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Social Engagement Among Older Adults With Mild Cognitive Impairment and Conversion to Dementia

by

Takashi Amano, MSW

A dissertation presented to
The Graduate School
of Washington University in
partial fulfillment of the
requirements for the degree
of Doctor of Philosophy

May 2019
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ABSTRACT OF THE DISSERTATION

Social Engagement Among Older Adults With Mild Cognitive Impairment and Conversion to Dementia

by

Takashi Amano, MSW

Doctor of Philosophy in Social Work

Washington University in St. Louis, 2019

Professor Nancy Morrow-Howell, Chair

Promoting social engagement is a promising approach to prevent or delay conversion from cognitive impairment no dementia (CIND) to dementia. However, little is known about social engagement among people with CIND. This dissertation project aimed to improve understanding of social engagement among people with CIND by addressing gaps in the literature. It had three specific aims including: to describe and identify factors associated with heterogeneity of social engagement among older adults with CIND, to assess the association between heterogeneity of social engagement and conversion from CIND to dementia, and to investigate the relationship among heterogeneity of social engagement, other types of activity engagement, and conversion from CIND to dementia. Data from two waves (2010 and 2014) of the Health and Retirement Study (HRS) were used. The sample consisted of 1,227 people who were classified as having CIND in 2010. To identify the heterogeneity of social engagement, Latent Class Analysis (LCA) was utilized. Multinomial logistic regression analysis was conducted to assess the association between factors and patterns of social engagement. Using LCA, three groups were identified: Formal and informal social engagement group, Informal social engagement only group, and Low

social engagement group. Some factors from four domains of WHO's ICF model were associated with probability of having certain patterns of social engagement. To assess the relationship between heterogeneity of social engagement and conversion from CIND to dementia, binary logistic regression was utilized. The result showed that people in the formal and informal social engagement group and informal social engagement only group had significantly lower probabilities of converting to dementia in four years. To investigate the relationship among different types of activity engagement and conversion from CIND to dementia, path analysis with structural equation model was utilized. The result revealed that the relationship between having the pattern of formal and informal social engagement and lower probability of converting to dementia in four years was mediated by having higher cognitive engagements. Findings suggest that social engagement is heterogeneous among people with CIND and there are some modifiable factors to promote social engagement among them. Results of this study also imply that promoting social engagement may be promising intervention to prevent or delay conversion from CIND to dementia. Findings further indicate that promoting social engagement may be more effective and efficient strategy since it promotes other activity engagements that may prevent or delay conversion from CIND to dementia.

Chapter 1: Introduction

Significance

Alzheimer's disease and vascular dementia, along with other forms of severe cognitive impairment, have profound effects on the lives of individuals and families. These forms of dementia lead to severe functional dependency, the need for intensive assistance, and often placement in residential care settings. The social and economic costs of dementia are enormous and may increase due to population aging—a recent study estimated 8.8% of people who were older than 65 had dementia in 2012 (Langa et al., 2017). Dementia has been recognized as one of the biggest challenges in the United States. In 2011, President Barack Obama signed into law the National Alzheimer's Project Act, which established the National Alzheimer's Plan in order to "confront the challenge dementia poses to our public health" (U.S. Department of Health & Human Services, 2018).

There is no cure for dementia; therefore, preventive intervention for higher risk groups is considered to be the most promising approach. One high-risk group for dementia is individuals with mild cognitive impairment. These individuals exhibit cognitive decline that does not significantly affect daily function. The term *cognitive impairment no dementia* or *cognitive impairment, not dementia* (CIND) is used to identify this condition (Fisher, Plassman, Heeringa, & Langa, 2008). CIND is not a rare condition among older adults; a recent study estimated that 11.6% of people aged 65 or older had this condition (Langa et al., 2017). Although not all people with CIND will eventually develop dementia, they are at higher risk of developing dementia, which is called conversion to dementia. One study showed that 47% of people with CIND had clinical diagnosis of dementia at the 5-year follow up, whereas only 15% of people without

cognitive impairment at the baseline were diagnosed with dementia over the same period of time (Tuokko et al., 2003). Identifying factors associated with lower risk of conversion from CIND to dementia may inform practical knowledge to develop effective preventive interventions.

Although many biomedical factors have been identified as predictors of risk of conversion from CIND to dementia, no effective preventive pharmacological intervention has yet been developed. In contrast, the nonpharmacological approach has been recognized as a promising alternative to the pharmacological approach. Typical preventive interventions with the nonpharmacological approach promote one or more social, physical, or cognitive activity (Horr, Messinger-Rapport, & Pillai, 2015; Rodakowski, Saghafi, Butters, & Skidmore, 2015). This approach is considered to be promising because many population-based studies have shown the association between higher engagement in these lifestyle activities and lower risk of developing dementia (e.g. Bassuk, Glass, & Berkman, 1999; Fratiglioni, Paillard-Borg, & Winblad, 2004; Zunzunegui, Alvarado, Del Ser, & Otero, 2003). Some studies have shown the effectiveness of nonpharmacological preventive interventions for people with CIND such as cognitive stimulation. Cognitive stimulation is a multimodal activity-based nonpharmacological intervention that aims to engage people with cognitive impairment in physical and cognitive activities in social settings (Spector, Orrell, & Woods, 2010; Woods, Aguirre, Spector, & Orrell, 2012). Some studies showed that participating in a cognitive stimulation intervention was associated with lower conversion from CIND to dementia (e.g. Jean, Bergeron, Thivierge, & Simard, 2010). However, evidence is almost exclusively based on results in clinical settings. Considering feasibility and availability of the intervention, it seems important to develop an intervention that promotes engagement outside clinical settings.

In order to develop an activity-based nonpharmacological intervention for people with CIND who are living in their own homes, it is especially important to understand social engagement among this population. One reason is that social engagement may have a unique association with lower risk of conversion from CIND to dementia. Many studies have suggested the association between more frequent social engagement and higher cognitive function in later life. According to Hertzog, Kramer, Wilson, and Lindenberger (2008), social engagement has a unique association with higher cognitive function after controlling for confounders related to other possible mechanisms such as depression and physical and cognitive engagements.

Although the causal mechanism is still inconclusive, some studies have suggested the existence of a direct mechanism between social engagement and cognitive function—engaging in social activity improves neuronal systems (Smith, Yao, Chen, & Kirby, 2018; Stern, 2002). Another reason is that active social engagement may encourage people to engage in physical and/or cognitive activities that are associated with higher cognitive function and lower risk of dementia. Some studies have suggested that people who were socially active were more likely to engage in more physical and cognitive activities than those who were not socially active (e.g. Brown et al., 2016). Therefore, an effective intervention should target promotion of social engagement among people with CIND.

Although promoting social engagement may be one promising strategy to provide better cognitive health for people with CIND, it may also be a challenging task. People with CIND may have particular difficulty in engaging in social activities because this condition affects their lives in various ways. People with CIND may have difficulty conducting prerequisite tasks for social engagement, such as arranging transportation or using the telephone. They may also have psychological disturbances caused by CIND such as depressive symptoms or apathy, which may

decrease their motivation to participate in social activities. Moreover, CIND may affect social relationship between people with CIND and the people in their lives because of stigma associated with this condition. Nevertheless, knowledge about social engagement among people with CIND in the existing literature is still limited.

Aims

This dissertation project seek to improve understanding of social engagement among people with CIND by addressing gaps in the literature. It has three specific aims including: to describe and identify factors associated with heterogeneity of social engagement among older adults with CIND, to assess the association between heterogeneity of social engagement and conversion from CIND to dementia, and to investigate the relationship among heterogeneity of social engagement, other types of activity engagement, and conversion from CIND to dementia. By doing so, it informs practical knowledge to develop effective and efficient community-based nonpharmacological interventions, which prevent or delay conversion from CIND to dementia. It also makes recommendations for future development of interventions and research based on the findings achieved in the project.

In the following sections, this dissertation first reviews relevant studies and identifies specific gaps in the literature. Second, it reviews related theoretical models to develop research questions and hypotheses that would address identified gaps. Third, it presents the methods to test those hypotheses. Fourth, it shows findings of this research project. Finally, it provides implications from this study and discussion for future studies.

Definition of Social Engagement

Social engagement tends to be loosely defined in the literature. The definition of social engagement used in this dissertation proposal is based on Morrow-Howell and Gehlert's (2012),

who include several factors as essential elements of social engagement: engagement in activity, social context, and volitional participation. In some studies, social engagement may include nonactivity constructs such as social network and social support as well as constructs such as social activity. Although these three constructs may all be associated with cognitive function (Krueger et al., 2009; Wang, He, & Dong, 2015), some studies imply more consistent relationships between cognitive impairment and social activity than with the other two constructs (Conroy, Golden, Jeffares, O'Neill, & McGee, 2010; Hertzog et al., 2008; Kelly et al., 2017). Social engagement may also include physical and cognitive activities, which may include some social context (e.g., walking may include meeting with friends, playing games may include interactions with other players). In this dissertation, however, social engagement is defined as engaging in social activities that always includes social exchange, although those social activities with physical and cognitive features are not excluded. This definition allows for investigating the relationship among social, physical, and cognitive engagement, which are all known to be associated with cognitive function. Nondiscretionary activities such as working and caregiving tend to be excluded from social engagement (Morrow-Howell & Gehlert, 2012). This dissertation also excludes nondiscretionary activities because engagement in those activities may include more complex context than engagement in voluntary activities.

Definition of Mild Cognitive Impairment

This study uses CIND to describe older adults with mild level of cognitive impairment but not a level of dementia. There is another term called *mild cognitive impairment* (MCI), which describes very similar condition as CIND and is often used interchangeably with CIND. In this dissertation, I use the term CIND because CIND is the broader term than MCI including impairment in any domains of cognitive function and any etiologies causing the impairment

(Fisher et al., 2008); therefore CIND may be more suitable for nonclinical community-based studies where detailed diagnostic information may not be available. In fact, CIND has been used in population-based studies with a nationally representative survey such as the Health and Retirement Study (HRS; Crimmins, Kim, Langa, & Weir, 2011; Fisher et al., 2008; Alzheimer's Association, 2010; Langa et al., 2017).

Chapter 2: Empirical and Conceptual Foundations

Previous Studies

Social Engagement and Cognitive Function in Later Life

Many studies have suggested an association of higher social engagement with higher cognitive function (Barnes, Mendes de Leon, Wilson, Bienias, & Evans, , 2004; Bassuk et al., 1999; Bourassa, Memel, Woolverton, & Sbarra, 2017; Haslam, Cruwys, & Haslam, 2014; Haslam, Cruwys, Milne, Kan, & Haslam, 2016; James, Wilson, Barnes, & Bennett , 2011; Lövdén, Ghisletta, & Lindenberger, 2005; Smits, van Rijsselt, Jonker, & Deeg, 1995; Thomas, 2011; Zunzunegui et al., 2003). However, the causal direction between social engagement and cognitive function is still inconclusive. Some studies suggested that higher social engagement contributes to improving or maintaining cognitive function (Bourassa et al., 2017; James et al., 2011; Thomas, 2011) and preventing or delaying development of dementia (Kuiper et al., 2015). Other studies argued that people with declining cognitive function tend to engage in less social activity (Brown et al., 2012; Saczynski et al., 2006; Small, Dixon, McArdle, & Grimm, 2012). This relationship—as Bielak, Mogle, and Sliwinski (2017) argued—is seemingly reciprocal.

The mechanism between social engagement and cognitive function has also been unclear. There are two major proposed pathways—direct and indirect. If there is a direct pathway, social engagement has a direct impact on neural system and cognitive function because it is cognitively stimulating. As an indirect pathway, two possible mechanisms have been proposed. First, social engagement reduces stress and depressive symptoms that are known predictors of cognitive decline or dementia. Second, social engagement encourages people to engage in more physical

and cognitive activities, which are also known protective factors against cognitive decline or dementia.

The existence of the direct pathway is theoretically and empirically endorsed. Theoretically, the environmental enrichment model posits that individuals living in an environment that allows them to engage in socially, physically, and cognitively complex activities would have higher cognitive abilities than those who are living in a simple environment. The cognitive reserve hypothesis holds that complex or cognitively stimulating activities may contribute to building "reserve" in individual's neural system, which serves as protective against neural pathology (Stern, 2002).

Empirically, the direct pathway has been suggested in observational studies and experimental studies. Many observational studies found an association between social engagement and subsequent higher cognitive function after controlling for other factors related to indirect mechanisms such as depressive symptoms and physical and cognitive engagement (Barnes et al., 2004; Bassuk et al., 1999; Bourassa et al., 2017; Fratiglioni et al., 2000; Haslam et al., 2014; 2016; Scarmeas, Levy, Tang, Manly, & Stern, 2001; Wang, Karp, Winblad, & Fratiglioni, 2002; Wilson et al., 2007; Zunzunegui et al., 2003). Notably, Haslam et al. (2014, 2016) showed that higher group (cultural activities and community activities) and individual (social contacts and social relationship) social engagements were both associated with higher baseline cognitive function but only group social engagement was associated with subsequent higher cognitive function. They suggested that group engagement may encourage greater cognitive stimulation, which improves cognitive outcomes than individual engagement does. Some evidence of the direct pathway is also seen in findings from randomized controlled trials. Five studies examined the effects of increasing lifestyle social engagement on cognitive function

(Carlson et al., 2008; Mortimer et al., 2012; Park et al., 2014; Stine-Morrow, Parisi, Morrow, & Park, 2008). In those studies, participants were randomly assigned to an intervention group or a control group. Those assigned to the intervention group engaged in regular lifestyle social activities. Three studies (Carlson et al., 2008; Mortimer et al., 2012; Stine-Morrow et al., 2008) found that the social activity intervention group had statistically significantly higher cognitive function than the control group after the intervention. On the contrary, Park et al. (2014) found no improvement in social activity group. However, they limited social activities to activities that did not involve active skill acquisition. This finding suggested that different types of social activities may be differently associated with cognitive function.

Social Engagement and Risk of Dementia

Promoting social engagement may be one possible intervention for preventing dementia as it has been shown that higher social engagement is associated with lower risk of developing dementia (Fratiglioni et al., 2004; Karp et al., 2006; Kuiper et al., 2015; Scarmeas et al., 2001; Wang et al., 2002; Wilson et al., 2007) as well as higher cognitive function. Recently, a task force formed by the *Lancet* identified social engagement as one of the later life ""potentially modifiable risk factors for dementia" (Livingston et al., 2017, p. 2677), along with smoking, depression, physical inactivity, and diabetes.

Although those studies have shown the association between the lack of social engagement and risk of developing dementia, few studies have been concerned with how promoting social engagement can be used as a preventive intervention. Nemoto et al. (2017) investigated the impact of the leadership role in-group social activities on the probability of developing dementia within a 10-year period among Japanese older adults. They showed that people who had leadership roles in their group social activities had lower risk of developing dementia than those who were regular nonleader participants. Results suggested that the

leadership role may allow participants to engage in more cognitively stimulating activities through social engagement.

Other evidence of effectiveness of promoting social engagement as a preventive intervention can be seen in studies of nonpharmacological activity based interventions that aim to prevent and/or delay conversion from CIND to dementia. Some studies have shown that a combination of social, physical, and cognitive activity engagement is associated with lower risk of conversion from CIND to dementia (Buschert et al., 2011; Dannhauser et al., 2014; Jeong et al., 2015; Lam, Chan, Leung, Fung, & Leung, 2015; Straubmeier et al., 2017; Train the Brain Consortium, 2017; Tsolaki et al., 2011). However, evidence is almost exclusively limited to clinical studies. One limitation of these clinical studies is that they only address outcomes or effects of engagement but does not describe activity engagement among people with CIND nor address factors associated with engagement. It seems essential to know more about social engagement among people with CIND to develop interventions or identify strategies to promote it among this group of people. Another gap in those clinical studies is that they tend to focus only on physical and cognitive activities, and social engagement tends to be treated as an active control or an additional effect of group activities. As a result, evidence is scarce about the unique contribution of social engagement on conversion from CIND to dementia.

Social Engagement among People with CIND

Many studies have suggested an association between declined cognitive function and lower social engagement (e.g. Barnes et al., 2004; Bassuk et al., 1999; Haslam et al., 2014, 2016; James et al., 2011; Lövdén et al., 2005; Zunzunegui et al., 2003). For example, James et al. (2011) showed that the rate of decline in cognitive function was reduced by an average of 70% in participants who frequently engaged in social engagement, compared to those who were infrequently engaged. Similarly, people with CIND may be less likely to engage in social

activities compared to people without cognitive impairment (Garms-Homolová et al., 2017; Kotwal, Kim, Waite, & Dale, 2016; Parisi, Roberts, Szanton, Hodgson, & Gitlin, 2015; Wang et al., 2015).

Some studies have further identified possible reasons why CIND may disturb social engagement, one of which is lowered functional ability to conduct social activities. For example, Bora and Yener (2017) suggested that CIND may affect social functions and showed that people with CIND had lower efficiency in using theory of mind and lower accuracy in facial emotion recognition. Moreover, although people with CIND do not have overt difficulties in basic activities of daily living (ADL), reduced cognitive abilities may have an impact on ability to conduct complex activities of daily living such as instrumental activities of daily living (IADL; Peres et al., 2006). Another reason is that neuropsychiatric symptoms may affect the motivation of people with CIND. People with CIND are more likely to have neuropsychiatric symptoms such as depression (Richard et al., 2013) and apathy (Robert, Mulin, Malléa, & David, 2010), which may affect their motivational and emotional states. Finally, CIND may alter social relationships because CIND may contribute to stigma. According to Beard and Neary (2013), a diagnosis of Alzheimer's disease may be seen as being given a "death sentence" or as "a loss of capacity to be one's self" (p. 141). They also revealed that people had uncertainty in distinguishing between mild cognitive impairment and Alzheimer's disease; therefore, a diagnosis of mild cognitive impairment may carry a fear similar to that of an Alzheimer's diagnosis. Hailu, Cannuscio, Dupuis, and Karlawish (2017) presented a case study of a person with mild cognitive impairment who felt worried and ashamed in social situations. Such stigma may have a negative impact on interpersonal relationships between people with CIND and others. In fact, although Kotwal et al. (2016) did not test the direct relationship, people with CIND may

have decreased social network and social support, which may be necessary for engaging in some social activities.

Although previous studies have suggested that people with CIND have reduced levels of social engagement, it has not been clear if there is heterogeneity among them. In fact, methods used to measure social engagement in this area are not suitable for investigating heterogeneity. One typical method used is to ask about participation in one activity, such as volunteering (Okura et al., 2017), socialization (Garms-homolová et al., 2017; Okura et al., 2017; Parisi et al., 2015), and attending a group (Agahi, Ahacic, & Parker, 2008; Okura et al., 2017; Parisi et al., 2015). Another typical method is summing a list of activities. Some of those studies use a researcher-developed list of activities (e.g., Chiu et al., 2013; Genziani et al. 2013; Hughes, Flatt, Fu, Chang, & Ganguli, 2013; Katja, Timo, Taina, & Tiina-Mari, 2014; Kendig, Browning, Pedlow, Wells, & Thomas, 2010; Kotwal et al., 2016; Krueger et al., 2009; Lam et al., 2015; Sampson, Bulpitt, & Fletcher, 2009), whereas others use a standardized scale such as the Victoria Longitudinal Study Activity Lifestyle Questionnaire (VLS-ALQ; Hultsch, Hertzog, Small, & Dixon, 1999); Christensen and Mackinnon's (1993) activity scale; Community Integration Questionnaire—Social Integration (CIQ-S; Willer, Rosenthal, Kreutzer, Gordon, & Rempel, 1993); and the Brief Assessment of Social Engagement (BASE) scale (Morgan, Dallosso, & Ebrahim, 1985).

Using a single activity may not allow for investigating overall heterogeneity of social engagement among the sample. Summary scores of a set of activities may indicate the overall quantified levels of engagement but may not capture overall patterns of social engagement. This gap is problematic because some activities complement whereas others compete with each other (Burr, Mutchler, & Caro, 2007). In response to this argument, an emerging trend can be seen in

identifying overall patterns of engagement (Burr et al., 2007; Croezen, Haveman-Nies, Alvarado, Van't Veer, & De Groot, 2009; Fernández-Mayoralas et al., 2015; Matz-Costa, Carr, McNamara, & James, 2016; Morrow-Howell et al., 2014; Park, Park, & Chiriboga, 2018). Two studies suggested that patterns can be identified specifically regarding social engagement. Croezen et al. (2009) used a K-mean cluster analysis and identified five groups of people who held similar patterns of social engagement: less socially engaged elderly, less socially engaged caregivers, socially engaged caregivers, leisure engaged elderly, and productive engaged elderly. Park et al. (2018) used a latent class analysis (LCA) and identified four patterns of social engagement among older Korean adults: community center/disengaged, diverse, friendship/leisure, and religion plus. People assigned to the community center/disengaged group were likely to go to community centers or adult day centers but not likely to engage in other activities. People in the diverse group were likely to engage in all activities included in the model. The friendship/leisure group was likely to meet with friends and do hobbies. The religion plus group was likely to engage in religious activities, meet with friends, and go to adult day centers. Identifying discrete groups or patterns of social engagement among the sample seems like a suitable method to describe heterogeneity of social engagement. However, no study has used these methods to describe patterns of social engagement among people with CIND.

Besides the lack of utilization of methods that allow for identification of patterns of social engagement, previous studies have failed to know what particular factors are associated with heterogeneity of social engagement among people with CIND. Some studies suggested sociodemographic factors such as female gender (Kotwal et al., 2016) and being married and having children (Hughes et al., 2013) were significant predictors of higher levels of social engagement among older adults with mild to moderate cognitive impairment, whereas others

suggest no association (Rovner, Barry, Casten, Robin, & Leiby, 2016; Sørensen, Waldorff, & Waldemar, 2008). Although environmental factors were not investigated in most studies, Parisi et al. (2015) suggested that availability of transportation may affect social engagement among people with cognitive impairment. Another rarely investigated but seemingly important factor is subjective memory complaints. Farrell et al. (2014) showed that having subjective memory complaints were associated with lower social engagement but not with nonsocial activity engagement among people with mild to moderate Alzheimer's disease. Finally, Sörensen et al. (2008) and Chiu et al. (2013) suggested that people with CIND who had more neuropsychiatric symptoms engaged in fewer social activities than those who had fewer neuropsychiatric symptoms. One gap in studies of this area is the lack of systematic investigations on factor associated with heterogeneity of social engagement among people with CIND.

In sum, one clear gap identified in the literature is a lack of systematic investigations on heterogeneity of social engagement and factors associated with the heterogeneity among people with CIND. Social engagement has not been described using methods that allow for identifying discrete patterns among the sample. Furthermore, none of the studies discussed above used theoretical frameworks to determine what factors should be included in their analytic models. Therefore, cumulative knowledge about factors related to social engagement among people with CIND has not been well established.

Social Engagement and Conversion from CIND to Dementia

Although previous studies suggest the association between higher social engagement and higher cognitive function and lower risk of developing dementia, it has not been clear whether social engagement has unique roles on conversion from CIND to dementia. Clinical studies of nonpharmacological interventions for people with CIND suggest that social engagement may be one essential component of preventing or delaying conversion. However, few studies have

examined the relationship between social engagement and conversion from CIND to dementia. Lam et al. (2015) randomly assigned older people with CIND living in Hong Kong into social activity (as an active control group), physical activity, cognitive activity, or physical and cognitive activity groups. They found that the social activity group had similar cognitive function as the cognitive activity and physical activity groups. Only the group in which people engaged in both physical and cognitive activities had significantly higher cognitive function than other groups. Two observational studies revealed inconsistent findings. Hughes et al. (2013) showed that people who engaged in more diverse social activities had lower risk of conversion from cognitive impairment no dementia (CIND) to dementia. On the other hand, Grande et al. (2014) found that the baseline score on social activity was not associated with the risk of conversion.

Evidence of the association between social engagement and conversion from CIND to dementia is mixed. This inconsistency may be due to the lack of consistent measures of social engagement. For example, Lam et al. (2015) promoted passive activities with social contacts and low physical and cognitive demands (e.g., tea gathering or shopping with friends) for the social engagement group as an active control. Huges et al. (2013) counted number of activities engaged in over the past years including: going to church or place of worship, attending a special family occasion, attending other social events (visiting friends/family, senior center, clubs, restaurants, lodge, bar), and working/volunteering. Grande et al. (2014) used a single dimension scale of social engagement including four individual items such as going on holiday, going to the theatre or concerts, going to museum, and singing. It is worth noting that Hughes et al. (2013) included work/volunteering, whereas Lam et al. (2015) and Grande et al. only included relatively passive social activities. As suggested by Park et al. (2014) and Nemoto et al. (2017), different types of social activities may be differently associated with risk of conversion. To capture and describe

this complex relationship, it seems essential to identify patterns of social engagement and examine the association between patterns of social engagement and conversion from CIND to dementia.

Mechanisms between Social Engagement and Conversion

Another clear gap in the literature is the lack of investigation on the possible mechanisms of the association between social engagement and conversion from CIND to dementia. One proposed mechanism between social engagement and better health outcomes in general is that social engagement enhances healthy behaviors such as physical engagement (Berkman & Krishna, 2014; Cohen, 2004), which enhances health outcomes. This theory may be applicable to cognitive function as one of the health outcomes (Hertzog et al., 2008; Kuiper et al, 2015; Rizzulo & Fratiglioni, 2014). Evidence on the relationship between social engagement and cognitive engagement is not clear but a similar relationship may be assumed. In clinical studies of cognitive stimulation therapy, the intervention is designed to be implemented in social settings because it motivates people with dementia to participate in cognitive activities (Spector, Gardner, & Orrell, 2011). In the community-based setting, Stine-Morrow et al. (2014) showed that people with larger social network size had more advantage on cognitive function from the team-based cognitive engagement program. They suggested that people with experience of more social engagement may engage in more complex tasks in cognitive engagement. In fact, Brown et al. (2016) showed that the association between social engagement and cognitive function was partially mediated by cognitive engagement. Furthermore, Nemoto and Suzuki (2018), through a review of literature, argued that promoting social engagement may be a more efficient way to prevent dementia because social engagement contains both physically and cognitively stimulating activities and also may promote physical and cognitive activities. However, it has not

been addressed to what degree social engagement operates through physical and cognitive engagements on conversion from CIND to dementia.

Theoretical Underpinnings

Preview

There are two theoretical models used to address gaps identified through the review of previous studies. The International Classification of Function, Disability, and Health (ICF; World Health Organization [WHO], 2001; 2002) model was used to describe heterogeneity of social engagement among people with CIND and to systematically identify factors associated with the heterogeneity. The environmental enrichment model is used to develop hypothesis on the relationship between heterogeneity of social engagement and conversion from CIND to dementia.

International Classification of Function, Disability, and Health

The ICF is a multicomponent classification of health and health-related domains. It provides standard language and a framework to describe health and disability states of the individual. WHO developed this framework in response to the demand for "universally applicable classification and assessment tools, both for activity levels and overall levels of participation, in basic areas and roles of social life" (WHO, 2002, p. 7).

As shown in Figure 1, the ICF model describes functioning as outcomes of interaction between contextual factors, function, and health condition. Contextual factors "represent the complete background of an individual's life and living" (WHO, 2001, p.16). Contextual factors include two subfactors—environmental factors and personal factors. Environmental factors include "social attitudes, architectural characteristics, legal and social structures, as well as climate, terrain and so forth" (WHO, 2002, p.11). Personal factors include "gender, age, coping

styles, social background, education, profession, past and current experience, overall behavior pattern, character and other factors that influence how disability is experienced by the individual" (WHO, 2002, p.11).

[See Figure 1]

Function is divided into three levels and four constructs: Body functions and structure, Activity, and Participation. Body functions and structure indicate physical functioning and anatomical parts of body. Activity is the execution of a task or action by an individual. Participation is involvement in a life situation. Health condition refers to diseases, disorders, and injuries (WHO, 2002).

Social engagement can be seen as a construct with a combination of activity and participation in the ICF diagram. Each social activity includes execution of a task or action and life situation (i.e. social context). Therefore, according to this framework, factors associated with social engagement among people with CIND may need to cover four constructs of environmental factors, and personal factors, body functions and structures, and health condition (other than having CIND).

The basic premise of this model is that social engagement is influenced not only by health condition (i.e., CIND) but also by interactions between other individual background factors. Therefore, on the basis of this model, social engagement is likely to be heterogeneous among people with CIND, and there are factors associated with the heterogeneity other than having CIND. Furthermore, factors associated with the heterogeneity of social engagement may be systematically selected based on this model.

The ICF model has been used to analyze the interaction between disease and disability and activity and participation. Reflecting the nature of this model, it has been used to investigate

activity and participation among people with some health conditions such as cerebral palsy, osteoarthritis, and mental disorders (Bruyère, VanLooy, & Peterson, 2005). This model also has been applied to studies of activity and participation among older adults with health conditions. Ellis, Cress, Wood, and Schenkman (2015) applied this model to investigate the relationship between physical functions and participation in physical activities among older adults with Parkinson's disease. They showed that physical functions are more strongly associated with participation in physical activities among people with Parkinson's disease than those who were without Parkinson's disease. However, few studies have attempted to describe comprehensive picture of activity and participation among older adults using the ICF model. Covelli, Raggi, Meucci, Paganelli, and Leonardi (2016) systematically reviewed studies of aging of people with Down's syndrome. They retrieved concepts of each study and linked them to concepts of the ICF model. Many of concepts retrieved were related to biomedical factors such as intellectual functions, general metabolic functions, mobility of joint functions, muscle power functions, gait pattern functions, and structure of the brain. They did not find any study that investigate comprehensive picture of activity and participation among people with this condition. Their results implied that studies of older people with health condition have largely focused on biomedical factors, and other factors have not been well investigated. One rare exception is a study conducted by Liu (2017) that identified factors associated with being frail among older adults based on the ICF model. They revealed that at least one variable under each domain of the model with multivariate analysis including a wide range of variables. They suggested that the ICF model is useful to describe comprehensive picture of activity and participation among older people with some health conditions. However, there is no study that examined activity and participation among people with mild cognitive impairment or dementia.

Environmental Enrichment Model

Early studies. The idea that experience shapes later development of brain and cognitive ability is not new and can be seen as early as 18th century. According to Renner and Rosenzweig (1987), a Swiss naturalist Charles Bonnet and an Italian scientist Michele Vincenzo Malacarne theoretically and empirically tested the hypothesis that exercise changes the size of the brain and cognitive ability in late 18th century. The idea was also seen in Charles Darwin's remark that "domestication reduced brain size; that is, relative impoverishment of experience in the domestic setting led to reduced development of the brain" (as qtd. in Renner & Rosenzweig, 1987, p. 2). However, by late 19th century from the observation of stability in brain size among adults, it was widely accepted that physiology of brain was fixed after the predetermined period (Renner & Rosenzweig, 1987). This dogma was generally held until the1950s (Renner & Rosenzweig, 1987).

After the 1940s, researchers started showing empirical evidence on the influence of rearing environment on later cognitive ability and brain development in rodents. Hebb (1947) examined the difference in task learning ability between rats reared in laboratory cages and those reared as pets. Results showed that those reared as pets could learn a simple task significantly better than rats kept in cages. His method of rearing animals in complex environments was later referred to as the environmental enrichment model and has been elaborated and used in many different studies to investigate the effects of complex environmental experience on brain and cognitive ability.

In the 1960s, some researchers started investigating the physiological mechanisms of the effect of environmental enrichment on cognitive ability. In particular, they began to examine the difference in brain anatomy, brain chemistry, and genes between animals reared in complex environments and those reared in impoverished environments. Rosenzweig (1966) showed that

being reared in enriched environment was associated with greater volume in the prefrontal cortex and more monoamine activities in mice's brain. They assigned rats into environmental complexity and training condition (ECT) or an impoverished condition (1C) and housed them for 80 days. Rats in ECT condition were housed in a large cage with 10 to 12 rats with inanimate materials for play (see Figure 2). Results showed that rats in ECT had larger cortex volume and more activity of acetylcholinesterase (ACh), which was related to learning and cognitive abilities.

[See Figure 2]

Definition of enriched environment. As reviewed above, in early animal studies the environmental enrichment model was used in order to test the effects of the relatively complex environment in comparison with the impoverished environment on animals' development of cognitive ability and brain. In animal studies, an enriched environment almost always means the cage setting seen as Figure 2c and is defined as environments with a combination of "inanimate and social stimulation" (Rosenzweig, Bennett, Hebert, & Morimoto, 1978). However, this definition is still unclear because optimal complexity of the environment is not indicated. As Greenough (1976) showed, it may be clear that extreme environments such as isolation on one end and overcrowding on the other end are both harmful for development of cognitive function; but what is the optimally "enriched" environment has not been determined. Van Praag, Kempermann, and Gage (2000) also pointed out that "enriched environment" usually means the opposite of impoverished experimental environment in animal studies, and it does not usually mean a more enriched environment than natural environment.

Although the definition of enriched environment is even less clear in human studies, it is largely defined as complex physical and social environments throughout the life course. Kramer, Bherer, Colcombe, Dong, and Greenough (2004) pointed out that the term *enriched* may not be

appropriate even in animal studies because an enriched environment is usually an environment that offers adequate challenges to the individual. They mentioned that the term *complex* should be more often used among researchers and offered a list of factors that represent such complex environments: educational attainment, occupational experience, and leisure activities. Schooler (1984) further specified this definition in his review of studies on psychological effects of "complex environment" throughout the life course. He argued that the complexity of the environment "is defined by its stimulus and demand characteristics" (p.259). According to him, environment is more complex when the individual receives more diverse stimuli, is required to make more decisions, makes decisions that require considering more factors, and handles more ill-defined and contradictory contingencies. He listed complexity of working experience, educational attainment, and cognitive training in later life as examples of complex environments. More recently, Cassarino and Setti (2015) specifically argued that higher levels of education, stimulating jobs, and more advantaged socioeconomic backgrounds, higher social engagement, more exercise, and mentally stimulating activities are all forms of environmental stimulation. They also argued geographical environment can act as a source of brain training and possibly contribute to cognitive resilience in older adults.

In sum, the enriched environment is defined as a complex and cognitively demanding social and physical environment. Especially in human studies, it can be defined as environment that allows or motivates people to engage in socially, physical, and cognitively demanding activities. Moreover, it is notable that the definition of enriched environment included activity itself. For example, Schooler (1984) included cognitive training as "complex environment" and Cassarino and Setti (2015) listed " higher social engagement," "more exercise," and "mentally stimulating activities" as "environmental stimulation." This inclusion suggests that

environmental enrichment can be defined as social, physical, and cognitive behaviors aroused in enriched environment.

Empirical Evidence of Environmental Enrichment Model

Numerous animal and human studies have examined the effects of some aspects of enriched environment. This section specifically focuses on studies that investigated mechanisms of how an enriched environment affect brain and cognitive ability of individuals. This section reviews both animal and human studies.

Animal studies. How do enriched environments affect cognitive ability in animals? There are two major processes in mechanisms behind an enriched environment affecting individuals (Fox, Merali, & Harrison, 2006). The first process is that the enriched environment changes behavior. It may be obvious that enriched environments change at least some aspects of behaviors in animals by offering opportunities to engage in cognitive and physical activities and social interactions. However, what changes in behavior account for effects of enriched environment may be a reasonable question. Ferchmin, Bennett, and Rosenzweig (1975) indicated that contacts with physical and social stimuli were essential elements. They compared brains and behaviors of rats reared in different environmental conditions. One group of rats were reared in a cage with inanimate objects and other rats (enriched condition: EC), another group was put in a smaller cage which was placed in the cage of the EC (observed condition: OC), and the other group was reared in a cage without inanimate objects nor other rats (impoverished condition: IC). They showed that EC had significantly heavier brain weight and better learning abilities than IC but OC was not different from IC. Ferchmin et al. concluded that because just observing and having minimal contact (brief nose-to-nose contacts through hardware cloth) did not yield differences, that actual contacts and interactions with inanimate objects and other rats were necessary elements of enriched environment.

The second process concerns the way enriched environments change the brain. It has been suggested by numerous studies that enriched environments have an impact on neural systems in animals. Van Praag et al. (2000), in their review of the neural influence of enriched environment, listed four changes caused by enriched environment: anatomical changes, electrophysiological changes, effects of growth factors, role of neurotransmitters. Van Praag et al. indicated that these changes in neural systems explained why enriched environments enhance the cognitive ability of animals. More recently, Smith et al. (2018) specifically investigated neural mechanisms behind the association between more social contacts and higher cognitive function and less neuron damage in mice. They compared group-housed mice and pair-housed mice in using cognitive tasks and biomarkers. The results showed that group-housed mice exhibited better performance in cognitive tasks and had reduced numbers of lba 1/CD68+ microglia—a marker of neuroinflammation—in the hippocampus, whereas pair-house mice did not. Their findings suggested that living in more complex social settings may contribute to better cognitive function and healthier brains.

Specifically, many animal studies have suggested that environmental enrichment influences the behaviors and brains of Alzheimer's disease model animals. For example, Arendash et al. (2004) used Alzheimer's disease model of transgenic mice (APPsw) and placed them either in an enriched environment (EE) or an impoverished environment (standard housing: SH) at age of 16 months. Compared to the SH group, the EE group showed better performance in memory and problem solving tasks. However, the EE group did not have significantly less amyloid beta (Aβ), which was considered to cause cognitive impairment in people with Alzheimer's disease, than SH. They concluded that long-term effects of environmental

enrichment could prevent further deterioration of cognitive function in people with Alzheimer's disease without decomposing Aβ in their brain.

Human studies. In human studies, mechanisms of the effect of enriched environment are even more difficult to study. Nevertheless, similar to animal studies, some studies have identified changes in behaviors (engagement) and the brain and the neural systems as mechanisms behind the enriched environment and higher cognitive function. Some studies have shown the association between living in enriched environments and having higher cognitive functions in later life. One specific example of such environments is having a larger social network. Zunzunegui et al. (2003) showed that larger numbers of relatives seen at least monthly and more social integrations (membership in a community association, at least monthly attendance of religious services, and visits to the community center) are both significant indicators of having higher cognitive function 4 years later. They concluded that mental stimulation and/or stress reduction through social contacts may explain these results, although they did not actually include variables related to those two mechanisms in their analytic model. Physical environments have also been identified as supportive for cognitive function. Cassarino and Setti (2015) reviewed studies about the relationship between geographical and physical environments (urban vs. rural or presence of green) and suggested that geographical and physical environments may contribute to better cognitive function in later life if they offer optimal cognitive/sensory, social, and physical stimuli. They also mentioned that these stimuli could overload and be harmful for cognitive functions.

Another example of an enriched environment is a socioeconomically advantaged neighborhood. Clarke et al. (2012) showed that people living in affluent neighborhoods had better cognitive functions and the effect was achieved through higher physical activity and social

integration (see Figure 3). Interestingly, stable residence in a neighborhood with higher percentages of older people was associated with higher cognitive function but longer residence in such a neighborhood was negatively associated with cognitive function. Clarke et al. argued that having more older people in the neighborhood provided more opportunities for social interactions but also prolonged residence may have resulted in the decline of older people due to collective aging in place. In other words, they indicated that increased social interaction was one of the necessary processes of neighborhood environment influencing better cognitive function.

[See Figure 3]

In sum, research has suggested that enriched environments affect the cognitive functioning of individuals by enriching behaviors of the individuals. In general, based on the enrichment model, it is hypothesized that individuals who engage in social, physical, and cognitive activities have higher cognitive function than those who do not. In particular, although complexity may be difficult to define in human behavior, it is hypothesized that individuals who engage in complex activities would have better cognitive function than those who do not.

Conceptual Framework

Figure 4 shows the conceptual framework, which was drawn from the WHO's (2001) ICF framework, environmental enrichment model, and previous empirical studies. This framework has three major parts. The first part is related to factors associated with patterns of social engagement. It shows that patterns of social engagement as a latent variable are estimated with observed variables of social activity engagement. It also describes the association between four constructs from the ICF and patterns of social engagement.

The second part regards the association between patterns of social engagement and risk of conversion from CIND to dementia. The hypothesized relationship between social

engagement and conversion from CIND to dementia is drawn from the environmental enrichment model.

The third part is a partial mediation model with patterns of social engagement as an independent variable, conversion from CIND to dementia as the dependent variable, and physical and cognitive engagement as mediating variables. Although this part of the model cannot be drawn directly from the environmental enrichment model and the relationship between engagements may be reciprocal and bidirectional, the premise of this model is that social engagement is a gateway to other engagements. The premise is developed based on several previous empirical studies reviewed in above sections. It may be possible to assume the moderating relationship among engagement and conversion from CIND to dementia, that is, the relationship between social engagement and conversion from CIND to dementia varies depending on the levels of physical and cognitive engagements. However, mediation model was tested because the focus of this dissertation was to examine the role of social engagement as a promoter of physical and cognitive engagements. Moreover, a partial—not full— mediation is hypothesized because of the possible existence of s direct pathway from social, physical, and cognitive engagement to cognitive function (Barnes et al., 2004; Bassuk et al., 1999; Bourassa et al., 2017; Fratiglioni et al., 2000; Haslam et al., 2014; 2016; Hertzog et al., 2008; Scarmeas et al., 2001; Wang et al., 2002; Wilson et al., 2007; Zunzunegui et al., 2003).

[See Figure 4]

Research Questions and Hypotheses

This dissertation aims to address three gaps in the existing literature. First, factors associated with heterogeneity of social engagement among people with CIND have not been systematically investigated. Second, the evidence of the association between social engagement and conversion from CIND to dementia is mixed. Third, the relationship among social, physical,

and cognitive engagements in relation to conversion from CIND to dementia has not been clear. The specific research questions and hypotheses in this dissertation project are following:

Research Question (RQ) 1: What factors are associated with social engagement among older adults with CIND?

Hypothesis 1-1: Personal (age, sex, socioeconomic status, and personality), environmental (living area, neighborhood environment, and social network), body structures and functions (activities of daily living and cognitive function), and health condition (depressive symptoms, self-rated health, self-rated memory, and chronic conditions) contribute to heterogeneity of social engagement patterns among people with CIND.

Hypothesis 1-2: Younger age, higher socioeconomic status, and more positive environment, higher functions, and better health are associated with having patterns that represent higher social engagement.

RQ 2: How is social engagement associated with the conversion from CIND to dementia?

Hypothesis 2: People with CIND who have patterns that represent higher levels of social engagement are less likely to convert from CIND to dementia in several years.

RQ 3: How is the relationship between patterns of social engagement and conversion from CIND to dementia mediated by physical and cognitive engagement?

Hypothesis 3: People with CIND who have patterns that represent higher levels of social engagement are more likely to engage in physical and cognitive activities, which partially accounts for the association between patterns of social engagement and conversion from CIND to dementia.

See Appendices A to C for variables corresponding to each RQ.

Chapter 3: Methods

Data and Sample

Research Question 1

Data were drawn from the 2010 wave of the Health and Retirement Study (HRS). Launched in the United States in 1992, HRS is a national longitudinal study that biennially surveys more than 22,000 adults aged 51 and older and their spouses. The HRS sample is considered statistically representative of households in the United States. Core HRS interviews were conducted in participants' homes or via telephone. Since 2006, HRS has collected Leave-Behind (LB; Smith, Ryan, Sonnega, & Weir, 2017) questionnaire data using self-administered questionnaires. The data were obtained from a randomly selected sample composed of 50% of participants who completed core HRS interviews in 2006, 2010, and 2014. The remaining 50% of participants were administered questionnaires in 2010 and 2014. The present study used data from the subsample of respondents completing the psychosocial questionnaires either by mail or telephone in 2010 and 2014. It should be noted that HRS utilizes different modes of data collection. Although most respondents were interviewed via telephone, HRS also utilizes face-to-face interviews for most of those who were 80 years or older (Ofstedal, Fisher, & Herzog, 2005). Herzog and Rodgers (1999) and Ofstedal et al. (2005) suggested that significant measurement errors stemming from the difference in modes of data collection were not observed. For the leave behind sub-module specifically, almost all (98.7%) of respondents completed the survey by returning mails. However, it should be noted that whether or not measurement errors exist and affect results of analyses using data from the leave-behind module is unknown. The latest data available (2016) was not used in this study because the sample for RQ1 served as a baseline for RQ 2 and RQ 3, for which the latest data were used.

In 2010, 11,213 respondents were selected as a sample for the LB. Among those who were eligible, 2,903 did not complete LB in 2010. The HRS sample includes respondents who are spouses of selected respondents and contains respondents younger than 51. Respondents were excluded if they were younger than 51 in 2010 (n = 408). People who were living in nursing homes (n = 76) were excluded because the focus of this study is social engagement in community settings. The sample was further narrowed down to people with CIND. Scores on Telephone Interview for Cognitive Status (TICS; Brandt, Spencer, & Folstein, 1988) were used. TICS is an assessment tool for cognitive function designed to be administered in an interview conducted either over the telephone or in person. Scores for the original TICS range from 0 to 35, with higher scores indicating better cognitive function. Psychometric properties of the TICS have also been validated in previous studies (e.g., Knopman et al., 2010). In this study, TICS-27, the shorter version of TICS was used to classify respondents into normal cognition, CIND, or dementia. TICS-27 was developed in order to include younger people for whom orientation and naming tasks could not be used (Crimmins et al., 2011; Alzheimer's Association, 2010). Cut-off points for the classification of CIND and dementia were developed to produce the same population distribution estimated by the Aging, Demographics, and Memory Study (ADAMS), a substudy of HRS. In ADAMS, respondents undertook detailed neuropsychological tests and specific diagnostic information was provided. Based on the diagnostic information, Langa, Kabeto, and Weir (in Alzheimer's Association, 2010) classified people who scored 0 to 6 into dementia, 7 to 11 into CIND, and 12 to 27 into normal cognition. HRS allows some respondents needed to have proxy respondent who answers questions on behalf of the participant. Proxy respondents were included in the analysis because deleting proxy respondents might have made the sample biased by selecting healthier people. However, it should be noted that TICS-27 score

was not available for those respondents who used a proxy. Because TICS-27 classification cannot be used for those with proxy respondents, Langa and Weir's classification for proxy respondents (Crimmins et al., 2011) was used. This classification method is based on a scale score calculated from three variables of proxy respondents' assessment: rate of participants' memory (0 = excellent, 1 = very good, 2 = good, 3 = fair, 4 = poor); number of instrumental activities of daily living difficulty (0–5: using a telephone, taking medication, handling money, shopping, preparing meals); and difficulty completing the survey because of cognitive impairment (0 = none, 1 = some, 2 = impairment prevents completion). The score ranges from 0 to 11 where higher score indicates more cognitive impairment. According to Langa and Wier's (Crimmins et al., 2011) method, respondents with scores 0 to 2 can be classified as normal cognition, those who scored 3 to 5 as CIND, and those who scored 6 to 11 as demented. Using these cut-off points, 6,341 people were classified as having normal cognition and 250 were classified as having dementia. Four respondents were excluded because they did not respond to any of social activity items in the LB. Four respondents were excluded because they were unable to complete the survey because of cognitive impairment. As a result, a total of 1,227 respondents were included in the final sample. See Figure 5 for the flow chart of the sample selection.

[See Figure 3.1]

Research Question 2 and 3

The same sample as RQ 1 was used for RQ 2 and RQ3 to estimate the latent variable of social engagement. For the subsequent regression analyses, the reduced sample was utilized. Some people died (n = 221) between 2010 and 2014. In addition, some people became ineligible in 2014 because of the study design related issue of HRS (n = 77). The reduced sample consisted of 929 people. See Figure 6 for the flow chart of the sample selection. This reduced sample was not used to estimate the latent variable because deleting a large portion of the sample (n = 298,

24.3%) would have given biased estimations regarding patterns of social engagement in 2010. For sensitivity analyses, the full sample (n = 1,227) with imputed variables was used.

[See Figure 3.2]

Measures

Research Question 1

Dependent variable. A total of eight indicators of social engagement were selected from the core and LB based on the definition of social engagement in this dissertation: engagement in activity taken place in social context with volitional participation. Five indicators were selected from the list of "social participation and social engagement" (Smith et al., 2017, p. 16) in the LB questionnaire (see Appendix D for the full list). Included social activities were "Do activity with children," "Volunteering with youth," "Other volunteer or charity work," "Attend educational course," and "Attend nonreligious organizations." Respondents were asked to rate their frequency of engaging in those activities on a 7-point scale (1 = never, 2 = not in the last month, 3 = at least once a month, 4 = several times a month, 5 = once a week , 6 = several times a week , 7 = daily). The responses were dichotomized into no (1 and 2) and yes (3 to 7) to indicate clear existence of engagement. Three other indicators were included. LB asked frequency of social contacts by three methods (meeting up, speaking on the phone, and writing or emailing) with three contacts (children, family, and friends). Respondents rated the frequency of each action with each contact on a 6-point scale (1 = less than once a year or never, 2 = once or twice a year, 3 = every few months, 4 = once or twice a month, 5 = once or twice a week, 6 = three or more times a week). Average scores were calculated within each action. The scores were dichotomized into no (1 or higher to lower than 4) and yes (4 or higher to 6).

Personal factors. Factors were selected in accordance with four domains of the ICF model. Personal factors included age group (51–60 years old, 61–70 years old, 71–80 years old, 81 years or older), gender (men, women), educational attainment (less than high school, high school, more than high school), race/ethnicity (White, African American, other), Hispanic ethnicity (Hispanic, not Hispanic), marital status (married/partnered, separated/divorced/widowed, never married), income (quartile of total household income), and (quartile of total household assets), and personality. For personality, two scale scores of personality traits were used: extraversion and openness to experience. Each score ranged from 1 to 4, and higher scores indicated more extraversion or openness to experience. Cronbach's alpha for each scale was .75 for extraversion, .80 for openness to experience (Smith et al., 2017).

Environmental factors. Environmental factors include living area (urban, suburban, exurban), neighborhood safety, neighborhood cohesion, and social network size. Neighborhood Physical Disorder Scale and Neighborhood Cohesion Scale (0–7) were used to measure neighborhood safety and cohesion respectively. Higher scores indicated lower safety and higher cohesion. Cronbach's alpha was .82 for the Neighborhood Physical Disorder Scale and .86 for the Neighborhood Cohesion Scale (Smith et al.'s, 2017). Social network size was measured using the composition of social network scale (0–4). Higher score indicates bigger social network size.

Health condition. Health conditions included depressive symptoms, self-rated health, and chronic conditions. Depressive symptoms were measured by the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977), an 8-item scale of depressive symptoms. A cutoff point of 4 or above was used to dichotomized the sample into two (0 = no depression [CES-D score from 0 to 3]; 1 = depressed [score of 4 or higher]; Zivin, Pirraglia, McCammon,

Langa, & Vijan, 2013). Self-rated health was measured by respondents' rating of their health on a 5-point scale (1 = poor condition, 2 = fair, 3 = good, 4 = very good, 5 = excellent). Chronic conditions were measured by the number of conditions from the eight conditions reported by the respondents. The conditions included high blood pressure or hypertension; diabetes or high blood sugar; cancer or a malignant tumor of any kind except skin cancer; chronic lung disease except asthma (such as chronic bronchitis or emphysema); heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems; stroke or transient ischemic attack (TIA); emotional, nervous, or psychiatric problems; and arthritis or rheumatism. This variable is highly skewed and was recoded into three categories (0 = no condition, 1 = one condition, 2 = two or more conditions).

Body functions and structures. Body functions and structures included ADL difficulty, self-rated memory, and cognitive function. ADL difficulty measurements included five categories: bathing, dressing, eating, getting in/out of bed, and walking across a room. Each score was calculated as the number of "yes" responses out of five. Because this variable is highly skewed, the sample was categorized into three levels: 0 = no difficulty, 1 = difficulty in one ADL, 2 = difficulties in two or more ADLs. Self-rated memory was measured by asking the question: "How would you rate your memory at the present time?" using a 5-point scale (1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent). Cognitive function was measured with TICS-27 and raw scores of the scale were included.

Research Question 2

Dependent variable. Conversion from CIND to dementia is the dependent variable for RQ 2. Conversion is defined as having dementia at 2014. Having dementia was measured as scoring 6 or less on TICS-27 (Crimmins et al., 2011; Langa et al., 2010; Langa et al., 2017) for

self-respondents and scoring 6 or greater on Langa and Weir's scale for proxy-respondents (Crimmins et al., 2011).

Independent variable. The latent variable of social engagement was estimated using latent class analysis (LCA; see statistical analysis section for details) with the sample used in RQ 1. The sample was classified based on the LCA.

Covariates. Covariates are selected from a range of constructs known to be associated with cognitive function in later life. Four groups of covariates were included: sociodemographic factors, functional factors, health-related factors, and study-design related factors for sensitivity analysis. Sociodemographic factors included age group, sex, education, race/ethnicity, Hispanic ethnicity, marital status, and social network size. Functional factors included numbers of ADL difficulty and cognitive function. ADL difficulty was measured in the same manner with RQ 1. For cognitive function, scores on four cognitive tasks were individually included (immediate word recall, delayed word recall, serial 7s and backward counting from 20). Health-related factors included depressive symptoms (CES-D), number of chronic conditions, self-rated memory, and self-rated health.

Two covariates related to the study design were included in the model. First, utilization of proxy respondent (0 = no, 1 = yes) was included because the sample includes people who used proxy respondents because of cognitive reasons in 2014. Second, for the sensitivity analysis with imputed full sample, an indicator of died or dropped between 2010 and 2014 was included.

Research Question 3

Dependent variable. Conversion from CIND to dementia in 2014 was included in the model for RQ 3 as a dependent variable.

Independent variable. Patterns of social engagement were included as an independent variable. See RQ 1 and 2 for the detail.

Mediating variables. Physical and cognitive activity engagements were included as mediating variables. Physical engagement was measured using three individual physical activities: home/car maintenance or gardening, playing sports or exercise, and walking 20 minutes. The HRS asks respondents to rate how often they engage in those activities on a 7-point scale (1 = never/not relevant, 2 = not in the last month, 3 = at least once a month, 4 = several times a month, 5 = once a week, 6 = several times a week, 7 = daily). All responses for physical activities were dichotomized as 0 = never/not relevant or not in the last month and 1 = at least once a month or more often. The number of 1's was counted across three activities. Possible score range was 0 to 3. Similarly, cognitive engagement is measured using eight individual cognitive activities: reading, playing word games, playing cards or games, writing, using a computer, baking or cooking something special, sewing or knitting, and doing a hobby. Possible score range for cognitive engagement was 0 to 8.

Covariates. Two sets of covariates were included separately in the model. The first set included covariates related to the association between social engagement and physical and cognitive engagement. For this set, all covariates used in the first research question (personal, environmental, body functions and structures, and health condition) were included. In addition, physical and cognitive engagements in 2010 were included. This first set of covariates was included in the regression analyses between independent variable and mediating variables. The second set included covariates related to risk of conversion from CIND to dementia. Covariates used in the RQ 2 were included as covariates for this set. This second set of covariates was included in three regression analyses on the dependent variable of conversion from CIND to dementia. In RQ 2, utilization of proxy in 2014 and indicator of died or dropped were included

as covariates regarding the study design. Because of the convergence issue, however, those variables were not included in analysis for RQ 3.

All variables used in this dissertation proposal are listed in Appendices A to C.

Statistical Analysis

Research Question 1

Latent class analysis (LCA) is used to investigate patterns of social engagement. LCA assesses the relationship between manifest data and unobserved variables (latent classes) and allows researchers to identify these latent classes from multivariate categorical data. Classes identified by LCA are categorical; therefore, cases within the data can be assigned into exhaustive and exclusive subsets (Eshghi & Haughton, 2011). In this dissertation, latent classes in which members have similar patterns of social engagement are identified. LCA has several advantages over other traditional clustering methods. First, it provides several model fit statistics, and the optimal number of classes can be empirically determined. Second, LCA is a robust method against violations of the assumptions such as homogeneity of variance, linearity, and local independence (Vermunt & Magidson, 2002). All eight indicators of social engagement were included in the model. LCA also provides the probability of each class member engaging in each individual social activity (Muthén & Muthén, 2000). Three model fit statistics were used to determine the number of classes. A significant result on the Lo–Mendell–Rubin (LMR) test indicates a significant improvement in model fit between k-class and (k-1)-class models (Lo, Mendell, & Rubin, 2001). The Bayesian Information Criterion (BIC) was also used. Lower BIC indicates better model fit. Finally, entropy, a measure of uncertainty in classification, was used. A higher entropy value indicates high certainty. Values range from 0 to 1.

After class number was determined, two procedures were be taken. First, bivariate descriptive analysis of latent class was conducted. Chi-square tests for categorical variables and ANOVA for continuous variables were conducted to assess the bivariate associations between factors and class membership. Second, multinomial logistic regression was used to examine the association between predictors and the latent class variable. Figure 7 shows the analytic model of RQ 1.

[See Figure 3.3]

Research Question 2

Based on the classification achieved through the LCA in RQ 1, each individual in the reduced sample was assigned a class of patterns of social engagement. The association between patterns of social engagement and conversion to dementia is assessed using the binary logistic regression analysis.

[See Figure 3.4]

Research Question 3

To address the third research question, a path analysis using structural equation models was used. This analysis allows for a simultaneous estimation of the direct, indirect, and total effects of social engagement on conversion from CIND to dementia. This model can also account for the potential correlated error within each construct (social engagement, physical engagement, cognitive engagement, and conversion from CIND to dementia) by setting specific indicators to freely correlate with each other. In the analytic model, a latent class of social engagement was estimated in the same manner with analyses in RQ 1. In addition, a mediation model was tested. Paths from patterns of social engagement to physical and cognitive engagement were adjusted for covariates of personal, environmental, body structures and functions, and health-related factors (see measurement section for details). Another path from

social engagement to conversion from CIND to dementia was adjusted for covariates including sociodemographic factors, health-related factors, functional factors, and other engagements (see measurement section for details). Finally, correlation between physical and cognitive engagement was assumed.

Based on Kline's (2016, pp. 267–268)recommended approach to fit evaluation, four criteria were used to assess the model fit of the structural model: model chi-square with its degrees of freedom and *p* value, Steiger-Lind root mean square error of approximation (RMSEA), Bentler comparative fit index (CFI), and standardized root mean square residual (SRMR). *p* values greater than 0.05, values smaller than 0.08 for RMSEA, values greater than 0.95 for CFI, and values smaller than 0.08 for SRMR were considered to indicate a good fit. The Sobel test (Preacher & Hayes, 2008) was used for a significant test of indirect effect.

In the HRS, spouses of the selected respondents were also automatically selected as respondents regardless of their age. Although in this dissertation people who were 50 or younger were excluded, some respondents were selected from the same household. Therefore the data are nested. In order to avoid biased estimation caused by the nested data, clustered robust standardized error would be used for LCA and subsequent regression analyses. All analyses were conducted using Stata version 14.2 and Mplus version 7.4.

[See Figure 3.5]

Missing Data

For the LCA and path analysis with SEM framework, full information maximum likelihood (FIML) estimator was used to handle missing data. For the multinomial logistic regression in RQ1 and the logistic regression analyses in RQ2, multiple imputation (MI) was used. Both FIML and MI are known to produce better estimates than other traditional ways of

handling missing data such as list-wise deletion (Allison, 2000). All of these procedures were applied to both main analyses and sensitivity analyses.

MI was conducted through three phases: imputation or fill-in phase, analysis phase, and pooling phase (UCLA Institute for Digital Research and Education). Briefly, in the imputation or fill-in phase, missing values were replaced with estimated values. In the imputation phase, this dissertation used fully conditional specification (CSF), specifically the multiple imputation with chained equation (MICE) because multivariate normality of distribution could not be assumed. Imputation phase was conducted using Stata because Mplus uses the joint model based on Markov Chain Monte Carlo (MCMC) method (Muthén & Muthén, 2017). Five data sets were created referring to a simulation study conducted by Asparouhov & Muthén (2014). In the analysis phase, the data sets with filled-in values were used to conduct the main analysis. Finally, in the pooling phase, parameter estimators obtained from each analysis were combined using Rubin's (1987) rule.

Chapter 4: Findings

Research Question 1

Latent Class of Social Engagement

Table 4.1 shows the model fit statistics of models with number of classes. As the class number increased, models were improved—model fit statistics of BIC decreased. I selected the three-class model as the best for of two reasons. First, the three-class model had the best BIC value (*BIC* = 8591.9), significantly better than the two-class model (*LMR* = 129.3, $p = .002$). Second, although the four-class model had a comparable LMR result (*LMR* = 45.1, $p = .0001$) and higher entropy (0.677), it includes a class with a small number of cases ($n = 79$), which would create cells with insufficient numbers of cases in the subsequent analyses.

[See Table 4.1]

According to the item response probabilities shown in Figure 4.1, I labeled classes as informal social engagement only ($n = 596$, 48.6%), formal and informal social engagement ($n = 228$, 18.6%), and low social engagement ($n = 403$, 32.8%). People assigned in the informal social engagement only class had high probabilities of engaging in informal social activities such as talking on the phone and meeting in person but not formal social activities such as activities with children and volunteering with youth and others. People in formal and informal social engagement engaged in both types of social activities. People in the low social engagement class only had a high probability for talking on the phone.

[See Figure 4.1]

Bivariate Analysis

Most factors had bivariate associations with class membership. Of the personal factors: sex ($\chi^2[2] = 6.39$, $p = .041$), education, ($\chi^2\ [4] = 34.00$, $p < .001$), income ($\chi^2\ [6] = 24.86$, p

< .001), assets (χ^2 [6] = 14.28, p = .027), extraversion (F[2, 1189] = 21.54, p < .001), and openness (F[2, 1167] = 16.25, p < .001), and agreeableness (F[2, 1186] = 11.17, p < .001) were associated with class membership. No environmental factor had a significant association. Among health condition factors: self-rated health (F[2, 1223] = 15.20, p < .001) and the number of chronic conditions (χ^2 [4] = 17.92, p = .001) were significantly associated with class membership. Body functions and structures significantly associated with class membership included ADL difficulty (χ^2 [4] = 25.27, p <.001), self-rated memory (F[2, 1216] = 4.21, p = .015), and cognitive function (F[2, 1216] = 8.21, p < .001). Results of all bivariate analyses are shown in Table 4.2.

[See Table 4.2]

Multinomial Logistic Regression Analysis

Results from the multinomial logistic regression analysis are illustrated in Table 4.3. All domains of factors (personal, environmental, body functions and structures, and health conditions) had at least one component that was significantly associated with class membership. Those who had more education (high school: *RRR* = 1.83, p = .005; more than high school: *RRR* = 3.04, p < .001); were separated, divorced, or widowed (*RRR* = 1.88, p = .009); had higher extraverted personality (*RRR* = 1.81, p = .006); had a larger social network size (*RRR* = 1.39, p = .014); reported higher self-rated health (*RRR* = 1.24, p = .012); and had better cognitive function (*RRR* = 1.16, p = .022) were more likely to be assigned to the formal and informal social engagement class than the informal social engagement only class. Those who were women (*RRR* = 0.73, p = .044); non-Hispanic Black/African American (*RRR* = .58, p = .004); had higher income (highest income: *RRR* = 0.39, p = .001); and higher assets (second lowest: *RRR* = 0.61, p = .008) were less likely to be assigned to the low social engagement class, whereas those who had higher education (more than high school: *RRR* = 1.60, p = .016), and more ADL difficulty

(two or more difficulties: $RRR = 1.52$, $p = .036$) were more likely to be assigned to low social engagement.

[See Table 4.3]

Research Question 2

Sample description

Of 1,227 people who were included in 2010, 298 (24.3%) died or dropped from the study between 2010 and 2014, and 155 (12. 6%) converted to dementia. Descriptive analyses were conducted to compare the baseline difference between the full sample ($n = 1,227$) and the reduced sample in which all cases dropped in 2014 were excluded ($n = 929$). Table 4.4 shows the result of bivariate analyses on all variables except for the dependent variable used in subsequent regression analysis. Statistically significant difference between two samples was found only in the variable of age group ($\chi^2(3) = 14.10$, $p = .003$).

[See Table 4.4]

Logistic Regression Analysis

Table 4.5 shows the results of logistic regression analyses. People who were assigned to the formal and informal social engagement groups had significantly lower probability of conversion to dementia in 4 years compared to people in the low social engagement group ($OR = 0.468$, $p = .015$). People in the informal social engagement only group also had significantly lower probability of conversion to dementia in 4 years than the low social engagement group ($OR = 0.629$, $p = .029$). However, the difference between the formal and informal social engagement only group and informal social engagement only group was not statistically significant ($OR = 0.760$, $p = .302$; informal social engagement only group as reference group). In the sensitivity analysis with the full sample, people who were assigned to the formal and

informal social engagement group had significantly lower probability of conversion to dementia in 4 years compared to people in the low social engagement group (*OR* = 0.539, *p* = .027). The informal social engagement only group did not have significant difference with the low social engagement group (*OR* = 0.768, *p* = .185). The formal and informal social engagement group did not have statistically significant difference with the informal social engagement group (*OR* = 0.703, *p* = .203; informal social engagement only group as reference group).

[See Table 4.5]

Research Question 3

Model Fit Statistics

The model was tested using two samples: full sample and reduced sample. Table 4.6 illustrates model fit statistics. The nonsignificant model chi-square was $\chi^2(14) = 10.40$, $p = .732$, estimated RMSEA lower than 0.001 (*90% CI*: 0.000 - 0.024), and CFI = 1.000 showed that the model has good fit. However, SRMR was 0.099, showing not good fit based on these statistics. Table 4.6 illustrates model fit statistics of the sensitivity analysis. With the imputed full sample, the model chi-square was $\chi^2(16) = 19.02$, $p = .268$, estimated RMSEA was lower than 0.001 (*90% CI*: 0.000 - 0.028), and CFI was 1.000, showing the model fit is good. This model also had high SRMR (0.127), which shows bad model fit. Overall, model fits for models with both samples showed good fit.

[See Table 4.6 and Table 4.7]

Path Analysis With SEM Framework

Table 4.6 also illustrates direct and indirect effects of social engagement on conversion from CIND to dementia. The indirect effect from social engagement group through cognitive engagement on conversion from CIND to dementia was statistically significant. People who had

higher cognitive engagement had lower probability of having dementia in 2014 through higher cognitive engagement (*OR* = 0.902, *p* = .009). Formal and informal social engagement group had higher physical engagement (*Coef.* = 0.351, *p* = .006) and cognitive engagement (*Coef.* = 1.809, *p*<.001) in 2014 compared to low social engagement. The sensitivity analysis with imputed full sample showed similar results. The indirect effect from social engagement group through cognitive engagement on conversion from CIND to dementia was statistically significant (*OR* = 0.925, *p* = .034). Formal and informal social engagement group had higher physical engagement (*Coef.* = 0.264, *p* = .013) and cognitive engagement (*Coef.* = 0.992, *p*<.001) in 2014 compared to low social engagement. See also Figure 4.2 and 4.3 for the path-diagram with results.

[See Figure 4.2 and Figure 4.3]

Chapter 5: Implications

Overview

As the population ages, more people will be living with CIND and dementia. The impact of dementia on society is enormous. Confronting challenges related to dementia is one of the most pressing public health issues. The fact that there is no cure available for dementia implies the need for shifting focus from a biomedical model to a preventive psychosocial model. As a preventive approach, promoting social engagement among people with CIND who are at risk of developing dementia may be promising. However, knowledge about social engagement among people with CIND is limited. As a result, no effective and efficient community-based interventions have been developed for them. Findings of this study may contribute to advancing the knowledge about social engagement among people with CIND and give implications for developing such interventions.

Implications from the findings of each research question are discussed in the following section. The first research question asks if there is heterogeneity in social engagement among people with CIND and what factors are associated with it. Identifying factors associated with social engagement among people with CIND may help to improve the accessibility of social programs for people with CIND. Although many social programs to promote social engagement are in use in the social work community, they may not be easily accessible to older people (Morrow-Howell et al., 2014). In order to develop effective and efficient social programs, it is essential to identify facilitators of and barriers to social engagement. Nevertheless, no systematic investigation on factors associated with social engagement among people with CIND has been conducted prior to this dissertation project. The second research question asks if the heterogeneity of social engagement was associated with conversion from CIND to dementia.

Findings from this research question may add evidence regarding the relationship between social engagement and cognitive health. They may also serve as another empirical evidence of environmental enrichment model. Furthermore, they may inform practical knowledge about interventions to prevent or delay conversion from CIND to dementia by promoting social engagement. The third research question was about the relationship among social, physical, and cognitive engagement and conversion from CIND to dementia. Findings from this research question will help better understanding of the mechanisms between social engagement and conversion from CIND to dementia. In addition, they would suggest more efficient way of promoting activity engagement among people with CIND.

Heterogeneity of Social Engagement and Associated Factors

There is a lack of understanding about the heterogeneity of social engagement and factors associated with it. This dissertation, informed by the WHO's ICF model, was the first to identify heterogeneity in patterns of social engagement and systematically investigate factors associated with social engagement among this population. Utilizing LCA, it identified three groups in which individuals with CIND shared similar patterns of social engagement. Factors were selected based on the WHO's ICF model and were shown to be associated with the patterns of social engagement.

Findings of this dissertation indicate that there is variability in patterns of social engagement. Three patterns of social engagement were identified: informal social engagement only; formal and informal social engagement; and low social engagement. Similar to previous studies, this dissertation found that many people with CIND were not socially engaged (Garms-Homolová et al., 2017; Genziani et al., 2013; Kotwal et al., 2016; Parisi et al., 2015) as evidenced by the fact that about one third of people with CIND were classified into the group of

low social engagement. Moreover, most people in the sample did not engage in formal social activities. These findings indicate that people with CIND may have particular challenges in engaging in formal social activities. In previous studies, physical function and mobility have been established as barriers to formal social activities (Adams, Leibbrandt, & Moon, 2011). This study extended previous findings by revealing that having CIND may also be a barrier to formal social activities. Findings also suggest that the methods utilized in this dissertation can be used to measure and describe heterogeneity of social engagement among people with CIND. This method should also be considered as one effective way to evaluate social programs that aim to promote social engagement among people with CIND.

People in the group of formal and informal social engagement engaged in wide range of social activities. This range indicates that some groups of people with CIND have the potential to engage in more social activities, especially in formal social activities. It is also worth noting that this dissertation did not identify any group characterized by engaging exclusively in formal social activities—people who engaged in formal social activities also engaged in informal social activities. This finding suggests that informal social engagement may be a prerequisite of formal social engagement, which is consistent with previous studies that showed people who were more likely to engage in informal social activities were also more likely to engage in formal social activities (Morrow-Howell et al., 2014; Park et al., 2018). This result is reasonable considering volunteers tend to be recruited through social ties (Dury et al., 2015). This dissertation showed that this relationship between formal social engagement and informal social engagement may hold among people with CIND and suggested the importance of having social ties for them. This finding implies that supporting informal social activities may be one key modifiable factor of promoting not only informal but also formal social engagement among people with CIND.

However, the cross-sectional design used for the first research question basically precludes causal inference on the relationship between formal social engagement and informal social engagement. Future studies should employ longitudinal design for better understanding of the relationship among different types of social activities.

At least one factor under each domain of WHO's ICF model was associated with probabilities of having patterns of social engagement. This result suggests that this model is useful in systematically investigating factors related to social engagement among people with CIND. Future study, however, should examine the relationship among four domains to have better understanding of factors associated with social engagement. Furthermore, although this study included a wide range of variables under four domains of the ICF model, there may be some other factors that are essential determinants of social engagement among people with CIND.

Some factors were shown to be associated with lower probabilities of being assigned to the low social engagement group compared to the informal social engagement only group. People who had higher socioeconomic status were less likely to be assigned to the low social engagement group. Those findings indicate that socioeconomic factors are crucial to prevent people with CIND from being disengaged in a wide range of social activities. Further examination of how those factors help people to engage at least in informal social activities is needed. For instance, the relationship between lower education, income, and assets and higher probability of being in the low social engagement group may be explained by the lack of availability of formal supports and resources. In fact, one study suggested that people with cognitive impairment were more likely to give up their valued social activities because of the lack of availability of transportation than those who did not have cognitive impairment (Parisi et

al., 2015). Tailoring supportive services such as transportation service to be more accessible and available to people with CIND with lower socioeconomic status may be one possible strategy to prevent extreme disengagement. The results also describe characteristics of people who had CIND and were disengaged from a wide range of social activities. They are useful in identifying clear target groups for interventions and strategies.

It is interesting to note that being non-Hispanic Black/African American, despite lower socioeconomic status, was associated with lower probability of being categorized in the low social engagement group. It is relatively well known that African American older adults tend to have more frequent contacts with family members than White older adults (Ajrouch, Antonucci & Janevic, 2001; Tang, Jang, Rauktis, Musa, & Beach, 2017; Taylor, Chatters, Woodward, & Brown, 2013). However, the findings of this study also suggest that even though non-Hispanic Black/African American people are more likely to engage in informal social activities, they may have some particular difficulty in engaging in formal social activities. Further studies are needed to examine possible reasons why non-Hispanic Black/African American people are not more likely to engage in formal social engagement despite their relatively higher informal social engagement.

This dissertation identified factors associated with being in the formal and informal social engagement group as opposed to the informal social engagement only group. People who were more educated; were separated, divorced, or widowed; had larger social networks; had higher self-rated health; and had higher cognitive function; had higher socioeconomic; or had better functional statuses were more likely to be assigned into the formal and informal social engagement group. The association between larger social network and the pattern of formal and informal social engagement is especially noteworthy and is consistent with the Berkman and

Krishna's (2014, p. 242) conceptual model. According to this model, social networks promote social engagement because they provide people in a network with "opportunities for companionship and sociability" (Berkman & Krishna, 2014, p. 245); that is, social networks function as informal social resources. Providing informal social resources may be key to promoting formal social engagement. Although there are many social programs and policies such as senior centers and congregate meal sites that aim to promote informal social resource for older adults (Morrow-Howell & Gehlert, 2012), most of them may not be designed specifically to reach to people with mild cognitive impairment; therefore, they may not be accessible or available to them. To promote formal social engagement more effectively, future studies are needed to examine detailed mechanisms of how larger social network size is associated with higher probabilities of engaging in formal social engagement among people with mild cognitive impairment.

Social Engagement and Conversion From CIND to Dementia

Evidence is still mixed regarding the association between social engagement and cognitive function. It is especially limited in regard to conversion from CIND to dementia. By using patterns of social engagement, this study advances knowledge about the association between social engagement and conversion from CIND to dementia. Utilizing LCA and subsequent binary logistic regression analysis, this dissertation shows that patterns of social engagement that represent higher level and more variety of social engagement were associated with probabilities of conversion to dementia in four years even after controlling for a wide range of covariates.

The result of this dissertation suggests that promoting social engagement may be one promising strategy to prevent or delay conversion from CIND to dementia. This study shows that

people who had patterns of higher and more varieties of social engagement had lower probability of conversion from CIND to dementia in four years. This conclusion is consistent with many studies that suggested the association between higher social engagement and higher cognitive function and lower probability of developing dementia (Bourassa et al., 2017; James et al., 2011; Kuiper et al., 2015; Thomas, 2011). The finding of this dissertation adds to the evidence that certain patterns of social engagement may prevent or delay conversion from CIND to dementia. Before this study, evidence of effectiveness of activity-based interventions for preventing or delaying conversion from CIND to dementia was mixed (Grande et al., 2014; Hughes et al., 2013; Lam et al., 2015) and almost exclusively limited to interventions of promoting physical and cognitive activities in clinical settings (e.g., Buschert et al., 2011; Dannhauser et al., 2014; Jeong et al., 2015; Straubmeier et al., 2017; Train the Brain Consortium, 2017; Tsolaki et al., 2011). This study added evidence of effectiveness of social engagement on cognitive health and extended the environmental enrichment model to the context of conversion from CIND to dementia in human study. Findings of this dissertation could be useful in developing interventional options for people who are not responsive or suitable for rigorous physical and cognitive trainings. The findings also suggest that such interventions should have combinations of social and cognitive engagements to be more effective on preventing or delaying conversion from CIND to dementia.

The findings of this dissertation have another important implication. They suggested that a combination of formal and informal social engagement may be key to preventing or delaying conversion from CIND to dementia. Although the informal social engagement only group also had significantly lower conversion than low social engagement group in the analysis using the reduced sample, the difference was not significant in the analysis using the full sample. On the

other hand, formal and informal social engagement group had significantly lower conversion than low social engagement group in both analyses. A combination of formal and informal social engagements may make unique contributions to cognitive health. This finding is consistent with previous studies that suggested different types of social activities are differently associated with cognitive function. Jopp and Hertzog (2010) and Bielak, Cherbuin, Bunce, and Anstey (2014) showed that cognitive demand for small group or one-on-one social activities is different from public or large group activities. Park et al. (2014) showed that social engagement that includes learning novel and cognitively demanding skills was associated with subsequent higher cognitive function, whereas social engagement without those demanding learning was not. Results of this dissertation and these previous studies are consistent with an environmental enrichment model that posits that individuals who engage in more cognitively stimulating activities have higher subsequent cognitive function. This dissertation adds to these findings the suggestion that cognitively stimulating social engagement may prevent or delay conversion from CIND to dementia. The difference between the formal and informal social engagement group and the informal social engagement only group was not statistically significant. This result suggests that simple informal social activities such as meeting up, talking on the phone, and writing mails may also be cognitively stimulating. Future study needs to address how formal and informal social engagements interact each other in terms of their effects on cognitive health.

Mechanism Between Social Engagement and Conversion

The mechanism underlying the association between being socially active and lower risk of developing dementia is unclear. This dissertation had a hypothesis that there are both direct and indirect pathways from social engagement to cognitive health. The direct pathway is that social engagement directly contribute to higher cognitive function because it is cognitively

stimulating. The indirect pathway is that social engagement promotes other activities such as physical and cognitive engagements that are associated with higher cognitive function. The results showed that people in the formal and informal social engagement group had higher physical and cognitive engagement; however, the direct effect from social engagement to conversion from CIND to dementia was not statistically significant. Indirect effect through cognitive engagement was significant but not through physical engagement.

One important finding was that having formal and informal social engagement pattern was associated with higher physical and cognitive engagement. This finding suggests that social engagement may be a gateway activity that promotes other activity engagements. In previous studies that examined patterns of activity engagement, evidence regarding the relationship between social engagement and physical and cognitive engagement was not well investigated. For example, Croezen et al. (2009) identified six groups of older adults based on their patterns of activity engagement: "voluntary," "physical," "visiting," "hobby," "work," and "care." Their results indicate that different types of activities may be competing each other. Although Morrow-Howell et al. (2014) also identified two groups that are characterized by their higher engagement in physical activities and work, their results also indicate that people who have higher levels of social engagement are more likely to have higher physical and cognitive engagements. Because of the cross-sectional nature of these two studies, the relationship among different types of activity engagements was unclear. This dissertation, using two time points, indicated that having a pattern of higher and more variety of social engagement may promote higher physical and cognitive engagements. This result also indicates that promoting social engagement—especially formal social engagement—may be an efficient strategy to promote health among older adults because it is well known that active engagement is associated with many health-related outcomes,

including better self-rated health (Morrow-Howell, Hinterlong, Rozario, & Tang, 2003), better subjective well-being (Baker, Cahalin, Gerst, & Burr, 2005), and lower depression (Glass, Mendes de Leon, Bassuk, & Berkman, 2006).

My findings also suggest that promoting social engagement may be an efficient intervention for prevention of dementia. As hypothesized, my results showed that social engagement operated through cognitive engagement on conversion from CIND to dementia. This result suggests that promoting social engagement can be a first target for preventive strategies for dementia. Although physical and cognitive activities have much more evidence of effectiveness on better cognitive health, they tend to be recognized as training. Many non-pharmacological interventions for people with mild cognitive impairment utilize strategies of cognitive training (e.g., Gates, Sachdev, Singh, & Valenzuela, 2011; Simon, Yokomizo, & Bottino, 2012; Stott & Spector, 2011), which provides standardized sets of repeated problems or tasks to improve specific domains of cognitive function (Clare & Woods, 2004). Some interventions with physical activities also utilize rigorous and intensive physical exercises (e.g., Anderson-Hanley et al., 2018; Devenney, Sanders, Lawlor, Rikkert, & Schneider, 2017). Although those training interventions may not have serious adverse events or side effects as pharmacological interventions do (Clare & Woods, 2004), dropout rates tend to be high (Katz, Jaeggi, Buschkuehl, Stegman, & Shah, 2014). In previous studies of non-pharmacological interventions for people with CIND, however, the issues of participation and adherence have not been well discussed. Some studies suggest that more socially active people may have better chance of participation in and adherence to programs (e.g., Bauman, Merom, Bull, Buchner, & Fiatarone Singh, 2016; Heath et al., 2012). Considering social engagement may be more attractive than trainings, it may be a necessary component of effective preventions. Further studies are needed to examine the

causal relationship between social engagement and conversion from CIND to dementia to make a conclusion.

Contrary to my hypothesis, physical engagement was not associated with conversion from CIND to dementia. Studies of physical activity only interventions have found mixed evidence of effectiveness on cognitive function of people with CIND. Gates, Singh, Sachdev, and Valenzuela (2013), using meta-analysis, did not find a positive effect of exercise on the cognitive function of people with MCI. In that study, four of 14 included studies used aerobic exercise but the other 10 studies used either walking or resistance training. These findings suggest that different physical activity may differently affect cognitive function. Using meta-analysis, Groot et al. (2016) showed that aerobic exercise had a positive effect on cognitive function of people with and without Alzheimer's disease, but nonaerobic interventions did not show such an effect. Therefore, although recent studies have focused on intense aerobic exercise for people with mild cognitive impairment (e.g., Anderson-Hanley et al., 2018; Devenney, Sanders, Lawlor, Rikkert, & Schneider, 2017), no clear evidence on effectiveness has been established. In this dissertation, three physical activities were used as indicators of physical engagement: home/car maintenance or gardening, playing sports or exercise, and walking 20 minutes. The result that physical engagement was not associated with conversion from CIND to dementia suggests that those physical activities may not be effective enough to prevent dementia among people with CIND. Nevertheless, this suggestion does not indicate that physical activities should not be recommended considering that physical activities have many other health-related benefits. Further study is needed to determine if social engagement operates through other physical activities on cognitive function among people with CIND.

Partially inconsistent with the hypothesis, the results showed that the relationship between social engagement and conversion from CIND to dementia was fully mediated by cognitive engagement, indicating a lack of a direct pathway from social engagement to conversion to dementia. However, this does not necessarily deny the existence of the direct pathway. This dissertation did not investigate the change in patterns of social engagement. It may not be reasonable to assume that people maintained consistent patterns of social engagement during the 4.year study period. Although few studies examined changes in patterns of activity engagement in later life, Michèle et al. (2017) indicated that heterogeneity of patterns of social engagement may decrease over time. It is possible that the influence of the pattern of social engagement at baseline was diminished over time. Future study is needed to model trajectories of patterns of social, physical, and cognitive engagements and cognitive function.

Implications for Social Program and Policy

Globally, dementia has been recognized as one of the most pressing public health issues. The WHO (2012) issued a report, *Dementia: A Public Health Priority*, aiming "to facilitate governments, policy-makers, and other stakeholders to address the impact of dementia as an increasing threat to global health" (p. v). In the United States, the importance of developing dementia-specific social programs and policy has been recognized since President Barack Obama signed into law the National Alzheimer's Project Act. Growing numbers of studies have contributed to establishing evidence for developing social programs and policy (e.g., Berg-Wegner et al., 2015; Gitlin, Marx, Stanley, & Hodgson, 2015; Livingston, et al., 2017). This dissertation has three specific implications for such social programs and policy.

First, the findings of this dissertation suggest a need for the development of social programs that are specifically designed to support social engagement among people with mild

cognitive impairment. This dissertation showed that some people engage in both formal and informal social engagement, and some factors are associated with the heterogeneity of social engagement among this population. This association implies that social engagement is modifiable among people with mild cognitive impairment despite the fact that previous studies revealed that many people with mild cognitive impairment are disengaged from various social activities (Garms-Homolová et al., 2017; Kotwal et al., 2016; Parisi et al., 2015; Wang et al., 2015). Although many social programs aim to promote social engagement among older adults, few programs are specifically designed to older adults with mild cognitive impairment. There are few examples of social programs that aim to promote social engagement among older adults with low functional abilities. Some volunteer programs offer flexible role replacement and supervised mentoring systems to support volunteers who are losing functional capacity. Studies have shown that residents in long-term care facilities experienced an increased well-being when they engaged in volunteer activities, such as mentoring students taking English as a second language (Yuen-Tsang & Wang, 2008) or creating flower arrangement and greeting cards for local hospice patients (Cipriani, Haley, Moravec, & Young, 2010). Considering the positive effects of volunteering in an environment where highly centralized and controlled management is a norm, it would be a promising future inquiry to explore the applicability of these supportive programs for volunteering to people with mild cognitive impairment who are living in their own home. Results of this dissertation also indicate that social programs aimed at promoting social engagement among people with mild cognitive impairment must provide informal social resources that allow people with mild cognitive impairment to engage in informal social engagement given that informal engagement may be key to promoting formal social engagement.

Future studies need to clarify two causal relationships: factors and patterns of social engagement, and patterns of social engagement and conversion from mild cognitive impairment to dementia.

Second, the findings of this dissertation could allow policy makers and other stakeholders to rationalize development and extension of social programs that promote social engagement among older adults. Although existing health and social service organization are challenged to expand social programs for social engagement (Morrow-Howell & Gehlert, 2012), they tend to face severe budget cuts. To have a better argument of extending support for such programs, they should demonstrate that social engagement is more than just filling time. Stakeholders can use the findings of this dissertation to argue that promoting social engagement among people with mild cognitive impairment is a potential effective and efficient intervention to prevent or delay dementia. Further more, they can claim that a community/population-based approach is necessary for effective interventions. As shown in this dissertation, some socioeconomic and environmental factors may promote or prohibit social engagement among people with CIND. To promote social engagement, therefore, broader strategies than clinical interventions such as integration of people with CIND into society and removing social and environmental barriers to participation may be necessary.

Finally, my findings suggest some modifications of national-level policy for dementia. In many countries, national-level policy has been developed and encouraged to create *dementia friendly* communities, in which people with dementia and their family members can have better lives (Alzheimer's Disease International, 2016). Dementia friendly communities encourage and ensure social inclusion of people with dementia. One thing this dissertation suggests is that policy based on the dementia friendly concept should be extended to people with mild cognitive impairment. As shown in this dissertation, many people with mild cognitive impairment may be

disengaged from a wide range of social activities. However, factors associated with disengagement may be modifiable with effective provisions of support. According to Lin and Lewis (2015), Finland is the only country that includes people with any level of cognitive impairment in their national plan for dementia. They have developed and provided programs tied to four principles of *memory friendly* Finland: (a) promoting brain health; (b) fostering a more open attitude towards brain health, treatment of dementing disease and rehabilitation; (c) ensuring a good quality of life for people with dementia and their families through timely support, treatment, rehabilitation, and services; and (d) increasing research and education (Ministry of Social Affairs and Health, 2013).

Another implication is that national policy for dementia should aim to create a society in which people with mild cognitive impairment or dementia can be seen as contributors, not merely as receivers of supports. This dissertation shows that formal social engagement may be key to preventing conversion to dementia. Some formal activities such as volunteering have direct benefits to society. This dissertation indicates that people with mild cognitive impairment can contribute to the society through formal social engagement if they have sufficient resources such as informal support. This argument is in the line of a concept of *dementia positive* society proposed by Lin and Lewis (2015). According to them, a society can be truly inclusive for people with dementia when it sees strength and ability of people with dementia and regard them as equal contributors. This dissertation suggests that promoting social engagement among people with mild cognitive impairment may be one specific practical strategy to achieve such a society.

Limitations

This study certainly has some limitations. First, its design basically precluded causal inferences. For example, the design for the first research question was cross-sectional, and it

cannot determine whether health related factors allowed people with CIND to engage in formal and informal social activities or if engaging in formal and informal social activities led to better health related outcomes. Future studies with longitudinal designs are needed to inform the development of social programs that promote outcomes, such as sustained social engagement among persons diagnosed with CIND, and beneficial outcomes that stem from sustained social engagement, such as better cognitive health and higher well-being. Furthermore, although two time points were used for second and third research questions, the causal relationship between patterns of social engagement and conversion from CIND to dementia still cannot be inferred because of the endogeneity issue. Even though the model included a range of covariates to control for confounding factors, there always is possibility of existing unknown confounding factors. Future study is needed to have better causal argument between patterns of social engagement and conversion from CIND to dementia by utilizing statistical analyses that can handle the endogeneity issue such as propensity score analyses.

Second, measurements for both engagements and cognitive function were limited. Measurements for social, physical, and cognitive engagements were selected from an available list of activities, but it is possible that some important activities were missing. For example, only three physical activities were selected, and aerobic exercise, which may be crucial for cognitive health, was missing. Measurement for social engagement may also fail to capture more nuanced information regarding social activities. Although it may be evident that formal social activities in this study such as volunteering, group attendance, and taking educational courses demand more complex and cognitively demanding tasks than informal social activities such as playing with children, meeting up, talking on the phone, and writing or emailing, this study did not examine what exact actions were taken when respondents engaged in these social activities. To come to a

better understanding about the relationship between social engagement, other engagements, and cognitive health, and to make better recommendations for effective interventions, future studies should investigate details of engagements and its relationship with cognitive health.

Measurement for cognitive function was also limited. Basing CIND on the score on TICS-27 did not ensure the inclusion of individuals with a clinical diagnosis. As shown in previous studies, the accuracy of diagnosing CIND with the TICS is far from perfect (Crimmins et al., 2011). This measurement issue may have resulted in including cognitively heterogeneous groups of people in the sample. However, I believe that the sample was the best available to represent the population of people with CIND in the United States.

Conclusions

Despite those limitations, the results of this study are valuable. Three patterns of social engagement were identified: informal social engagement only, formal and informal social engagement, and low social engagement. The study demonstrated that social engagement is heterogeneous among people with CIND and that patterns of social engagement can be identified and described. This result indicates that social engagement is modifiable among people with CIND. Some factors associated with the heterogeneity were systematically identified using the WHO's ICF model. Providing social resources such as informal social support may contribute to promoting social engagement among them. This dissertation also showed that patterns of social engagement were associated with conversion from CIND to dementia. This finding indicates that the environmental enrichment model can be extended to the context of conversion from CIND to dementia. It also implicates that promoting formal and informal social engagement may be key to preventing conversion from CIND to dementia. Finally, this dissertation showed that the relationship between patterns of social engagement and conversion from CIND to dementia was

mediated by cognitive engagement. This result implies that some mechanism of the relationship between patterns of social engagement and cognitive health may be explained by indirect effect through cognitive engagement. Further, it indicates that social engagement may be a gateway activity, and that promoting social engagement among people with mild cognitive impairment should be considered as an effective and efficient intervention that can prevent dementia, and promotion should be achieved through developing social programs and policy. Future studies in this area should pay attention to measuring heterogeneity, systematically investigating associated factors, and testing theoretical rigorousness of the environmental enrichment model to add evidence on to this dissertation. Those efforts should also be made when evaluating social programs and policy that aim to prevent dementia by promoting social engagement among people with mild cognitive impairment.

Tables and Figures

Tables

Table 4.1. Model fit statistics of LCA

	2-Class		3-Class		4-Class		5-Class	
df	232		224		217		207	
BIC	8675.3		8591.9		8607.7		8648.0	
Entropy	0.616		0.588		0.677		0.644	
LMR test[a]	426.5	*p*<.0001	129.3	p = .002	45.1	p = .0001	22.1	p = 0.062
Proportion								
Class 1	315	(25.7%)	596	(48.6%)	79	(6.4%)	165	(13.4%)
Class 2	912	(74.3%)	228	(18.6%)	149	(12.1%)	43	(3.5%)
Class 3			403	(32.8%)	637	(51.9%)	87	(7.1%)
Class 4					362	(29.5%)	187	(15.2%)
Class 5							745	(60.7%)

Note: [a] LMR test = Lo–Mendell-Rubin test

Table 4.2. Descriptive analyses of patterns of social engagement

	All		Formal and informal		Informal		Low			
n = 1227	*n,M*	*%, SD*	*n, M*	*%, SD*	*n, M*	*%, SD*	*n, M*	*%, SD*		
Personal factors										
Age group										
51–60	286	(23.3)	58	(25.4)	147	(24.7)	81	(20.1)	$\chi^2(6) = 10.8733$	$p = .092$
61–70	283	(23.1)	57	(25.0)	133	(22.3)	93	(23.1)		
71–80	367	(29.9)	74	(32.5)	176	(29.5)	117	(29.0)		
81–	291	(23.7)	39	(17.1)	140	(23.5)	112	(27.8)		
Sex										
Male	546	(44.5)	96	(42.1)	250	(42.0)	200	(49.6)	$\chi^2(2) = 6.3937$	$p = .041$
Female	681	(55.5)	132	(57.9)	346	(58.1)	203	(50.4)		
Education										
Less than high school	472	(38.5)	54	(23.7)	252	(42.3)	166	(41.2)	$\chi^2(4) = 33.9987$	$p<.001$
High school	435	(35.5)	87	(38.2)	214	(35.9)	134	(33.3)		
More than high school	320	(26.1)	87	(38.2)	130	(21.8)	103	(25.6)		
Race/ethnicity										
Non-Hispanic White	666	(54.3)	120	(52.6)	309	(51.9)	237	(59.0)	$\chi^2(6) = 12.086$	$p = .060$
Non-Hispanic Black	333	(27.2)	70	(30.7)	175	(29.4)	88	(21.9)		
Hispanic	194	(15.8)	29	(12.7)	97	(16.3)	68	(16.9)		
Other	33	(2.7)	9	(4.0)	15	(2.5)	9	(2.2)		
Marital status										
Married/partnered	706	(57.5)	123	(54.0)	342	(57.4)	241	(59.8)	$\chi^2(4) = 2.5666$	$p = .633$
Separated/divorced/widowed	461	(37.6)	93	(40.8)	227	(38.1)	141	(35.0)		
Never married	60	(4.9)	12	(5.3)	27	(4.5)	21	(5.2)		

Lowest	456	(37.2)	66	(29.0)	235	(39.4)	155	(38.5)	$\chi^2(6) = 24.8553$	$p<.001$
2nd lowest	386	(31.5)	73	(32.0)	169	(28.4)	144	(35.7)		
2nd highest	249	(20.3)	55	(24.1)	115	(19.3)	79	(19.6)		
Highest	136	(11.1)	34	(14.9)	77	(12.9)	25	(6.2)		
Asset										
Lowest	377	(30.7)	64	(28.1)	175	(29.4)	138	(34.2)	$\chi^2(6) = 14.2780$	$p = .027$
2nd lowest	362	(29.5)	56	(24.6)	194	(32.6)	112	(27.8)		
2nd highest	287	(23.4)	56	(24.6)	135	(22.7)	96	(23.8)		
Highest	201	(16.4)	52	(22.8)	92	(15.4)	57	(14.1)		
Personality -Extraversion	3.14	(0.58)	3.33	(0.04)	3.15	(0.02)	3.02	(0.03)	$F(2,1189) = 21.54$	$p<.001$
Missing	37	(3.0)								
Personality - Openness	2.79	(0.60)	2.98	(0.04)	2.79	(0.03)	2.69	(0.03)	$F(2,1167) = 16.25$	$p<.001$
Missing	57	(4.7)								
Environmental factors										
Living area										
Urban	557	(45.4)	105	(46.3)	281	(47.2)	171	(42.4)	$\chi^2(4) = 3.3976$	$p = .494$
Suburban	307	(25.0)	60	(26.4)	138	(23.2)	109	(27.1)		
Exurban	361	(29.4)	62	(27.3)	176	(29.6)	123	(30.5)		
Missing	2	(0.2)								
Neighborhood physical disorder score	11.58	(6.47)	11.69	(0.43)	11.36	(0.27)	11.82	(0.34)	$F(2,1167) = 0.62$	$p = .537$
Missing	57	(4.7)								
Neighborhood cohesion score	11.17	(6.46)	11.22	(0.46)	10.77	(0.26)	11.73	(0.34)	$F(2,1168) = 2.53$	$p = .080$
Missing	58.00	(4.73)								
Social network size	3.15	(0.84)	3.26	(0.05)	3.14	(0.03)	3.11	(0.05)	$F(2,1214) = 2.41$	$p = .090$
Body function and structures										
ADL difficulty										

No difficulty	894	(72.9)	191	(83.8)	432	(72.5)	271	(67.3)	$\chi^2(4) = 25.2729$	$p<.001$
One difficulty	162	(13.2)	25	(11.0)	80	(13.4)	57	(14.1)		
Two or more difficulties	171	(13.9)	12	(5.3)	84	(14.1)	75	(18.6)		
Cognitive function	9.52	(1.35)	9.84	(0.08)	9.48	(0.06)	9.40	(0.07)	$F(2,1216) = 8.21$	$p<.001$
7	133	(10.8)	15	(6.6)	68	(11.5)	50	(12.5)		
8	169	(13.8)	22	(9.7)	85	(14.4)	62	(15.5)		
9	239	(19.5)	39	(17.2)	117	(19.8)	83	(20.8)		
10	286	(23.3)	60	(26.4)	140	(23.7)	86	(21.6)		
11	390	(31.8)	91	(40.1)	181	(30.6)	118	(29.6)		
Missing	10	(0.8)								
Proxy respondent										
No	1217	(99.2)	227	(99.6)	591	(99.2)	399	(99.0)	$\chi^2(2) = 0.5610$	$p = .755$
Yes	10	(0.8)	1	(0.4)	5	(0.8)	4	(1.0)		
Health condition										
Depressive symptoms (CES-D)										
Not depressed (0–3)	967	(78.8)	191	(84.1)	470	(79.5)	306	(76.7)	$\chi^2(2) = 4.9222$	$p = .085$
Depressed (4–8)	250	(20.4)	36	(15.9)	121	(20.5)	93	(23.3)		
Missing	10	(0.8)								
Self-rated memory	1.71	(0.98)	1.87	(0.06)	1.69	(0.04)	1.64	(0.05)	$F(2,1216) = 4.21$	$p = .015$
Self-rated health	2.79	(1.11)	3.15	(0.07)	2.70	(0.04)	2.72	(0.06)	$F(2,1223) = 15.20$	$p<.001$
Number of chronic conditions										
No condition	138	(11.3)	37	(16.2)	61	(10.2)	40	(9.9)	$\chi^2(4) = 17.9223$	$p = .001$
One condition	219	(17.9)	55	(24.1)	102	(17.1)	62	(15.4)		
Two or more conditions	870	(70.9)	136	(59.7)	433	(72.7)	301	(74.7)		

Table 4.3. Multinomial logistic regression on patterns of social engagement

	Formal and Informal[a]			Low		
n = 1,227	*RRR*[b]	*SE*		*RRR*	*SE*	
Personal factors						
Age group (ref: 50–60)						
61–70	1.36	0.256		1.46	0.214	
71–80	1.28	0.263		1.35	0.213	
81–90	0.82	0.297		1.40	0.241	
Sex (ref: Male)						
Female	0.95	0.173		0.71	0.149	*
Education (ref: less than high school)						
High school	1.77	0.214	**	1.11	0.163	
More than high school	3.03	0.245	***	1.60	0.196	*
Marital status (ref: Married/partnered)						
Separated/divorced/widowed	1.83	0.241	*	0.78	0.187	
Never married	1.90	0.447		1.13	0.341	
Race/ethnicity (ref: Non-Hispanic White)						
Non-Hispanic Black	1.25	0.230		0.60	0.191	**
Hispanic	1.12	0.282		0.82	0.226	
Other	1.75	0.462		0.85	0.478	
Income (ref: Lowest)						
2nd lowest	1.52	0.225		1.13	0.173	
2nd highest	1.21	0.271		0.86	0.214	
Highest	0.84	0.331		0.38	0.295	**
Asset (ref: Lowest)						
2nd lowest	0.70	0.233		0.64	0.182	*
2nd highest	0.87	0.262		0.74	0.206	
Highest	1.19	0.302		0.68	0.269	
Personality -Extraversion	1.47	0.195	*	0.77	0.147	
Personality - Openness	1.05	0.175		0.88	0.150	
Environmental factors						
Living area (ref: Urban)						
Suburban	1.39	0.207		1.24	0.168	
Exurban	1.16	0.214		1.11	0.171	

Neighborhood physical disorder	1.01	0.020		0.99	0.018	
Neighborhood cohesion	1.01	0.020		1.03	0.018	
Social network size	1.38	0.135	*	0.97	0.091	
Health condition						
Depression (CES-D; ref: Not depressed)						
Depressed (4–8)	1.03	0.235		1.18	0.174	
Self-rated health	1.24	0.088	*	1.14	0.075	
Chronic conditions (ref: No condition)						
One condition	0.89	0.292		0.96	0.279	
Two or more conditions	0.63	0.264		0.96	0.258	
Body functions and structures						
ADL difficulty (ref: No difficulty)						
One difficulty	1.02	0.259		1.07	0.195	
Two or more difficulties	0.57	0.345		1.51	0.200	*
Self-rated memory	0.99	0.091		1.00	0.075	
Cognitive function	1.15	0.064	*	0.97	0.052	
(intercept)	0.00	1.064	***	2.06	0.813	

NOTE: [a] Formal and informal = Formal and informal social engagement group; Low = Low social engagement group; reference was informal social engagement only group; note that relative risk ratios are based only on comparisons with the reference group, [b] RRR = Relative Risk Ratio, $^{*}p<.05$ $^{**}p<.01$ $^{***}p<.001$

Table 4.4. Comparison of samples

	Reduced sample (n = 929)		Full sample (n = 1227)			
	n, M	*%, SD*	*n, M*	*%, SD*		*p*
Patterns of social engagement						
Low social contact	192	(20.7)	228	(18.6)	$\chi^2(2) = 2.13$	0.344
Informal social contact	283	(30.5)	403	(32.8)		
Formal social contact	454	(48.9)	596	(48.6)		
Age group						
51–60	249	(26.8)	286	(23.3)	$\chi^2(3) = 14.10$	0.003
61–70	244	(26.3)	283	(23.1)		
71–80	272	(29.3)	367	(29.9)		
81–90	164	(17.7)	291	(23.7)		
Sex						
Male	394	(42.4)	546	(44.5)	$\chi^2(1) = 0.94$	0.333
Female	535	(57.6)	681	(55.5)		
Education						
Less than high school	354	(38.1)	472	(38.5)	$\chi^2(2) = 0.27$	0.873
High school	339	(36.5)	435	(35.5)		
More than high school	236	(25.4)	320	(26.1)		
Marital status						
Married/partnered	539	(58.0)	706	(57.5)	$\chi^2(2) = 0.18$	0.912
Separated/divorced/widowed	342	(36.8)	461	(37.6)		
Never married	48	(5.2)	60	(4.9)		
Race/ethnicity						
Non-Hispanic White	467	(50.3)	666	(54.3)	$\chi^2(3) = 3.47$	0.325
Non-Hispanic Black	277	(29.8)	333	(27.1)		
Hispanic	156	(16.8)	194	(15.8)		
Other	28	(3.0)	33	(2.7)		
Missing	1	(0.1)	1	(0.1)		
Income						
Lowest	352	(37.9)	456	(37.2)	$\chi^2(3) = 0.19$	0.979
2nd lowest	287	(30.9)	386	(31.5)		
2nd highest	185	(19.9)	249	(20.3)		
Highest	105	(11.3)	136	(11.1)		

Social network size	3.21	(0.80)	3.15	(0.84)	$t(2154) = -1.68$	0.094
ADL difficulty						
No difficulty	702	(75.6)	894	(72.9)	$\chi^2(2) = 2.14$	0.343
One difficulty	114	(12.3)	162	(13.2)		
Two or more difficulties	113	(12.2)	171	(13.9)		
Cognitive function (TICS-27)	9.59	(1.3)	9.52	(1.35)	$t(2154) = -1.21$	0.226
Proxy in 2014						
No	927	(99.8)	1217	(99.2)	$\chi^2(1) = 3.44$	0.064
Yes	2	(0.2)	10	(0.8)		
Depression (CES-D)						
Not depressed (0–3)	740	(79.7)	967	(78.8)	$\chi^2(1) = 0.04$	0.833
Depressed (4–8)	187	(20.1)	250	(20.4)		
Missing	2	(0.2)	10	(0.8)		
Chronic conditions						
No condition	119	(12.8)	138	(11.3)	$\chi^2(2) = 2.34$	0.311
One condition	179	(19.3)	219	(17.9)		
Two or more conditions	631	(67.9)	870	(70.9)		
Self-rated memory	1.75	(0.97)	1.71	(0.98)	$t(2154) = -0.94$	0.346
Self-rated health	2.87	(1.10)	2.79	(1.11)	$t(2154) = -1.66$	0.096

Table 4.5. Result of logistic regression analysis on conversion from CIND to dementia in 2014

	n = 929 (reduced)				*n* = 1,227 (imputed)			
	OR[a]	*SE*	*p*		*OR*[a]	*SE*	*p*	
Independent variable								
Patterns of social engagement (ref: Low)								
Formal and informal	0.468	0.312	0.015	*	0.539	0.278	0.027	*
Informal only	0.629	0.212	0.029	*	0.768	0.198	0.185	
Covariates								
Age group (ref: 51–60)								
61–70	1.789	0.327	0.075		1.591	0.311	0.136	
71–80	2.790	0.322	0.001	**	2.500	0.310	0.004	**
81–90	10.052	0.363	0.000	***	8.263	0.340	0.000	***
Sex (ref: Male)								
Female	0.962	0.216	0.859		0.939	0.214	0.769	
Education (ref: less than high school)								
High school	0.659	0.229	0.068		0.749	0.273	0.304	
More than high school	0.489	0.293	0.015	*	0.547	0.269	0.028	*
Marital status (ref: Married/partnered)								
Separated/divorced/widowed	0.739	0.269	0.261		0.826	0.261	0.467	
Never married	0.440	0.593	0.166		0.428	0.559	0.131	
Race/ethnicity (ref: Non-Hispanic White)								
Non-Hispanic Black	1.689	0.258	0.042	*	1.698	0.239	0.028	*
Hispanic	1.666	0.282	0.070		1.781	0.342	0.112	
Other	0.679	0.791	0.624		0.656	0.794	0.598	
Income (ref: Lowest)								
2nd lowest	0.715	0.240	0.162		0.830	0.262	0.483	
2nd highest	0.573	0.324	0.085		0.710	0.420	0.433	
Highest	0.512	0.459	0.145		0.544	0.584	0.317	
Social network size	0.689	0.134	0.005	**	0.728	0.178	0.102	
ADL difficulty (ref: No difficulty)								
One difficulty	0.881	0.313	0.684		0.997	0.249	0.990	

Cognitive function (TICS-27)	0.823	0.074	0.008	**	0.826	0.072	0.011	*
Proxy respondent in 2014 (ref: not proxy)	1.036	0.406	0.931		0.939	0.343	0.854	
Depression (CES-D; ref: Not depressed)								
Depressed (4–8)	1.727	0.248	0.028	*	1.613	0.249	0.061	
Chronic conditions (ref: No condition)								
One condition	0.677	0.405	0.335		0.685	0.416	0.367	
Two or more conditions	0.812	0.345	0.546		0.871	0.346	0.689	
Self-rated memory	0.945	0.107	0.598		0.991	0.092	0.919	
Self-rated health	1.078	0.098	0.441		1.076	0.087	0.396	
Died or dropped (ref: Not died or dropped)					1.139	0.256	0.616	
(intercept)	3.371	1.004	0.226		1.713	1.166	0.651	

NOTE: [a] OR = Odds ratio; [b] * $p<.05$ ** $p<.01$ *** $p<.001$

Table 4.6. Results of path analysis with the reduced sample (n = 929)

	Reduced sample (n = 929)											
	Conversion to dementia				Physical engagement				Cognitive engagement			
	OR[a]	*SE*	*p*		*Coef*	*SE*	*p*		*Coef*	*SE*	*p*	
Direct effects												
Patterns of social engagement												
Formal and informal (FI)	0.762	0.179	0.129		0.351	0.128	0.006	**	1.089	0.167	0.000	***
Informal only (IO)	0.834	0.120	0.131		0.014	0.392	0.971		0.340	0.201	0.090	
Physical engagement (PE)	0.999	0.060	0.990									
Cognitive engagement (CE)	0.910	0.034	0.005	**								
Indirect effects												
FI > PE	1.000	0.021	0.990									
IO > PE	1.000	0.001	0.991									
FI > CE	0.902	0.040	0.009	**								
IO > CE	0.969	0.022	0.151									
	Statistic	*p*	Lower	Upper								
Model fit statistics												
$\chi 2$ (18)	10.400	0.732										
CFI	1.000											
RMSEA	<0.000		0.000	0.024								
SRMR	0.099											

Table 4.7. Results of path analysis with the full sample (n = 1,227)

	Full sample (n = 1,227)											
	Conversion to dementia				Physical engagement				Cognitive engagement			
	OR[a]	*SE*	*p*		*Coef*	*SE*	*p*		*Coef*	*SE*	*p*	
Direct effects												
Patterns of social engagement												
Formal and informal (FI)	0.823	0.170	0.252		0.264	0.106	0.013	*	0.992	0.201	0.000	***
Informal only (IO)	0.919	0.116	0.466		-0.054	0.122	0.657		0.214	0.407	0.599	
Physical engagement (PE)	1.027	0.061	0.661									
Cognitive engagement (CE)	0.924	0.033	0.018	*								
Indirect effects												
FI > PE	1.007	0.016	0.660									
IO > PE	0.999	0.005	0.766									
FI > CE	0.925	0.037	0.034	*								
IO > CE	0.983	0.033	0.610									
	Statistic	*p*	Lower	Upper								
Model fit statistics												
$\chi 2$ (16)	19.017	0.268										
CFI	1.000											
RMSEA	<0.000		0.000	0.030								
SRMR	0.131											

Figures

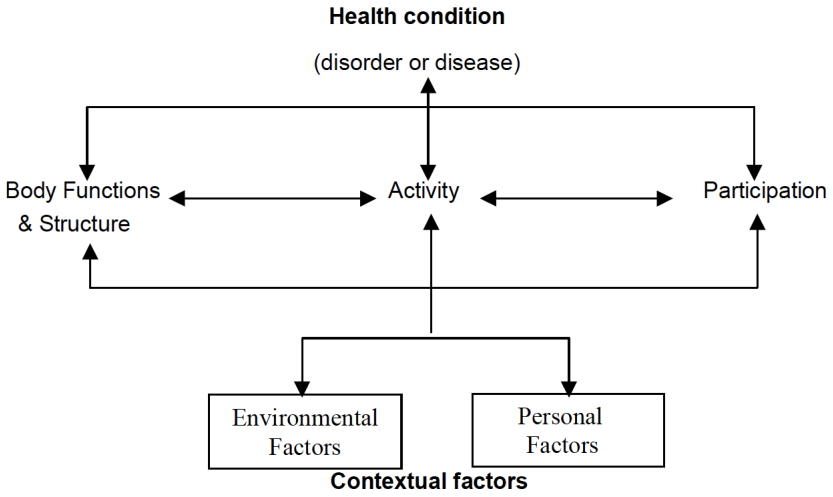


Figure 2.1. Model of function and disability in ICF (WHO, 2002)

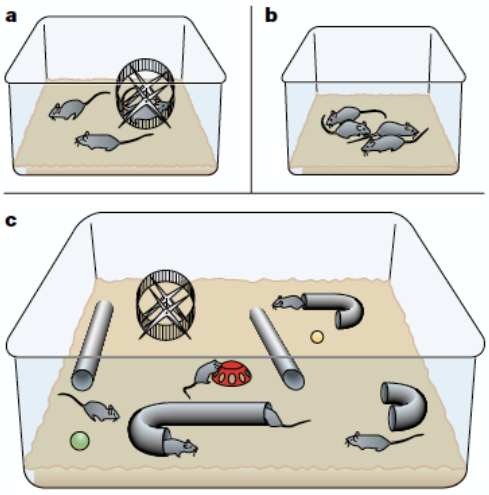


Figure 2.2. Illustration of enriched environment for rats (Van Praag et al., 2000, p. 192*)*.

Note. a. Impoverished only voluntary exercise cage; b. Impoverished only social interaction cage; c. Enriched social interaction, stimulation of exploratory behavior, and a running wheel for exercise.

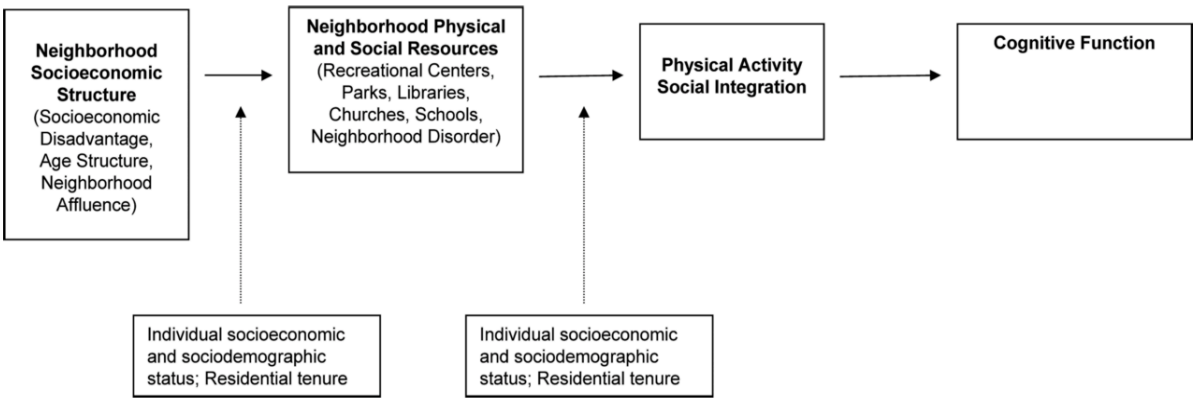


Figure 2.3. Hypothetical pathways in the relationship between neighborhood socioeconomic structure and cognitive function (Clarke et al., 2012)

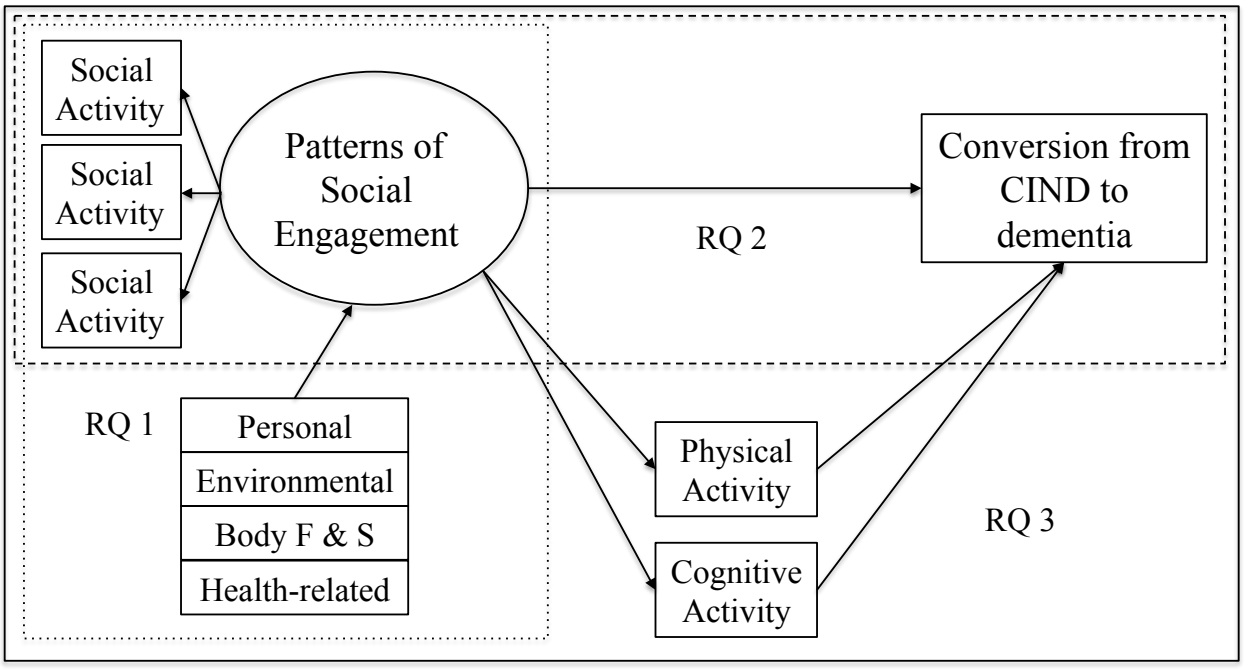


Figure 2.4. Conceptual framework.

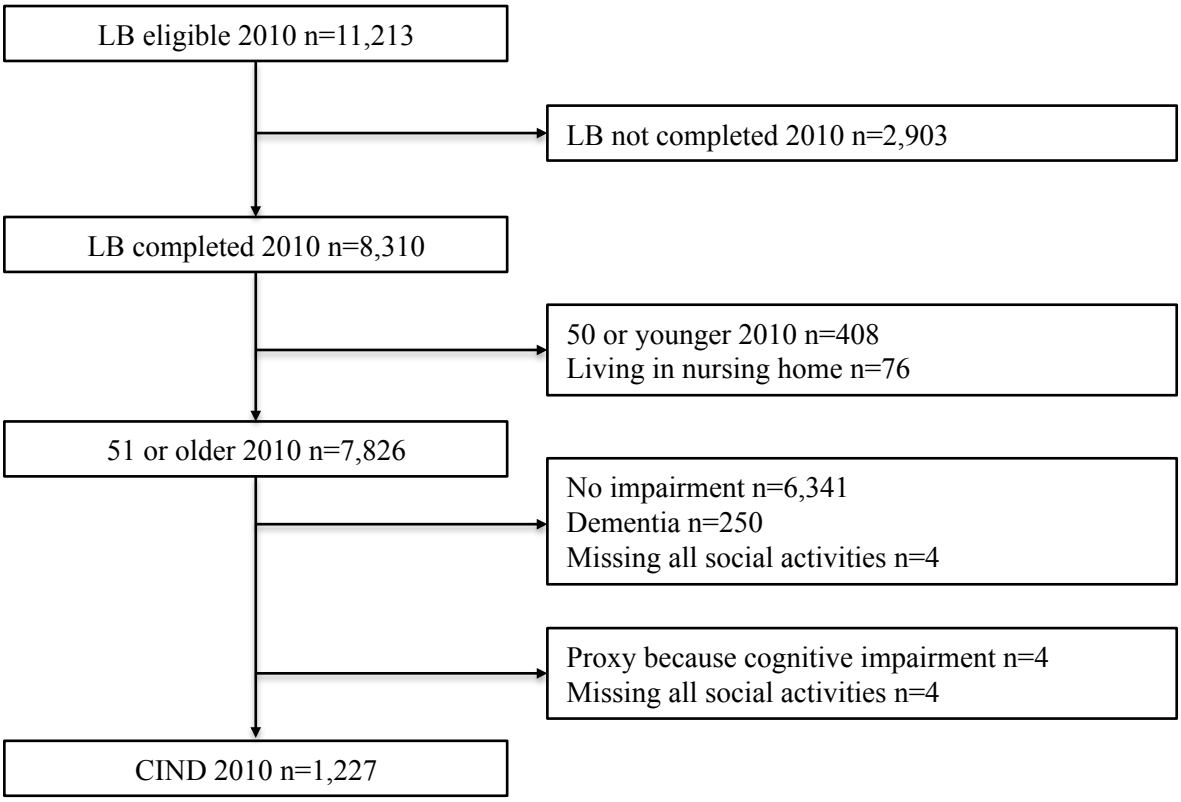


Figure 3.1. Sample selection flow chart for the Research Question 1

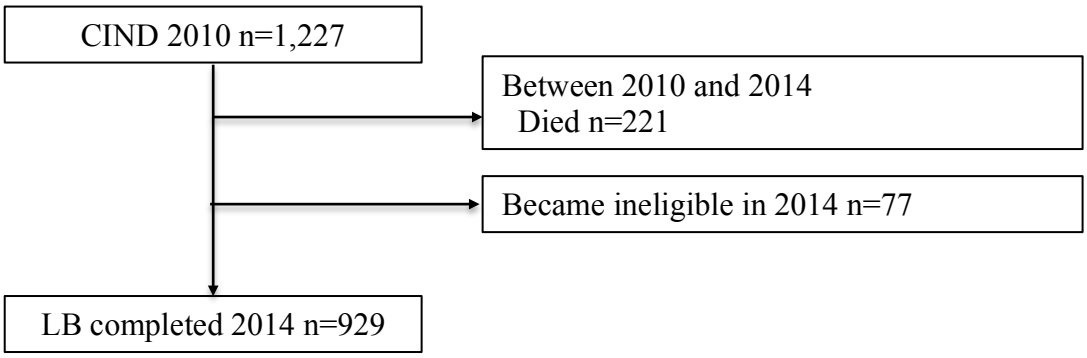


Figure 3.2. Sample selection flow chart for the Research Question 2 and 3

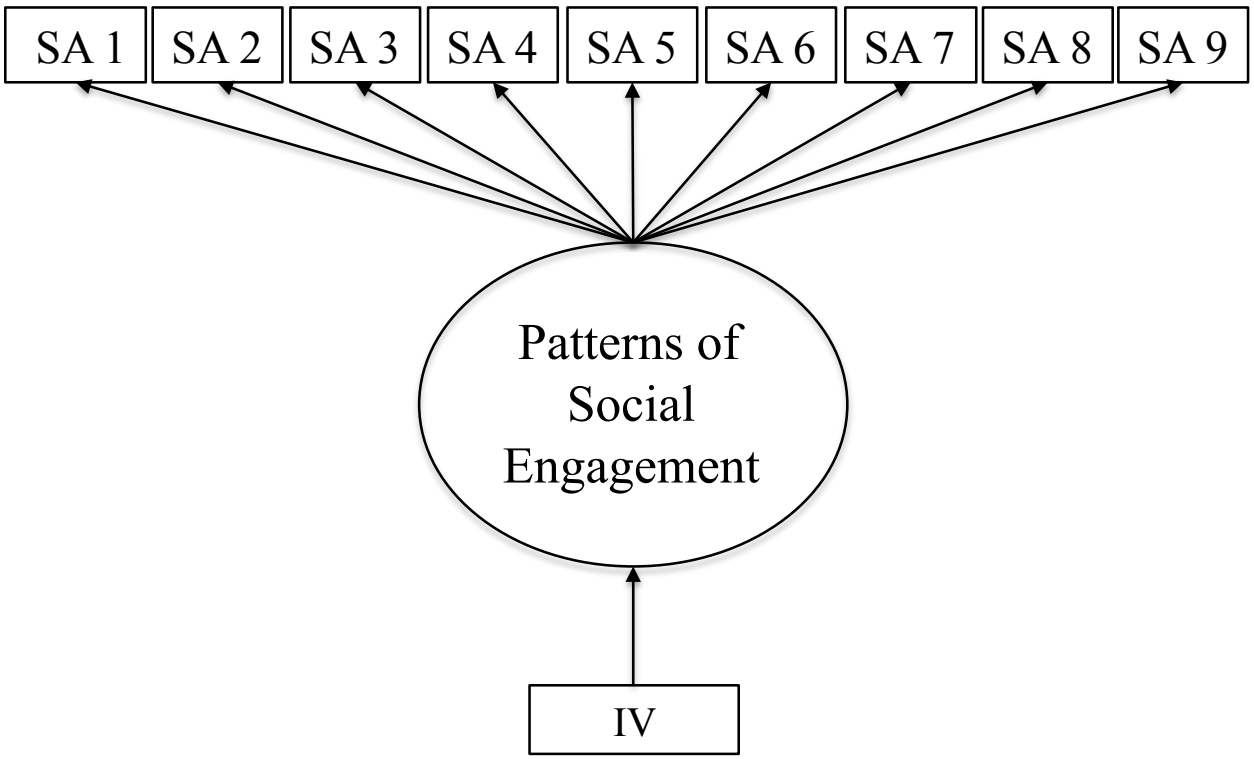


Figure 3.3. Analytic model for Research Question 1

Note. SA is social activity indicators including SA1: do activity with children; SA2: volunteering with youth; SA3: other volunteer or charity work; SA4: attend educational course; SA5: attend nonreligious organizations; SA6: meeting up; SA7: speaking on the phone; SA8: writing or emailing. IV is independent variables including personal factors (age group, sex, educational attainment, race/ethnicity, Hispanic ethnicity, marital status, income, asset, personality); environmental factors (living area, neighborhood physical disorder, neighborhood cohesion, social network); body functions and structure (ADL difficulty, cognitive function, use of proxy); health conditions (depressive symptoms, self-rated memory, self-rated health, number of chronic conditions)

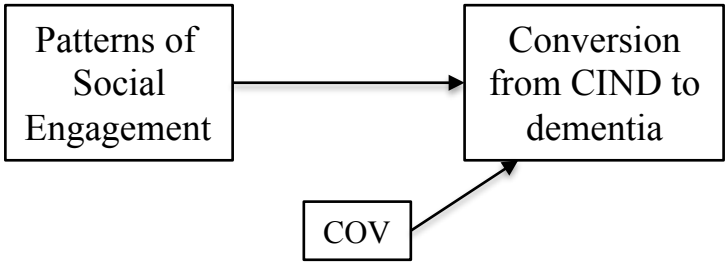


Figure 3.4. Analytic model for Research Question 2

Note. Patterns of social engagement is a class assignment obtained from LCA; COV is covariates including sociodemographic factors (age group, gender, education, marital status, race/ethnicity, Hispanic, social network), health-related factors (depressive symptoms, self-rated memory, self-rated health, chronic conditions), functional factors (ADL difficulty, cognitive function, use of proxy), and other engagements (physical engagement, cognitive engagement).

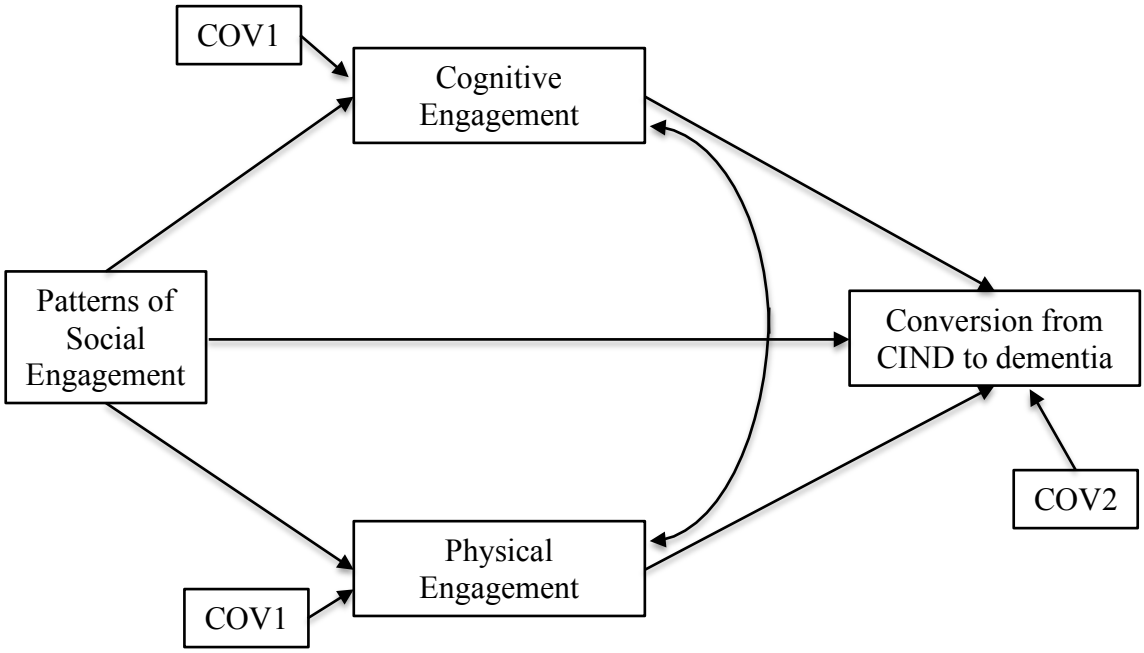
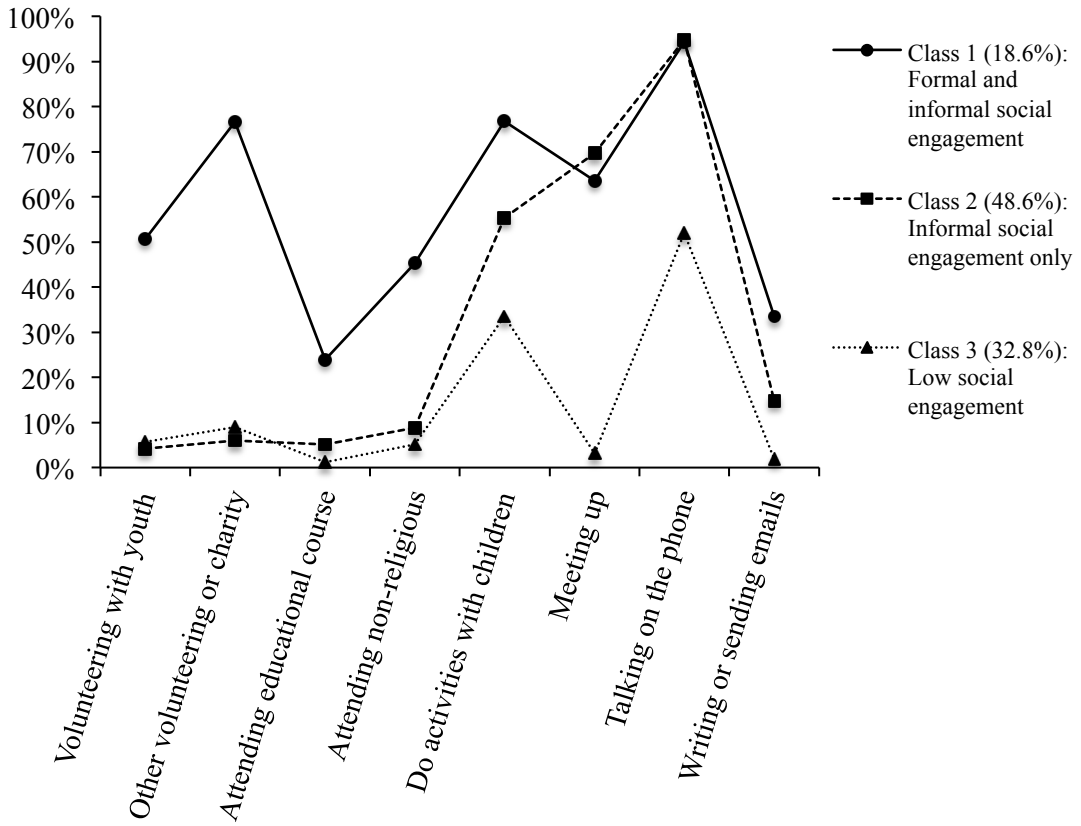


Figure 3.5. Analytic model for Research Question 3

Note. Note. Patterns of social engagement is a class assignment obtained from LCA; COV is covariates. COV 1 includes personal factors (age group, sex, educational attainment, race/ethnicity, Hispanic ethnicity, marital status, income, asset, personality); environmental factors (living area, neighborhood physical disorder, neighborhood cohesion, social network); body functions and structure (ADL difficulty, cognitive function, use of proxy); health conditions (depressive symptoms, self-rated memory, self-rated health, number of chronic conditions); and other engagements (physical engagement, cognitive engagement). COV2 includes sociodemographic factors (age group, gender, education, marital status, race/ethnicity, Hispanic, social network); health-related factors (depressive symptoms, self-rated memory, self-rated health, chronic conditions); and functional factors (ADL difficulty, cognitive function).

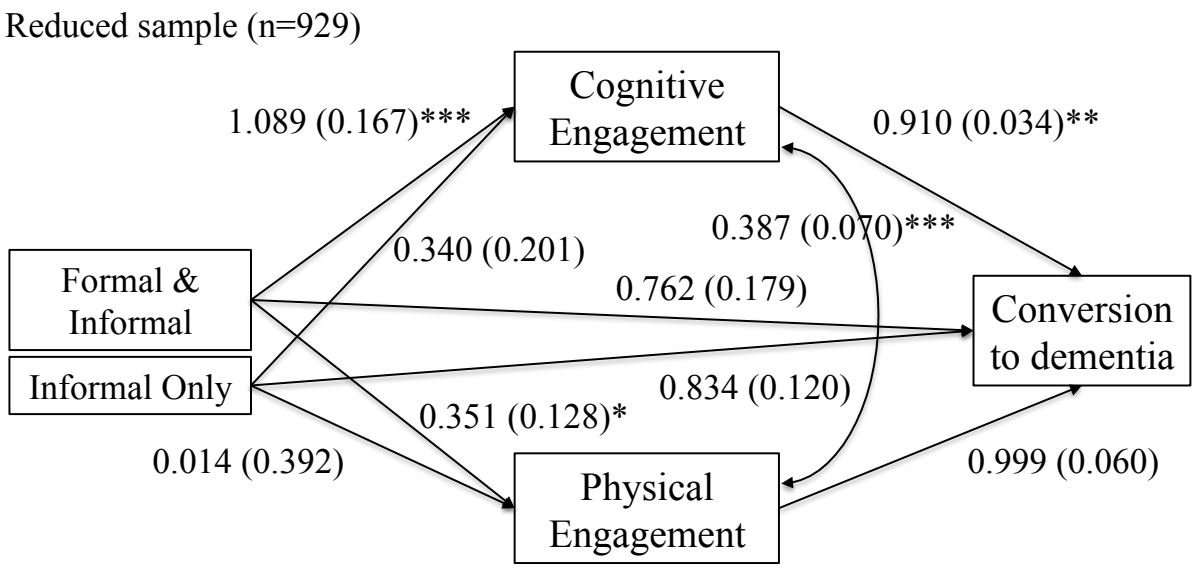


		Class 1	Class 2	Class 3
	n	228	596	403
	(%)	(18.6%)	(48.6%)	(32.8%)
2	Volunteering with youth	**50.6**	4.2	5.7
3	Other volunteering or charity work	**76.6**	6.0	8.9
4	Attending educational course	23.9	5.1	1.2
5	Attending nonreligious organization	45.3	8.8	5.2
1	Do activities with children[b]	**76.7**	**55.3**[a]	33.5
6	Meeting up	**63.5**	**69.6**	3.2
7	Talking on the phone	**94.4**	**94.7**	**51.9**
8	Writing or sending emails	33.5	14.8	1.9

[a] item response probability>.5 in bold to facilitate interpretation

[b] Children included grandchildren, nieces/nephews, or neighborhood children

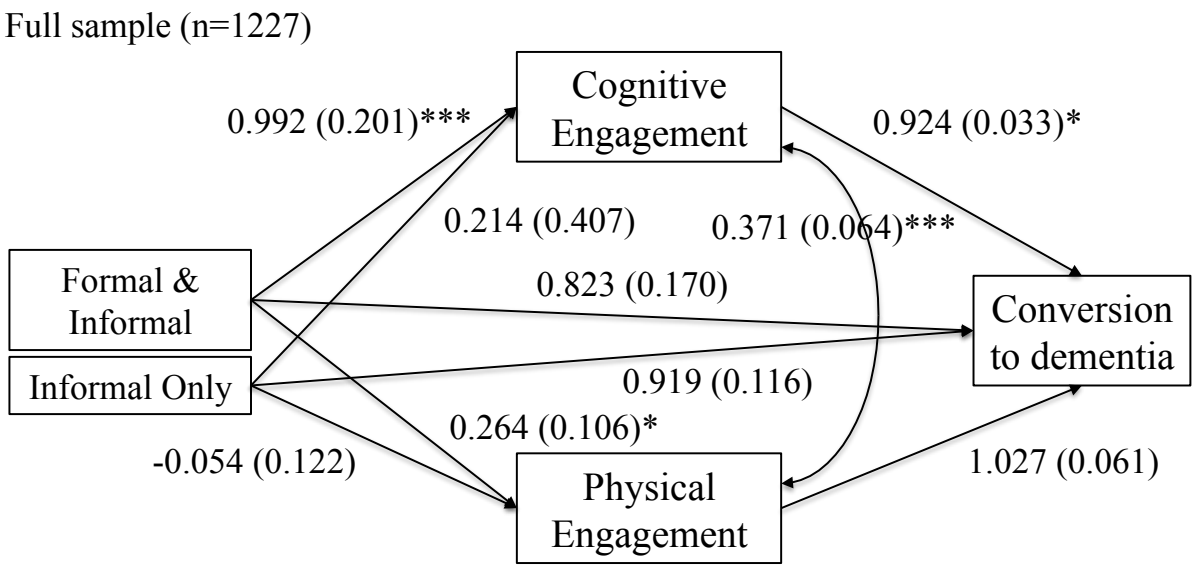
Figure 4.1. Item response probabilities of each social activity



Indirect effects				
Fornal and informal -> Physical engagement	1.000	0.021	0.990	
Informal only -> Physical engagement	1.000	0.001	0.991	
Fornal and informal -> Cognitive engagement	0.902	0.040	0.009	**
Informal only -> Cognitive engagement	0.969	0.022	0.151	

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

Figure 4.2. Direct and indirect effects of social engagement on conversion from CIND to dementia with reduced sample



Indirect effects				
Fornal and informal -> Physical engagement	1.007	0.016	0.660	
Informal only -> Physical engagement	0.999	0.005	0.766	
Fornal and informal -> Cognitive engagement	0.925	0.037	0.034	*
Informal only -> Cognitive engagement	0.983	0.033	0.610	

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

Figure 4.3. Direct and indirect effects of social engagement on conversion from CIND to dementia with full sample

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Appendix A: List of Variables for Research Question 1

Variables for RQ 1

DV: Social engagement			
Do activities with children		These first questions are about the activities in your life now. Please tell us how often you do each activity.	Yes (1 = Never/Not Relevant, 2 = Not in the last month); High (3 = At least once a month, 4 = Several times a month, 5 = Once a week, 6 = Several times a week, 7 = Daily)
Volunteering with youth			
Other volunteer or charity work			
Attend educational course			
Attend nonreligious organizations			
Meeting up (average across contacts)	Meet with children	On average, how often do you do each of the following? Please check the answer that shows how you feel about each statement.	No (1 = Less than once a year or never, 2 = Once or twice a year, 3 = Every few months); Yes (4 = Once or twice a month, 5 = Once or twice a week, 6 = Three or more times a week)
	Meet with family		
	Meet with friends		
Speaking on the phone (average across contacts)	Speak on the phone with children		
	Speak on the phone with family		
	Speak on the phone with friends		
Writing or emailing (average across contacts)	Write or email with children		
	Write or email with family		
	Write or email with friends		
IV: Predictors of social engagement			
Personal factors			
Age group			1 = 51 - 60 2 = 61 - 70 3 = 71 - 80 4 = 81 or older
Sex			1 = Male, 2 = Female
Education			1 = less than high school 2 = high school 3 = more than high school

Marital status			1 = (Married, Married spouse absent, Partnered;) 2 (Separated, Divorced, Separated/divorced, Widowed); 3 (Never married)
Race/ethnicity			1 = Non-Hispanic White 2 = Non-Hispanic Black/African American, 3 = Hispanic, 4 = Other
Income		Total household income	quartile
Asset		Total household asset	quartile
Personality	Extraversion	Average across items	1 to 4
	Openness to experience	Average across items	1 to 4
Environmental factors			
Living area		Urban/suburban/rural residency	1 = Urban, 2 = Suburban, 3 = Exurban
Neighborhood environment	Neighborhood physical disorder scale	Average across four items	1 to 7
	Neighborhood cohesion scale	Average across four items	1 to 7
Social network	Composition of social network scale	Do you have a husband, wife, or partner with whom you live?	0 to 4
		Do you have any living children?	
		Do you have any other immediate family, for example, any brothers or sisters, parents, cousins or grandchildren?	
		Do you have any friends?	
Body functions and structure			
ADL difficulty		bathing, eating, dressing, walking across a room, and getting in or out of bed	0 No difficulty, 1 = One difficulty, 2 = Two or more difficulties
Cognitive function		TICS-27 raw score	7 to 11
Health condition			
Depressive symptoms		CES-D	0 = No depression (0 to 3) 1 = Depressed (4 or higher)

Self rated memory	How would you rate your memory at the present time?	1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent
Self-rated health	Would you say your health is excellent, very good, good, fair, or poor?	1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent
Number of chronic conditions	1) high blood pressure or hypertension; 2) diabetes or high blood sugar; 3) cancer or a malignant tumor of any kind except skin cancer; 4) chronic lung disease except asthma such as chronic bronchitis or emphysema; 5) heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems; 6) stroke or transient ischemic attack (TIA); 7) emotional, nervous, or psychiatric problems; and 8)arthritis or rheumatism	0 No difficulty, 1 = One difficulty, 2 = Two or more difficulties

Appendix B: List of Variables for Research Question 2

Variables for RQ 2

DV: Dementia in 2012			
Dementia in 2014	TICS-27 and proxy classification in 2014	0 = Not dementia; 1 = Dementia	
IV: Social engagement			
Class of social engagement		See RQ 1 variable list for indicators	
Covariates			
Sociodemographic factors			
Age group			1 = 51 - 60 2 = 61 - 70 3 = 71 - 80 4 = 81 or older
Sex			1 = Male, 2 = Female
Education			1 = less than high school 2 = high school 3 = more than high school
Marital status			1 = (Married, Married spouse absent, Partnered;) 2 (Separated, Divorced, Separated/divorced, Widowed); 3 (Never married)
Race/ethnicity			1 = Non-Hispanic White, 2 = Non-Hispanic Black/African American, 3 = Hispanic, 4 = Other
Social network	Composition of social network scale	Do you have a husband, wife, or partner with whom you live?	0 to 4
		Do you have any living children?	
		Do you have any other immediate family, for example, any brothers or sisters, parents, cousins or grandchildren?	
		Do you have any friends?	

Health-related factors			
Depressive symptoms		CES-D	0 = No depression (0 to 3) 1 = Depressed (4 or higher)
Self rated memory		How would you rate your memory at the present time?	1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent
Self-rated health		Would you say your health is excellent, very good, good, fair, or poor?	1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent
Number of chronic conditions		1) high blood pressure or hypertension; 2) diabetes or high blood sugar; 3) cancer or a malignant tumor of any kind except skin cancer; 4) chronic lung disease except asthma such as chronic bronchitis or emphysema; 5) heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems; 6) stroke or transient ischemic attack (TIA); 7) emotional, nervous, or psychiatric problems; and 8)arthritis or rheumatism	0 No condition, 1 = One condition, 2 = Two or more conditions
Functional factors			
Cognitive function (2010)	Immediate word recall (for self-respondents only)	I'll read a set of 10 words and ask you to recall as many as you can. I have purposely made the list long so that it will be difficult for anyone to recall all the words -- most people recall just a few. Please listen carefully as I read the set of words because I cannot repeat them. When I finish, I will ask you to recall aloud as many of the	0 to 10

		words as you can, in any order. Is this clear?	
	Delayed word recall (for self-respondents only)	Recall words in the above list after several other questions.	0 to 10
	Series minus 7s (for self-respondents only)	Now let's try some subtraction of numbers. One hundred minus 7 equals what? (Five times)	0 to 5
	Backward counting 20 (for self-respondents only)	For this next question, please try to count backward as quickly as you can from the number I will give you. I will tell you when to stop.	0 to 2
ADL difficulty		bathing, eating, dressing, walking across a room, and getting in or out of bed	0 No difficulty, 1 = One difficulty, 2 = Two or more difficulties
Other variable			
Proxy respondent Died or dropped		use of proxy in 2014 died or became ineligible for the survey between 2010 and 2014	1 = No, 2 = Yes 1 = No, 2 = Yes

Appendix C: List of Variables for Research Question 3

Variables for RQ 3

DV: Dementia in 2014			
Dementia in 2014	TICS-27 and proxy classification in 2014	0 = Not dementia (7 or higher); 1 = Dementia (0 to 6)	
IV: Social engagement			
Latent class of social engagement		See RQ 1 variable list for indicators	
MV: Activity engagement			
Physical engagement in 2014		Number of physical engagement	0 to 3
Cognitive engagement in 2014		Number of cognitive engagement	0 to 8
Covariates 1 (IV-DV, MV-DV)			
Sociodemographic factors			
Age group			1 = 51 - 60 2 = 61 - 70 3 = 71 - 80 4 = 81 or older
Sex			1 = Male, 2 = Female
Education			1 = less than high school 2 = high school 3 = more than high school
Marital status			1 = (Married, Married spouse absent, Partnered;) 2 (Separated, Divorced, Separated/divorced, Widowed); 3 (Never married)
Social network	Composition of social network	Number of people in social network	0 to 4
Health-related factors			
Depressive symptoms		CES-D	0 = No depression (0 to 3) 1 = Depressed (4 or higher)
Self rated memory		How would you rate your memory at the present time?	1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent
Self-rated health		Would you say your health is excellent, very good, good, fair, or poor?	1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent

Number of chronic conditions		Number of chronic conditions.	0 No condition, 1 = One condition, 2 = Two or more conditions
Functional factors			
Cognitive function (2010)		Immediate recall	0 to 10
		Delayed recall	0 to 10
		Series minus 7s	0 to 5
		Backward counting	0 to 2
ADL difficulty		Number of ADL difficulty	0 No difficulty, 1 = One difficulty, 2 = Two or more difficulties
Covariate 2 (IV-MV)			
Personal factors			
Age group			1 = 51 - 60 2 = 61 - 70 3 = 71 - 80 4 = 81 or older
Sex			1 = Male, 2 = Female
Education			1 = less than high school 2 = high school 3 = more than high school
Marital status			1 = (Married, Married spouse absent, Partnered;) 2 (Separated, Divorced, Separated/divorced, Widowed); 3 (Never married)
Race/ethnicity			1 = White, 2 = Black/African American, 3 = Other
Hispanic			1 = No 2 = Yes
Income		Total household income	quartile
Asset		Total household asset	quartile
Personality	Extraversion	Average across five items	1 to 4
	Openness to experience	Average across seven items	1 to 4
Environmental factors			
Living area		Urban/suburban/rural residency	1 = Urban, 2 = Suburban, 3 = Exurban

Neighborhood environment	Neighborhood physical disorder scale	Average across four items	1 to 7
	Neighborhood cohesion	Average across four items	1 to 7
Social network	Composition of social network	Number of people in social network	0 to 4
Body functions and structure			
ADL difficulty		bathing, eating, dressing, walking across a room, and getting in or out of bed	0 No difficulty, 1 = One difficulty, 2 = Two or more difficulties
Cognitive function		TICS-27 raw score	7 to 11
Health condition			
Depressive symptoms		CES-D	0 = No depression (0 to 3) 1 = Depressed (4 or higher)
Self rated memory		How would you rate your memory at the present time?	1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent
Self-rated health		Would you say your health is excellent, very good, good, fair, or poor?	1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent
Number of chronic conditions		Number of chronic conditions.	0 No condition, 1 = One condition, 2 = Two or more conditions

Appendix D: Social Participation—Social Engagement in LB

No	Activities	Inclusion
1	Care for a sick or disabled adult	No
2	Do activities with grandchildren, nieces/nephews, or neighborhood children	No
3	Do volunteer work with children or young people	Social
4	Do any other volunteer or charity work	Social
5	Attend an educational or training course	Social
6	Go to a sport, social, or other club	No
7	Attend meetings of non-religious organizations, such as political, community, or other interest groups	Social
8	Pray privately in places other than a church or synagogue	No
9	Read books, magazines, or newspapers	Cognitive
10	Watch television	No
11	Do word games such as crossword puzzles or Scrabble	Cognitive
12	Play cards or games such as chess	Cognitive
13	Do writing (such as letters, stories, or journal entries)	Cognitive
14	Use a computer for e-mail, Internet or other tasks	Cognitive
15	Do home or car maintenance or gardening	Physical
16	Bake or cook something special	Cognitive
17	Make clothes, knit, embroider, etc.	Cognitive
18	Work on a hobby or project	Cognitive
19	Play sports or exercise	Physical
20	Walk for 20 minutes or more	Physical