in older adults' sensory and cognitive function and help those with decreased sensory or cognitive function seek appropriate health care and develop healthy behaviors.

The Over-the-Counter (OTC) Hearing Aid Act was passed in 2017. Beginning in 2020, if not sooner, older adults will have access to OTC hearing aids (Frellick, 2019). The average cost of hearing aids is $4700 and it is not covered by Medicare (Frellick, 2019; Medicare. gov, 2019). Companies, like Bose, are in the process of developing more advanced and cheaper hearing aids (AARP, 2019).

It was reported that a lower percentage of older adults of lower socioeconomic status wear hearing aids (McKee et al., 2018). This may be related to their lower health literacy regarding hearing aids and the high cost of hearing aids (McKee et al., 2018). Therefore, health practitioners and policy makers should pay attention to health disparities among lower SES older adults and create more access to adequate hearing loss treatment or rehabilitation.

Older adults with vision loss are exposed to potential safety risks during daily tasks like driving and walking (American Optometric Association, 2019). There are many causes of vision loss among older adults, including but not limited to diabetic retinopathy, age-related macular degeneration, and cataracts (American Optometric Association, 2019). Health education is particularly important to increase the awareness of and improve adaptations to the challenges related to vision loss among older adults. Healthcare providers should provide health education that corresponds to the reason for vision loss and help older adults manage the related challenges and complications.

Early detection of cognitive decline may contribute to preventing the progression of cognitive decline and dementia. Effective January 2017, Medicare started covering care planning for people with cognitive impairment (Alzheimer's Association, 2016). Health care providers and family caregivers of older adults should take advantage of Medicare, and help to increase early detection of cognitive impairment and encourage diagnostic evaluation of dementia (Alzheimer's Association, 2018; Maslow & Fortinsky, 2018).

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Biography

Shaoqing Ge was born in Shandong Province, China. Ms. Ge graduated from Shandong University in 2012 with a Bachelor of Medicine in Nursing Science. In 2014, she completed the Master of Public Health (MPH) Program at Tulane University School of Public Health and Tropical Medicine. In August 2014, Ms. Ge enrolled in the Duke University School of Nursing PhD Program. During her doctoral program, Ms. Ge has been awarded several scholarships and awards. Ms. Ge has first-authored three peer-reviewed manuscripts and co-authored three. She has also presented at several academic conferences. Ms. Ge is a member of Gerontological Society of America (GSA) and Sigma Theta Tau Beta Epsilon Chapter. Ms. Ge has taken leadership roles in the Duke Graduate and Professional Student Council (GPSC) and in the Standing Committee of the Duke University Board of Trustees.