Multidimensional Typology of Social Networks of Older Adults and Its Association with Cognitive and Physical Function in Late Life

by

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DEDICATION

To my brother, Humza, who is wise beyond his years.

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LIST OF ABBREVIATIONS

aBIC	adjusted Bayesian information criterion
ADL	Activities of daily living
AIC	Akaike information criterion
BIC	Bayesian information criterion
BMI	Body Mass Index
CCFM	Chicago Cognitive Function Measure
GLMM	Generalized linear mixed model
HRS	Health and Retirement Study
IADL	Instrumental activities of daily living
LCA	Latent class analysis
LL	Log likelihood
LRT	Likelihood ratio test
MAR	Missing at random
MCI	Mild cognitive impairment
MoCA	Montreal Cognitive Assessment
NORC	National Opinion Research Center
NSHAP	National Social Life, Health, and Aging Project
OR	Odds ratio
SD	Standard deviation
SE	Standard error
SPMSQ	Short Portable Mental Health Questionnaire
US	United States

ABSTRACT

Social networks of older adults are an important risk factor for various health outcomes including mental health, well-being, and pre-mature mortality. Despite their relevance for health in old age, measurement of social networks to date has focused largely on isolated network characteristics, and their influence has primarily been examined in relation to emotional and mental health outcomes. As a result, the multidimensional nature of social networks and their association with aging-relevant outcomes of disability, mobility, and cognitive function remains poorly understood. In this dissertation, we used data from the National Social Life, Health, and Aging Project (NSHAP), a large, nationally-representative, prospective cohort, to examine the multidimensional and heterotypic nature of older adults' social networks and their influence on various functional health outcomes.

In the first study, we derived multidimensional social network types among older adults in the United States by applying latent class analysis to nine observed network characteristics representing the structure, function, and quality of relationships. We found that older adults can be classified into five distinct network types that differ in network size, social support, and presence of a partner: *diverse, supportive network with partner*; *average network with partner*; *partner-centered network*; *large, supportive network without partner*; and *restricted, family-centered network without partner.* Membership in these network types varied by age, sex, race/ethnicity, education, and income.

Next, we examined the relevance of these network types for physical functional health in a prospective analysis and found the association between network types and functional health to be somewhat equivocal. Compared to the *diverse, supportive network with partner*, the *partner-centered network* and the *average network with partner* had a lower risk of onset of activities of daily living disability in the short-term (5-year risk) but not the long-term (10-year risk). Network types also had an effect on mobility, such that older adults in the *restricted, family-centered network without partner* had significantly slower walking times than those in the *diverse, supportive network with partner*. These network types, however, did not have a longitudinal effect on change in mobility.

Lastly, the third aim of this dissertation was to examine the association of social network types with cognitive function in later life. We found that social network types were not associated with onset of cognitive impairment during the 10-year study. Although unadjusted analyses suggested a higher risk of cognitive impairment onset among those in one of the two *restricted* network types: *partner-centered network* and *restricted, family-centered network without partner*, adjustment for sociodemographic and health-related background characteristics rendered these associations insignificant.

Taken together, the results of this dissertation provide evidence of the heterogeneity of older adults' social networks. By taking a pattern-centered approach that simultaneously considers the structural, functional, and qualitative network characteristics, we offer a more nuanced view of individuals' social relationships in the form of network types. The overall pattern of findings did not suggest a clear link between network types and changes in functional health outcomes, with the possible exception of short-term changes in disability. Nevertheless, the social network types identified in this dissertation can inform ways to increase available

social support and reduce social isolation among older adults. Consideration of social network resources, at least in the short term, may also offer opportunities for the prevention and postponement of certain functional limitations in old age.

CHAPTER I

Introduction

Overview

Rapid aging of society and associated demographic and social changes have altered the salience of older adults' social networks as a public health issue. As of 2017, 31 million Americans aged 65 and over were living alone compared to 23 million in 2005.[1] The proportion of older adults living in isolation is increasing due to geographic migration of children, older adults themselves relocating, and family networks becoming smaller and more dispersed. These secular trends have resulted in changes in the composition of social networks of older adults, prompting the need to use more current data to examine the influence of older adults' social network patterns on their health. Findings to date suggest that social networks are an essential component of healthy aging as they provide older adults with opportunities for social engagement and exchange of information and social support.[2] As there is large variability in aging-associated health outcomes, and integration into social networks varies within and across individuals, further research determining which social network patterns or types relate to healthy aging is needed.

There is a small but growing literature linking social network types to various health conditions in old age. However, causal inference from prior studies has been limited due to the cross-sectional nature of the associations[3–6] and the lack of emphasis on the multidimensional nature of social networks.[5–7] Furthermore, the impact of negative social interactions in the

context of social network types and their association with health remains largely unexplored. For instance, despite a large social network and frequent contact with network ties, individuals may experience declines in health if their network ties are not supportive or if their social interactions are stressful. Studies that capture the complexity of the construct of social networks and how older adults' network types relate to their functional and cognitive health are thus warranted. This dissertation takes a multidimensional approach to characterizing the social networks of older adults, and examines their effect on functional health in late life. I use data from the National Social Life, Health, and Aging Project (NSHAP), a longitudinal, population-based study of health and social factors that aims to understand the well-being of older Americans. First (Aim 1), I develop a multidimensional typology of social networks of older adults in the United States. Second (Aim 2), I investigate how these social network types influence the development of disability in daily activities and change in mobility. Third (Aim 3), I examine the association between the identified social network types and onset of cognitive impairment among older adults.

Social Networks and Health

There is ample evidence in epidemiology of the critical role social relationships play in the determination of health status and survival.[5,8–10] Berkman and Syme (1979) were among the first to demonstrate the protective effect of having extensive social ties on all-cause mortality, independent of socioeconomic status and health behaviors, in a large sample of community residents in Alameda County, California.[8] In 1982, House et al corroborated Berkman and Syme's findings in the Tecumseh Community Health Study cohort using a wider range of social relationships and activities; they found that individuals reporting a higher level of participation in social relationships and activities were less likely to die, and that this association held across age,

occupational, and health-status groups.[11] Since these seminal works, researchers have found that the influence of social relationships on mortality is comparable to the effects of other well-established risk factors of mortality including smoking, obesity, physical activity, and air pollution.[10] Greater social integration not only prevents premature mortality but also reduces the risk of a number of other health outcomes in the general population, including hypertension,[12–14] diabetes,[15] coronary heart disease,[16–18] stroke,[19–21] and depression.[22–26] Additionally, social networks have beneficial effects on inflammatory markers associated with cardiovascular disease[27–29] and primary immune system parameters that regulate host resistance.[30–33] These associations are due, at least in part, to the emotional and material support offered by social relationships. Beyond these, there are multiple mechanisms by which social networks may influence health, some of which are discussed below.

Physiological and psychological mechanisms

Social networks provide opportunities for support, social influence, social engagement, and access to resources and material goods. These psychosocial resources, in turn, impact health through physiological, psychological, and health behavioral pathways as indicated in Berkman and Krishna's (2014) conceptual model of how social networks impact health.[34] For instance, shared norms around health behaviors, such as alcohol consumption, dietary patterns, and physical activity, are sources of social influence that affect health by shaping behavior.[34] Similarly, social networks can affect health by promoting social participation and engagement, which reinforce meaningful social roles and provide a sense of meaning and belonging.[34] Social engagement also offers opportunities for direct stimulation of cognitive functions, and plays an important role in maintaining cognitive reserve and promoting cognitive resilience, specially following a stressful experience.[35] Along with psychological and health behavioral pathways,

social networks have been linked to health through more proximate physiological pathways. These include hypothalamic pituitary adrenal (HPA) axis response, allostatic load, immune function, cardiovascular reactivity, and inflammation. Supportive network relationships can act as a buffer against stress and prevent stress-related functional decline.[36,37] On the other hand, negative interactions with intimate ties can lead to elevated HPA axis response[33] and increased allostatic load which contribute to elevated blood pressure and disruption of sleep and cognitive function.[38]

Importance of Social Networks in Late Life

It is important that we examine social networks as risk factors for various health outcomes specifically in older age groups for several reasons. First, older adults are one of the fastest growing population subgroups, with the percentage of the population aged 65 and over expected to increase from 15 percent in 2014 to 24 percent in 2060.[39] Second, older adults are at a higher risk for mortality and nearly all morbid events such as cancer, cardiovascular disease, and neurodegeneration.[40] Third, social networks can have a direct impact on the health of the elderly as they are more likely to involve close social ties in health discussions and medical decision making compared to younger individuals.[41] Fourth, older adults experience many life transitions, including onset of illness or injury, unemployment or forced retirement, widowhood, and death of close friends and family members, which can be particularly stressful. [42–44] According to the buffer hypothesis, an individual's social network is particularly important for well-being in the presence of stress.[45] The buffer hypothesis proposes that in response to acute and chronic stressors, social relationships deliver resources that promote adaptive behavioral and neuroendocrine responses, thereby moderating or buffering the harmful effect of stressors on health.[46] Finally, older adults' personal social networks are rarely stable with at least some

turnover experienced within a period of just a few years.[47,48] This is partly due to major losses in their social networks as a result of age-related life transitions mentioned above, and partly because as adults grow older they prefer to engage in fewer but beneficial contacts. The socio-emotional selectivity theory[49] suggests that social motives change as individuals become more aware of their mortality. Older adults place a lower value on information seeking and a higher value on emotional satisfaction; this often involves narrowing social interactions to intimate ties with whom they have more rewarding relationships and letting go of more distant relationships that are not emotionally rewarding.[49] Therefore, it is important to understand changes in the social networks of older adults and how older adults' social networks influence their health risk.

Among older adults, having a large and diverse set of social relationships is associated with a reduced risk of onset and progression of disability.[50–53] Similarly, greater social support in late life is protective against elevated blood pressure and cardiovascular dysfunction,[54,55] ischemic heart disease,[56] and cancer mortality.[57] Socially engaged and well-supported older adults are also less likely to experience cognitive decline[9,58,59] and dementia.[60,61] In contrast, individuals who are socially isolated have a 29% higher risk of mortality,[62] have twice the risk of Alzheimer's disease, and generally experience more rapid cognitive decline than individuals who are socially connected.[63,64] Overall, social networks are an essential component of healthy aging as they reduce the risk of multiple morbidities and premature mortality through provision of social support and opportunities for social engagement and exchange of information.[2,11]

Assessment and Measures of Social Networks

Despite this impressive body of evidence which shows that social networks are beneficial for health, the nature of older adults' social networks, changes in these networks over time, and how they influence health are still poorly understood. One reason might be that most previous

researchers relied on rather crude measures of social integration that only capture supportive social ties e.g., measures that encompass only one's spouse or partner, children, or other close relatives.[65] Others have used summary measures which require participants to make summary "global" characterizations of their social ties, such as the Social Network Index[30] which captures overall levels of affiliation through reports of participation in 12 types of social relationships. Although these measures are easy to administer in large-scale survey research, they fail to capture the multifaceted nature of social networks. More recently, in attempts to understand underlying mechanisms through which social networks protect against negative health outcomes, researchers have focused their efforts on identifying which specific characteristics of social networks are best predictors of health. In doing so, they have emphasized individual dimensions of social networks at the expense of others. Social network characteristics are broadly categorized into two dimensions – structural and functional – which operate through different pathways to affect health and wellbeing.[66]

Structural network characteristics

Structural network characteristics refer to the extent to which individuals are situated within social networks.[67] They include features such as network size (number of relationships), frequency of contact with network members, network diversity (number of different social roles such as family, friends, and neighbors), and spatial proximity of network members.[3] Network structure determines the type and quantity of resources available. For instance, having a large network offers several opportunities for social engagement and cognitively stimulating interactions that in turn enhance well-being. Similarly, having a diverse network offers ample opportunities to compensate for any losses in older adults' social networks as well as the

opportunity to call on a diverse set of resources in response to specific social, emotional, and health-related needs.[68]

Functional network characteristics

Functional characteristics of social networks reflect the specific purposes served by relationships and often refer to the various kinds of support exchanged with network ties including emotional support, instrumental support, and informational support.[69,70] Emotional support is related to the love and sympathy provided by intimate relationships.[71] Emotional support influences health through the promotion of self-efficacy and self-esteem that allow individuals to effectively cope with stressful situations. Instrumental support refers to help provided with tangible needs such as a ride to the hospital, getting groceries, or paying bills.[34] Informational support relates to the provision of relevant information and advice in response to specific needs.[34] Instrumental and informational types of support influence health by increasing access to material goods and resources and by creating opportunities to share norms around behaviors and by providing support for behavioral decisions. The measurement of network function was traditionally restricted to actual receipt or exchange of these various kinds of support. However, in the broader literature, opportunities for exchange of support or perceived availability of support are also considered functional resources.[72] The perception of availability of support and actual receipt of support are only moderately correlated and both appear to be equally important for health.[73] In this dissertation, we conceptualize network function to include both received and perceived social support, emotional closeness between network members, and subjective quality of relationships.[3,67]

Negative interactions: Social strain in relationships

Relationships vary in their positive and negative qualities - the downside of social relationships includes excessive demands and criticism, perceived isolation, and conflict.[34] Negative social interactions can have a more substantial impact on health and well-being than perceived support[74,75] and most often occur among network members that are more intimate ties.[34] Strain in social relationships has been associated with increased inflammation, increased psychological distress and depression, reduced sleep quality, poorer self-rated health, and changes in cortisol and cardiovascular health.[34,76,77] Research examining the relationship between social networks and health among older adults has largely ignored the health effects of negative social interactions.

In sum, much of the epidemiologic research to date has relied on a-dimensional indices of network structure or function, ignoring the fact that various aspects of social networks are interrelated and social network compositions are more complex than has been recognized previously. And so far, findings are inconsistent with regard to which network characteristics are the best predictors of health. Some studies have found stronger benefits of structural characteristics[78–81] whereas others have found functional characteristics to have more direct protective health effects.[82–84] Although examining isolated dimensions of social networks is convenient and informative, it is reasonable to assume that adding up individual network characteristics (e.g., network size) does not equate to the effect of being embedded in a network with a particular array of attributes (e.g., small network size with high diversity and high emotional support).

Theoretical Framework for Social Network Typology

As researchers grasp the complexity and heterotypic nature of social networks, initial efforts have been made to model social networks as multidimensional constructs using pattern centered approaches. General theories and empirical findings lend support to the notion that social networks of older adults are not homogeneous, and in fact, vary in their complexity. The Social Convoy Model[85,86] proposes that individuals are surrounded by a network of people, and the composition and quality of this network varies across individuals. Because gains, such as new friendships through marriage and job entry, and losses, such as discontinuation of contact with in-laws after divorce, in network members diverge among individuals there is great variability in older adults' social convoys. Empirically, we know that a range of social networks exist in late life due to differences in personal and family history such as marital status and number of children; social context such as culture and religion; and differences in physical and mental health that influence the capacity of older adults to develop new relationships and replace lost ones. For example, an older married woman might have a large network of members primarily consisting of family. In contrast, an older single woman with decreased mobility might have a small network as she is unable to participate in social activities, and a network consisting primarily of individuals who are able to offer caregiving support.

Network typologies offer an alternative way to represent and interpret the multifaceted empirical phenomena of social networks. Litwin and Shiovitz-Ezra describe network type as a "composite characterization of the interpersonal groupings in which individuals are embedded."[6] The development of social network typologies dates back to the early 1990s when Wenger derived five social network types among community-dwelling older adults in England and Wales, which later served as diagnostic criteria for gerontological social work practice.[87,88]

Subsequent studies have derived network types among older adults on the basis of varying criteria including dimensions of size,[89] network composition,[3–7] involvement in community groups,[5] social support, and relationship satisfaction.[3,89] The four main robust network types that have been identified across multiple settings include *diverse* (reflecting a variety of relationships across various roles), *family-focused* (network consisting primarily of relatives), *friend-focused* (network consisting primarily of friends), and r*estricted* (small network with few supportive relationships) types. Beyond these, different bases for the delineation of network types across studies have resulted in additional network types. For instance, Litwin et al (2006) identified two additional network types (*community-clan*, *neighbor*) using indicators of contact with neighbors and involvement in religious and other group activities.[5] Park et al (2013) identified three additional types (*unmarried/diverse*, *married*/co-*residence*, *unmarried*/*restricted*) using dimensions of marital status and co-residence.[7] In contrast, Ellwardt et al (2016) identified four completely unique network types among non-kin networks (*large-supportive*, *large-unsupportive*, *small-supportive*, *small-unsupportive*) using measures of network size, diversity, and support.[89]

These network types mainly reflect variations in the structure of social networks (e.g., marital status, network composition, and diversity)[5–7] with the exception of a few studies that additionally include characteristics of relationship function and quality.[3] Previous research shows that individuals in different types of networks vary in the quality of support received[3] and that individuals with a similar network structure can also vary in the amount of support they receive or in their satisfaction with that support.[3] Hence, there is a need to consider both structural and functional network characteristics simultaneously in the construction of social network types. Such a holistic approach can provide a fuller and more complex picture of the interpersonal

environment in late life, compared to isolated measures that reflect different individual aspects of one's social environment.

Linking Social Network Types to Health

Network types and mortality, emotional health, and health behaviors

Social network types have been examined in relation to mortality, emotional health, and health-related behaviors. A common finding is that *restricted* social network types, which indicate limited engagement in social relationships, are associated with higher mortality risk across various settings, and a higher risk of depressive symptoms and low subjective well-being.[5,90] In contrast, *diverse* social network types, which are characterized by access to various social resources, have been associated with a lower mortality risk and with better psychological wellbeing.

Among studies of mortality, Litwin & Shiovitz-Ezra (2006) found that older Israeli adults in the *diverse* and *friend-focused* network types had a lower risk of mortality compared to individuals belonging to *restricted* networks.[5] In a more recent cross-country survey, Santini et al (2015) observed that older adults in *restricted* social networks types had a significantly higher mortality risk compared to the *locally integrated* social network type.[90] Among studies of mental health, Fiori et al (2006) observed that depressive symptomology was highest for individuals in the *non-friends* and lowest for individuals in the *diverse* network.[91] Similarly, Park et al (2013) found that members of the *diverse* and *married/co-residence* network types had significantly lower levels of depressive symptoms compared to the *restricted* network types. Compared with a *restricted* network type, *diverse*, *friend-centered*, and *religious activity-centered* network types have also been associated with lower anxiety and greater happiness among older adults[6].

Additionally, social network types have been shown to predict the risk of alcohol abuse,[92] engagement in physical activity,[92] and utilization of health and social services.[93]

Initial evidence from these studies indicates that social network types can potentially be used as robust predictors of mental and behavioral health outcomes. However, the association between social network types and the physical health outcomes of disability, physical mobility, and cognitive function among older adults still remains poorly understood.

Network types and physical and cognitive function

Disability, physical mobility limitations, and cognitive decline are prevalent aging related conditions that lead to increased dependence among older adults and a diminished quality of life. As of 2017, over 10 million (22%) people aged 65 and older in the US were living with mobility difficulty, over 7 million (14%) had an independent living difficulty, and over 4 million (9%) were living with cognitive difficulty.[1] The prevalence of physical mobility limitations and cognitive decline has been shown to increase with age. In one population-based study in the US, the prevalence of mobility disability increased from 22% among women aged 70 years to 81% among those aged 90 years. Similarly, among men, the proportion disabled increased from 15% at age 70 to 57% at age 90.[94]

Preliminary evidence suggests that social network types may have a differential effect on physical functional health in old age. In a population of community-dwelling Israelis, Litwin (1998) observed that older adults in *diverse*, *friend*, and *neighbor* network types had, on average, a lower rate of disability in basic activities of daily living (ADLs); whereas, older adults in the *religious family* and *attenuated* networks had higher than average rates of disability.[95] Corroborating these findings, in a subsequent study Litwin (2003) found that older adults in *family* and *restricted* networks had a significantly higher degree of disability compared to other

network types[96] It remains unclear if social network types are also associated with changes in mobility over time in old age. Given the effect of network types on emotional and mental health outcomes, the study of social network types and their impact on cognitive function is an area of inquiry with considerable potential. However, to our knowledge, no study has examined the influence of network types on cognitive function.

Summary and Specific Aims

As discussed earlier, there is ample evidence for the beneficial effects of greater social embeddedness on functional and cognitive health. Larger social networks, more frequent social contact, greater diversity in social ties, and emotional support are independently related to reduced risk of cognitive decline, most likely through pathways of intellectual stimulation and enhancement of neural plasticity.[9,58,97,98] In a similar vein, larger networks, greater social interaction, and emotional support, have been shown to protect against difficulties in mobility and disability in activities of daily living.[51,52,99]

Despite extensive evidence of the beneficial effects of social networks on functional and cognitive health, little is known about the relation between social network types and these aging related outcomes. The goal of this dissertation is to move beyond simple indices and isolated indicators of social networks and examine the physical health of elderly in relation to network typologies. The relationship between social networks and health as captured by simple measures of size and support is likely not the same as that captured by network types. This is because network typologies capture systematic variation in multiple structural and functional elements of social networks and are therefore able to consider the complexity of one's interpersonal environment. It is likely that elderly in different network types will have different health risks and by examining typologies we can identify particular network types that are at a higher risk of

decline in physical health. Because not all social ties are equally close, equally supportive, or perform similar functions, individuals in one network type may be more or less susceptible to loss of network members or lack of stable support, depending on the composition of one's network. As a result, elderly in different network types may be more likely to present with certain types of health problems than others. Lastly, by investigating network typologies we may be able to identify certain network types that have completely different health benefits beyond just the benefits of having a larger or more supportive social network.

The specific aims and hypotheses of this dissertation are outlined below.

Specific aim 1

To identify distinct social network types among older Americans, considering a combination of structural and functional network characteristics, and to examine the prevalence and predictors of these network types in a nationally representative sample of older adults.

Sub aims

1. To identify and determine the prevalence of distinct types of social networks among older adults, characterized by variations in the network structure, social support, and social strain.
2. To assess the extent to which sociodemographic characteristics predict membership in each of the social network types. Characteristics of interest include age, sex, race and ethnicity, education, and income.
3. To examine differences in social network types by age cohort and in the prevalence rates of each network type between a younger and older cohort of adults aged 75 and over.

Specific aim 2

To examine the association of social network types identified in aim 1 with onset of activities of daily living (ADL) disability and changes in mobility in a nationally representative sample of older Americans.

Hypotheses

1. Individuals in social network types that represent larger, more diverse, and more supportive networks will have lower odds of experiencing ADL disability onset compared to individuals in network types representing smaller, less diverse, and less supportive networks.
2. Individuals in social network types that represent larger, more diverse, and more supportive networks will experience less decline in mobility compared to individuals in network types representing smaller, less diverse, and less supportive networks.

Specific aim 3

To determine whether the social network types identified in aim 1 are associated with onset of cognitive impairment in a nationally representative sample of older Americans.

Hypothesis

1. Individuals in social network types that represent larger, more diverse, and more supportive networks will have lower odds of experiencing cognitive impairment onset compared to individuals in network types representing smaller, less diverse, and less supportive networks.

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CHAPTER 2

Social Network Types of Older Americans: A Latent Class Approach Using Structural and Functional Network Characteristics

Introduction

Social networks are an essential component of healthy aging as they reduce the risk of multiple morbidities and premature mortality through provision of social support and opportunities for social engagement and exchange of information.[1,2] At the same time, social networks of older adults are sensitive to change due to loss of network members, and usually shrink over time as older adults become increasingly selective in who remains a part of their social network.[3] The nature of older adults' social networks and changes in these networks over time are still poorly understood. One reason might be that most previous research relied on summary measures that fail to capture the complexity of social networks.[4] Even among studies that characterized the social networks of older adults using more sophisticated measures, such as network typologies, the focus was on a single dimension, usually the structure, of social networks.[5–12] Since level of social support can vary across networks with a similar structure, it is important to take both the structural and functional dimensions of social networks into account. In the present study, we develop a network typology of older adults characterized by variations in the structure and function of social networks including a dimension of social strain. We determine the prevalence of the identified social network types in our sample and examine the distribution of these network types across socio-demographic subgroups of older adults.

Numerous studies have shown that particular characteristics of social networks are protective against a number of adverse health outcomes in old age. Social network characteristics are broadly categorized into two dimensions – structural and functional – which operate through different pathways to affect health and wellbeing.[13] Structural aspects refer to the extent to which individuals are situated within social networks.[14] They include features such as network size (number of relationships), frequency of contact with network members, network diversity (number of different social roles such as family, friends, and neighbors), and spatial proximity of network members.[15] Network structure determines the type and quantity of resources available. For instance, having a large network offers several opportunities for social engagement and cognitively stimulating interactions that in turn enhance well-being. Similarly, having a diverse network offers ample opportunities to compensate for any losses in older adults' social networks as well as the opportunity to call on a diverse set of resources in response to specific social, emotional, and health-related needs. A large and varied set of social relationships is associated with reduced risk of disability,[16,17] elevated blood pressure,[18] cardiovascular dysfunction,[19] and ischemic heart disease.[20]

Functional aspects of social networks reflect the specific purposes served by relationships. The measurement of network function was traditionally restricted to actual receipt or exchange of various kinds of support including emotional support, instrumental support, and informational support.[21,22] However, in the broader literature, opportunities for exchange of support or perceived availability of support are also considered functional resources.[23] In this study, we conceptualize network function to include received and perceived social support, emotional closeness between network members, and subjective quality of relationships.[14,15] Both received and perceived social support have beneficial effects for health. Well-supported older

adults are less likely to experience mental health problems such as depression and experience higher positive well-being.[24,25] High levels of social support reduce the likelihood of experiencing severe psychological distress in times of stressful events such as death of a family member or serious illness by buffering the effects of stress.[26–28] In addition to psychological well-being, social support positively influences physical health, longevity, and recovery from myocardial infarction, stroke, and hip fracture.[29–32] In contrast, those with low support have a poorer prognosis of coronary heart disease and are at an increased risk of cardiac and all-cause mortality.[33–35] In terms of more specific age-related health outcomes, there is some evidence that social support is associated with reduced risk of cognitive decline, dementia, and functional decline although findings for these outcomes have been mixed.[17,36–40]

There is strong evidence of the protective effect of social relationships on health in late life; however, this protective effect is threatened as social networks of older adults tend to shrink over time. The socioemotional selectivity theory asserts that as individuals age perceived limitations on time lead to a decline in the number of network members, particularly peripheral ones such as distant friends and acquaintances.[3] In addition to the active optimization of social networks by withdrawing from less satisfying relationships, social networks of older adults undergo turnover within a period of few years due to inevitable age-related life events such as onset of illness, retirement, and death of loved ones.[41–43]

There is large variability in the occurrence of the aforementioned age-related life events and therefore in integration into social networks across individuals, which results in considerable heterogeneity in the social networks of older adults. This heterogeneity has also informed general theories of social networks and their development trajectories. The social convoy model proposes that individuals are surrounded by a network of people (i.e., their social convoy), and

the composition and quality of this network varies across individuals.[44,45] Because gains, such as development of new relationships with in-laws and friends through marriage and job entry, and losses, such as discontinuation of contact with in-laws and friends after divorce, job exit, and relocation, in network members diverge among individuals there is great variability in older adults' social convoys. Empirically, we know that a range of social networks exist in late life due to differences in personal or family history such as marital status and number of children; social context such as culture and religion; and differences in physical and mental health that influence the capacity of older adults to develop new relationships and replace lost ones. For example, an older married woman might have a large network of members primarily consisting of family. In contrast, an older single woman with decreased mobility might have a small network as she is unable to participate in social activities, and a network consisting primarily of individuals who are able to offer caregiver support.

The nature of older adults' social networks and changes in these networks over time are still poorly understood, likely due at least in part to their heterogeneity and complexity. The existing literature has failed to capture the complexity of the social networks of older adults, as it relies primarily on summary and unidimensional measures of social networks. Summary measures require participants to make global characterizations of their social relationships, and do not capture specific aspects of social networks that may be more important than others. Unidimensional measures emphasize a single aspect of social networks at the expense of others e.g., only investigating the effect of the size of a network without consideration of the level of support or strain experienced in relationships. As a result, unidimensional measures fail to adequately capture the multidimensional nature of social networks.

An alternative method to characterize the different ways in which older adults integrate into their social networks is to take a pattern-centered approach, such as constructing a network typology, to identify network types, of older adults that exhibit similar patterns of network characteristics. In contrast to focusing on individual network aspects, identification of network types is an effective approach to examining the different combinations of network attributes that usually characterize social relationships. Currently, a uniform concept of network types of older adults does not exist in the literature on network typologies. The four main network types that have been identified across multiple settings include: *diverse network*, reflecting a variety of relationships across various roles; *family-focused network*, consisting primarily of relatives; *friend-focused network*, consisting primarily of friends; and *restricted network*, a small network with few supportive relationships.[5,9,11,15,21] Beyond these, other studies in different populations have found additional network types. For instance, Litwin and Shiowitz-Ezra (2006) using data from Israel identified two additional network types, *community-clan* and *neighbor* using dimensions of contact with neighbors and involvement in religious and other group activities. Park et al. (2013) identified three additional types, *unmarried/diverse*, *married/co-residence*, and *unmarried/restricted* using dimensions of marital status and co-residence among community-dwelling older Korean immigrants. Despite some consensus in the network types among studies that primarily examined structural characteristics, such as network size, relationship type, marital status, and co-habitation, functional characteristics have seldom been addressed. There are a few exceptions to the studies that have predominantly focused on structural aspects. Studies by Fiori and colleagues, using data from the early 1990s from Germany, Japan, and the US, included characteristics of network function and relationship satisfaction.[15,21] Through cluster analysis, the researchers identified six network types with support as a distinctive dimension. A more recent

study by Ellwardt, Aartsen, and van Tilburg (2016) included measures of social support in addition to network size and diversity; they identified four unique network types among non-kin networks of older adults from the Longitudinal Aging Study Amsterdam including *large-supportive*, *large-unsupportive*, *small-supportive*, and *small-unsupportive* network types.

To our knowledge, network typologies using both structural and functional components have not been developed using a recent population sample from the United States. Additionally, the existing work on typologies has rarely incorporated information on strained or negative social relations. Relationships vary in their positive and negative qualities, with some evidence suggesting that strain in relationships, such as excessive demands and criticism, have a more substantial impact on health and well-being than perceived support.[46,47] Experiencing strain in social relationships has been associated with increased psychological distress and depression, physical impairment, reduced sleep quality, poorer self-rated health, and greater functional limitations.[48–53]

We propose that structural and functional network characteristics should be considered simultaneously in the construction of social network types in order to gain a fuller and more complex picture of the interpersonal environment in late life. The aim of the present study is twofold: first, to identify and determine the prevalence of distinct classes of social networks, characterized by variations in the structure and function, including social support and social strain, of social networks; and second, to assess the extent to which sociodemographic characteristics predict membership in each of the network types.

Methods

Sample and data collection

Data for the study came from the National Social Life, Health, and Aging Project (NSHAP). NSHAP is a longitudinal, population-based study of health and social factors, designed to understand the well-being of community-dwelling older Americans. Participants aged 57 to 85 years at baseline were recruited using a complex, multi-stage area probability sample in 2005-2006 with oversampling of African Americans, Latinos, men, and the oldest old (75-84 years at the time of screening). Our analysis used data from the 3,005 participants who completed interviews during the first wave – a weighted response rate of 75.5%. Data collection consisted of a face-to-face interview including a brief self-administered questionnaire, in-home collection of biomeasures, and a leave-behind questionnaire.

Operationalization of network types

NSHAP collected egocentric social network and social support data from all respondents during the in-home interview and leave-behind questionnaire. Respondents were asked the following question: "From time to time, most people discuss things that are important to them with others. For example, these may include good or bad things that happen to you, problems you are having, or important concerns you may have. Looking back over the last 12 months, who are the people with whom you most often discussed things that were important to you?" This item is a well-established name generator for network studies in sociology and has been used to generate important insights about influential social contacts in adults' lives. For each network member identified by the respondent, data were collected on relationship type, gender, age, frequency of contact, co-habiting status, emotional closeness, and the likelihood of the respondent talking to the network member about health matters. In addition to identifying

respondents' confidants and their characteristics, NSHAP also captured exchange of support from potentially important relationship types including partner, family, and friends.

Observed variables. Network types were derived through application of latent class analysis using observed variables that reflect both structural and functional components of the social network. Nine observed variables were used to derive the latent classes. These included items representing structural aspects: network size, diversity, and frequency of contact; items representing functional aspects: involvement of network members in health discussions, emotional closeness, and social support from partner, family, and friends; and an item indicating experience of strain in relationship with partner.

Network size. Network size was determined by summing the number of contacts reported by a respondent across three broad relationship types (partner, family, friends) using an ordinal scale: *none* (0), *one* (1), *two to three* (2), *four to nine* (3), *ten to twenty* (4), *and more than twenty* (5). The overall size of the network was then recoded into three categories (1=*small*, 2=*medium*, 3=*large*) using tertiles.

Network diversity. Network diversity was assessed by counting the number of different relationship roles in an individual's confidant network. Respondents identified their relationship to each confidant using 17 options consisting of five broad relationship roles: *spouse/partner* (spouse, ex-spouse, romantic or sexual partner), *family* (parent, parent in-law, child, step-child, brother or sister, other relative of yours, other in-law), *friends*, *neighbors*, *other* (co-worker or boss; minister, priest, or other clergy; psychiatrist, psychologist, counselor, or therapist; caseworker or social worker; housekeeper or home health care provider). The diversity variable captured the extent to which an individual's network was diverse on a scale of 0-17. The final

score for network diversity was recoded into three categories (1=*low*, 2=*medium*, 3=*high*) using tertiles.

Frequency of contact. For each confidant, respondents were asked how often they talked to them, including face-to-face, via telephone and email. Potential responses included: *less than once a year* (1), *once a year* (2), *a couple times a year* (3), *once a month* (4), *once every two weeks* (5), *once a week* (6), *several times a week* (7), *every day* (8). Responses were scored according to the approximate number of times per year the respondent interacted with each confidant (e.g., "once a month" = 12; "every day" = 365) and then summed across all network members to obtain a measure of overall volume of contact. The overall volume of contact was then recoded into three categories (1=*low*, 2=*medium*, 3=*high*) using tertiles.

Involvement of network members in health-related discussions. Respondents were asked how likely they were to talk to each of the confidants about a health problem they were concerned about or if they needed to make an important decision about their own medical treatment. Responses on the ordinal scale ranged from 1 (*not likely*) to 3 (*very likely*). Responses were summed across all the network members identified by the participant and then recoded into three categories (1=*low*, 2=*medium*, 3=*hig*h) using tertiles.

Emotional closeness. Emotional closeness was measured by the question: "How close do you feel is your relationship with [name]?" Responses on the ordinal scale ranged from 1 (*not very close*) to 4 (*extremely close*). Responses were summed across all the confidants identified by the participant and then recoded into three categories (1=*low*, 2=*medium* 3=*hig*h) using tertiles.

Social support. For three separate relationship types (partner, family, and friends) respondents were asked: (a) "How often can you open up to [partner/ members of your family/

friends] if you need to talk about your worries? Would you say *hardly ever* (1), *some of the time* (2), or *often* (3)?" and (b) "How often can you rely on [partner/ members of your family/ friends] for help if you have a problem? Would you say *hardly ever* (1), *some of the time* (2), or *often* (3)?" Responses to these two questions were combined into a single social support variable for each of the relationship types, resulting in three categorical latent class observed variables. For family and friends, the support variables were coded as follows: (1) *low*, (2) *medium*, (3) *high support*. For partner, the support variable was a combination of the presence of a partner (i.e., whether one has a partner or not) and level of support received (low versus high support): (1) *partner absent*, (2) *partner present, low support*, (3) *partner present, high support*.

Social strain. Social strain in relationship with a partner was assessed by asking respondents: (a) "How often does partner make too many demands on you?" and (b) "How often does partner criticize you?" The response categories were *hardly ever* (1), *some of the time* (2), or *often* (3). Similar to the social support variable, social strain from partner was a combination of the presence of a partner and the level of strain experienced (low versus high strain): (1) *partner absent,* (2) *partner present, low strain,* (3) *partner present, high strain.* NSHAP included additional questions on social strain experienced in relationships with family members and friends; however, the responses showed very little variation and did not contribute any unique information to typology characterization. As a result, social strain in relationships with family and friends was not included in the construction of the latent network types.

Covariates

In order to identify sociodemographic predictors of network class membership, we included a number of covariates measured at baseline, including: age (in years), sex (male, female), race and ethnicity (White; Black; Hispanic, non-Black; Other), educational attainment

(less than high school; high school diploma or equivalent; vocational, some college, or associate's degree; bachelor's degree or higher), and annual household income in previous year (<$25,000; $25,000 - <$50,000; $50,000-$100,000; >$100,000).

Statistical analysis

Identifying distinct classes of social networks. We performed a latent class analysis (LCA) where respondents with similar network patterns were grouped into classes, such that each class represented a distinct social network type. The latent classes were treated as mutually exclusive and exhaustive. The social network types were derived using unweighted latent class models with 9 polytomous observed variables, or items, based on the assumption that both the latent network type and the observed variables are categorical. A brief description and summary statistics of the latent class observed variables are presented in Table 2.1. Starting from a single-class model we stepwise increased the number of classes until the model fit leveled off and we obtained conceptually distinct network types that were meaningful. Model fit was determined using information criteria, including the Akaike information criterion (AIC), Bayesian information criterion (BIC), adjusted Bayesian information criterion (aBIC), and entropy, which is a measure of latent class separation. The final model with the optimal number of classes was selected on the basis of a combination of model fit, parsimony, and interpretability. Network type labels were assigned to latent classes based on the overall pattern and distribution of the item-response probabilities for that class.

Sociodemographic predictors of class membership. To identify predictors of network type membership, we used a latent class multinomial logistic regression analysis in which the dependent variable was the latent class assignment, and the explanatory variables were the socio-demographic covariates. First, for each of the covariates, a separate latent class model was

estimated, and the significance of the single covariates was determined by means of a log-likelihood test comparing the baseline model without the covariate to the corresponding model that included the covariate. Second, to test whether each covariate was significant over and above the effect of the other covariates, we compared model fit of the model that included all of the covariates against that of a corresponding model that included all of the covariates except the particular covariate being tested. Third, a final model with all significant covariates was computed to estimate the size of each effect. Age was modeled as a continuous covariate and the remaining categorical covariates were coded as dummy variables.

All statistical analyses accounted for stratification and clustering of the NSHAP sample design, unequal probabilities of selection, and nonresponse to calculate weighted, nationally representative population estimates and "robust" or "sandwich" standard errors. Analyses were conducted in SAS 9.4 using PROC LCA. Missing data on the latent class and latent class observed variables are permitted in PROC LCA and are assumed to be missing at random. However, missing data on covariates is not allowed, and 285 records with missing data on covariates in the latent class multinomial logistic regression analysis were excluded from the analysis.

Results

Baseline characteristics

Tables 2.2A and 2B present the baseline summary statistics for the sociodemographic and social network variables. The sample (N=3,005) consisted of approximately 52% women and 48% men, with an average age of 68 years (SD= 9 years). The majority of the sample identified as White (80.7%), followed by Black (10.0%), Hispanic non-Black (6.8%), and other (2.5%). Most of the participants had at least a high school or equivalent education (81.5%) and previous

annual household income of $25,000 or more (71.1%). About one third of the participants were currently employed (34.9%). More than half of the participants were married (66.4%), followed by 16.9% widowed, 11.3% divorced or separated, 3.3% never married, and 2.2% living with a partner.

Latent network types

We hypothesized that different types of latent social networks can be delineated based on variations in the number and diversity of relationships, social support, and social strain. The series of unconditional latent class models revealed five classes, as the model fit improved until the five-class model and leveled off thereafter. Additional classes became substantially similar in their interpretation to those already estimated, therefore we disregarded solutions with more classes in favor of non-redundancy and parsimony. Model fit, determined using AIC, BIC, and aBIC, was slightly better for the five-class model compared to all other models and entropy was similar between the four- and five-class solutions. The results of the five-class solution were also more interpretable compared to the four-class solution so we continued with estimates from the five-class LCA model. Fit statistics for models with three to five classes are presented in the Supplementary Table SM 2.1.

Based on the five-class solution, we assigned respondents to the latent class corresponding with their maximum posterior probability of membership. Table 2.3 provides an overview of the five latent social network types, their prevalence in the NSHAP sample and the distribution of the observed network variables (i.e., item-response probabilities) across classes. Our interpretation of the five social network types revealed three major dimensions: partner presence; size and diversity of relations; and level of social support. The first dimension represented the presence versus absence of a partner and quality of relationship with the partner.

The second dimension described the network size, variation in role relations, and frequency of contact with network members. Larger and more diverse networks featured many relations, multiple relationship roles, and frequent contact with network members. In contrast, smaller and less diverse networks featured fewer relations, low dispersion of relationship roles, and infrequent contact with network members. The third dimension delineated the degree to which an individual relied on their network members for support: respondents in supportive networks were more likely to discuss health problems with their contacts, to feel emotionally close to them, and to be able to rely on and open up to their contacts often; whereas respondents in unsupportive networks were less likely to discuss health problems with their network members, did not feel particularly emotionally close to them, and did not feel comfortable relying on or opening up to their network members often.

The most prevalent network type in our study was the *diverse, supportive network with partner* (31%) followed by the *average network with partner* (27%). The *partner-centered network* (15%) and the *large, supportive network without partner* (16%) were less prevalent. The network type with the lowest membership was the *restricted, family-centered network without partner* (11%).

Diverse, supportive network with partner (31%). The first network type, which was also the most prevalent, was characterized by an extensive number of relationships and high diversity in network relations. Respondents reported very frequent contact with network members, a higher level of emotional closeness, and a higher likelihood of discussing health problems with confidants. Older adults in this network reported receiving high levels of support from all three major relationship types: partner, family, and friends. Compared to other network types, a smaller proportion of individuals in this type reported experiencing high strain in the

partner relationship (26%). Altogether, this network type was the largest, most varied and contained much social support, thereby being highly functional and complex in structure.

Average network with partner (27%). The second type consisted of individuals that reported medium or average levels on the majority of observed variables. Most respondents in this type reported medium levels of variation in relationship roles as well as medium levels of emotional closeness and likelihood of discussing health problems with members in their network. Although older adults in this network were more likely to experience high rather than low levels of support from partner and family, they reported experiencing medium levels of support from friends. Thus, individuals in this network type maybe described as having an average network.

Partner-centered network (15%). The third type was characterized by low diversity in types of relationships and less frequent contact with network members. Older adults in this network reported a lower likelihood of discussing health problems with their confidants and did not feel emotionally close to members in their network. A distinctive feature of this type was the high levels of support received from partner compared to other relationships. Although on average older adults in our sample were more likely to report low rather than high levels of strain in their relationship with their partner, compared to other classes a higher proportion of individuals in this type reported experiencing high strain in the partner relationship. Altogether, this network type was restricted with most reliance on partner for support.

Large, supportive network without partner (16%). The fourth type included individuals that had a large although not particularly diverse network. Older adults in this type felt emotionally close to their network members and were highly likely to discuss health problems with them. Respondents in this network did not have a partner and relied heavily on

their family and friends for support. Overall, this network type was large and well-functioning, but not diverse.

Restricted, family-centered network without partner (11%). The fifth type, and smallest in prevalence, resembled the opposite of the previous type to a great extent. Although individuals in both types did not have a partner, those in the *restricted, family-centered network without partner* had very little variation in relationship roles and infrequent contact with network members. Older adults in this network were unlikely to discuss health problems with their confidants and did not feel emotionally close to them. A distinctive feature of this type was the increased reliance on family, but not friends, for support. In sum, this network was restricted with family as the main source of support.

Altogether these results confirmed our hypothesis that several distinct types of social networks can be empirically distinguished among older adults. These types appeared to differ meaningfully in the presence versus absence of partner, number and diversity of relationship roles, as well as the amount of perceived social support.

Sociodemographic correlates of social network types

Age, sex, race, education and income emerged as important predictors of membership in the latent social network types. Table 2.4 shows the odds ratios and corresponding 95% confidence intervals for each of the sociodemographic covariates. A one-year increase in age was associated with marginally increased odds of being in the *large, supportive network without partner* (OR=1.03; 95% CI: 1.01, 1.04) and the *restricted, family-centered network without partner* (OR=1.04; 95% CI: 1.02, 1.05) relative to the *average network with partner* (reference class). Similarly, women had higher odds of being in a network type with no partner (*large, supportive network without partner* and *restricted, family-centered network without partner*)

compared to the reference class and lower odds of being in the *partner-centered network*. Blacks compared to Whites had lower odds of being in the *diverse, supportive network with partner* (OR=0.61; 95% CI: 0.44, 0.85) relative to the reference class. Hispanics compared to Whites had higher odds of being in the *partner-centered network* (OR=1.55; 95% CI: 1.15, 2.09) and lower odds of being in one of the supportive network types (*diverse, supportive network with partner* and *large, supportive network without partner*) relative to the reference class. In general, those with less than a bachelor's education had higher odds of being in the *partner-centered network* and lower odds of being in the *large-supportive network without partner* compared to those who had a bachelor's degree or more. Individuals in all three income categories (less than $100,000) had higher odds of being in a network type with no partner (*large, supportive network without partner* and *restricted, family-centered network without partner*) compared to those with an annual household income of $100,000 or more. In results not shown, we found that employment status and number of chronic illnesses were not associated with network type membership after controlling for age, sex, education, and income.

Discussion

The objectives of this study were to determine the latent class structure that captures the heterogeneity in social networks of older adults, to estimate the prevalence of these latent network types in this population, and to identify sociodemographic covariates that are predictive of membership in the latent network types. Using nine different characteristics of social networks representing the structure, function, and quality of relationships we identified five distinct social network types: *partner-centered network*; *diverse, supportive network with partner*; *average network with partner*; *large, supportive network without partner*; and *restricted, family-centered*

network without partner. Membership in these social network types varied by age, sex, race, education, and income.

The network types that emerged in the NSHAP sample correspond broadly to the four network types commonly found in the literature: *diverse*, *friend-focused*, *family-focused*, and *restricted.*[5,8,10,21] With the addition of functional characteristics and variables that capture the quality of relationships, we were able to identify five instead of four network types typically represented by structural characteristics alone. Compared to previous studies, we identified two, instead of one, 'diverse' network types that differed in the presence versus absence of partner; one restricted network type that was also family-focused; and no friend-focused network type. Similar to Ellwardt et al. (2016) who included a measure of social support, we found perceived support to be an important dimension of social networks with two network types delineated on the basis of social support (*diverse, supportive network with partner* and *large, supportive network without partner*).

Partner status proved to be a defining feature of the social network typology. Unlike the commonly identified network types in the literature, all five network types in our sample had the presence versus absence of a partner as an important dimension, leading us to identify two additional network types that do not correspond to the common network types: *large, supportive network without partner*; and *partner-centered network*. Partner status is an important predictor of health because married individuals and those living with a partner generally have better health and survival outcomes in old age compared to those without a partner.[54] Relationship with a spouse or partner is fundamentally different from other relationships as it often involves cohabitation which is not an essential feature of other relationships. Partner status also influences what the rest of one's network looks like such that individuals with a partner often have access to

more resources through in-laws and friends of the partner. Partners also provide higher levels of various kinds of support including material support, care, reassurance, and emotional closeness in times of illness. At the same time, being in an unhappy or stressful partnership can be particularly detrimental for one's well-being and has been shown to increase the risk of premature mortality.[55,56] Given the significance of the partner relationship, it is not surprising that presence versus absence of a partner emerged as an important dimension of network type in our sample.

In addition to social strain experienced in the partner relationship, we also had data on negative interactions with friends and family. However, contrary to our expectation, social strain experienced in relationship with family and friends did not emerge as a discriminating characteristic of network types and was therefore removed from the LCA model. In general, assessing the quality of social relations using indicators of 'makes too many demands' and 'criticizes often' presents difficulties as prevailing social norms in this generation of older adults may lead to an underreporting of negative social interactions. Previous studies have shown that older adults are more likely to report interpersonal tensions with spouses than with other family members such as children.[57] It is also possible that older adults experience fewer negative social interactions or are better able to cope with negative social situations than younger adults. According to socioemotional selectivity theory, older adults attempt to optimize the gains from social relationships by reducing contact in relationships that are negative or dissatisfying, particularly as the time horizon in life shortens.[3] It is easier to withdraw from family and friends who make excessive demands and are critical than it is to withdraw from one's partner. This in turn might explain why we observed variation in strain in the partner relationship but not in those with friends and family members. One would still expect there to be some social strain

experienced with relationships that are not as easily abandoned, such as with immediate family members. The effect of social strain on older adults' access to resources like support deserves closer scrutiny. Future studies should use more specific questions on interactions with individual family ties including adult children, grandchildren, and other family member caregivers, rather than questions about interactions with one's family in general, to better capture the social strain experienced in familial relations and its consequences for well-being.

Consistent with previous research on social network types based on structural network features, less educated individuals and Blacks had a low probability of having a highly diverse network.[5,8] Women and older adults were more likely to be in networks without a partner which may represent the fact that women often outlive men and older adults generally have a higher likelihood of losing their partner to death, divorce, or separation. Those with lower income were also more likely to be in a network type without a partner. Previous studies have established that low-income individuals are at a higher risk of all-cause mortality.[58] Therefore, it is likely that in partnerships with a lower household income, the likelihood of a partner dying would be higher compared to partnerships with a higher income. Individuals with lower income are also more likely to never marry.[59] This finding could also be driven by the fact that loss of a partner would result in a lower household income. Taken together, these findings suggest that women, older adults, Blacks, and those with lower socioeconomic status are at an added disadvantage; they are more likely to be in a restricted network type and to not have a partner and therefore, have fewer potential resources and a lower level of support available.

This study has expanded the social relations of older adults and network typology literature in a number of ways. First, it takes a multidimensional approach by including all aspects of social relations in the classification of network types allowing for a more nuanced

assessment of older adults' social networks than has been achieved by previous research. For instance, we would expect individuals in diverse networks to receive ample support from their network members and to be fairly satisfied with their network relationships. However, our findings suggest that structure and function do not always correlate, i.e. individuals with a similar network structure can vary in the amount of support they receive and in their satisfaction with that support. Second, it considers the influence of strain in social relationships as an important network feature, which has largely been ignored in earlier network typology research. As noted previously, negative social interactions with close network members can have adverse consequences for health and well-being.[49,50,53] In our study, individuals generally tended to report low levels of social strain with their partner although there was some variation across the five network types in the proportion of older adults reporting social strain with their partner.

Third, the study uses data from NSHAP which allowed us to capture the complexity of social networks by including aspects of not just size and diversity but also social support and strain. NSHAP data included several specific measures of support such as emotional closeness, being able to open up to and rely on social contacts, and being able to discuss matters of health with network members. NSHAP also allowed us to capture specific aspects of social strain including excessive demands and criticism from network members. In addition to having detailed data on social networks, NSHAP has the advantage of a large sample size that is representative of the entire older adult population in the United States.

Another strength of this study was the use of LCA to derive network types – this is in contrast to the various clustering procedures, such as k-means or hierarchical clustering, employed in previous research.[6,9] Unlike cluster analysis, LCA is based upon a statistical model, therefore, maximum likelihood estimates can be used to classify respondents based upon their

posterior probability of class membership.[60] Assigning a probability to class membership in LCA, as opposed to a weight of 0 or 1 as in K-means clustering, prevents biasing the estimated class-specific means.[61] In addition, various diagnostics are available in LCA to establish the ideal number of classes whereas the K-means procedure provides no such assistance in determining the number of classes.[60,61] Finally, LCA allows inclusion of covariates to predict individuals' latent class membership and the prevalence of each network type in the population.[62]

Some limitations of the present study should also be acknowledged. Although comprehensive data on various measures are available in NSHAP, the social network data are egocentric and collected through self-report. Although NSHAP excluded respondents with a history of dementia, social network data are measured from the perspective of the 'ego' (i.e., respondent) and may therefore be subject to some degree of unreliable recall and social desirability bias.[63] Unlike data based on observation, data collection based on recall may be better for understanding participants' perception of the closeness and support in social relationships.[63] Research has shown that perceived support is an equally strong, if not stronger, predictor of well-being than received support.[64] Additionally, since we did not utilize data on ties between all members of a network we were unable to capture the complex socio-centric structures in which individuals are embedded. Future studies should go beyond the ego-centered approach employed in this study by taking a socio-centric or whole network approach and by treating social networks as systems of interacting individuals to gain additional information about older adults' social networks.

Awareness of the existence of network types can elucidate the varied interpersonal environments in which older adults are embedded and how these environments can in turn affect their health. Network types can be utilized to identify the kinds of available resources, such as

informal caregiving that older adults may call upon during times of serious illness, hospitalizations, and other difficulties in daily life. This network approach can also prove useful in identifying older adults that are at an increased risk of becoming socially isolated, such as those in restricted networks or networks without a partner. Socially isolated individuals generally lack sufficient support necessary to function independently in their community and are also at a higher risk of early mortality and adverse health outcomes.[65] By identifying socially isolated individuals and those lacking sufficient support, we can offer targeted opportunities for social engagement through participation in educational, social, and physical activity programs, thereby improving the emotional well-being and quality of life of older adults.

This study provides evidence of the heterogeneity of older adults' social networks and highlights the often-overlooked fact that social networks of older adults are multidimensional. By taking a pattern-centered approach that simultaneously considers structural, functional, and qualitative social network variables, the present study offers a more nuanced view of individuals' social relationships in the form of network types. The social network types identified in this study may have implications for understanding the determinants of aging related outcomes and could inform interventions that increase the amounts of available social support and reduce social isolation among older adults.

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Tables

Table 2.1 Description of Observed Latent Class (Indicator) Variables in National Social Life Health and Aging Project (NSHAP)

Structural characteristics	**Interview questions**
Network size	1. Other than [partner], how many family members or relatives do you have whom you feel close to? 2. About how many friends would you say that you have?
Network diversity	1. Which of the following best describes [name]'s relationship to you? (1) *spouse,* (2) *ex-spouse,* (3) *romantic/sexual partner,* (4) *parent,* (5) *parent-in-law,* (6) *child,* (7) *step-child,* (8) *brother or sister,* (9) *other relative of yours,* (10) *other in-law,* (11) *friend,* (12) *neighbor,* (13) *co-worker or boss,* (14) *minister, priest, or orther clergy,* (15) *psychiatrist, psychologist, counselor, or therapist,* (16) *caseworker/social worker,* (17) *housekeeper/home health care provider,* (18) *other*
Frequency of contact	1. How often do you talk to this person? (1) *less than once a year* , (2) *once a year,* (3) *a couple times a year,* (4) *once a month,* (5) *once every two weeks,* (6) *once a week,* (7) *several times a week,* (8) *everyday*
Functional characteristics	
Involvement of network members in health related discussions	1. Suppose you had a health problem that you were concerned about, or needed to make an important decision about your own medical treatment. How likely is it that you would talk with [name] about this: would you say (1) *not likely* , (2) *somewhat likely* , or (3) *very likely* ?
Emotional closeness	1. How close do you feel is your relationship with [name]? (1) *not very close,* (2) *somewhat close,* (3) *very close,* (4) *extremely close*
Partner support	1. How often can you open up to [name] if you need to talk about your worries? Would you say (1) *hardly ever* , (2) *some of the time* , or (3) *often?* 2. How often can you rely on [name] for help if you have a problem? Would you say (1) *hardly ever* , (2) *some of the time* , or (3) *often* ?
Family support	1. How often can you open up to members of your family if you need to talk about your worries? Would you say (1) *hardly ever* , (2) *some of the time* , or (3) *often* ? 2. How often can you rely on them for help if you have a problem? Would you say (1) *hardly ever* , (2) *some of the time* , or (3) *often* ?
Friends support	1. How often can you open up to your friends if you need to talk about your worries? Would you say (1) *hardly ever* , (2) *some of the time* , or (3) *often* ? 2. How often can you rely on them for help if you have a problem? Would you say (1) *hardly ever* , (2) *some of the time* , or (3) *often* ?
Partner strain	1. How often does [name] make too many demands on you? Would you say (1) *hardly ever* , (2) *some of the time* , or (3) *often* ? 2. How often does [name] criticize you? Would you say (1) *hardly ever* , (2) *some of the time* , or (3) *often* ?

Table 2.2A Weighted Sociodemographic Characteristics of the Sample at Wave 1 (N=3,005)

Sociodemographic characteristics	% (Mean)	N (S.D.)	Sum
Age	68.02	9	3005
Gender			
Male	48.47	1457	
Female	51.53	1548	3005
Education			
Less than high school	18.53	557	
High school or equivalent	26.95	810	
Vocational certificate / some college or associate's degree	30.02	902	
Bachelors or more	24.5	736	3005
Household income in the previous year			
Less than $25,000	28.88	787	
$25,000 - $49,999	30.72	837	
$50,000 - $99,999	26.28	716	
$100,000 or more	14.13	385	2725
Currently working			
Yes	34.97	1050	
No	65.03	1953	3003
Race/Ethnicity			
White	80.67	2416	
Black	10.02	300	
Hispanic, non-Black	6.84	205	
Other	2.47	74	2995
Marital Status			
Married	66.36	1994	
Living with a partner	2.15	65	
Separated	1.04	31	
Divorced	10.3	310	
Widowed	16.85	506	
Never married	3.29	99	3005

*N does not sum to 3,005 and percentages do not add up to 100% because only participants without missing data were considered for each variable.

Note. Percentages and N are presented for categorical variables and Means and Standard Deviations are presented for age (continuous variable).

Table 2.2B Weighted Social Network Characteristics of the Sample at Wave 1

Structural social network variables	% (Mean)	N (S.D.)	Sum
Network size			
Small (*0-<9*)	16.87	479	
Medium (*9-<22*)	38.91	1105	
Large (*22-42*)	44.23	1256	2840
Network diversity (*number of different relationship roles*)			
Low (*0-<2*)	32.93	985	
Medium (*2-<4*)	35.97	1076	
High (*4-6*)	31.09	930	2991
Volume of contact (*number of times contacted ties in a year*)			
Low (*0-<625.5 times*)	32.12	960	
Medium (*625.5-<990.5 times*)	33.79	1010	
High (*990.5-2190 times*)	34.09	1019	2989
Functional social network variables			
Involvement of network members in health related discussions			
Low	26.05	779	
Medium	29.30	876	
High	44.65	1335	2990
Emotional closeness			
Low	26.34	785	
Medium	32.05	955	
High	41.61	1240	2980
Social support			
Level of partner support			
No partner	26.89	804	
Low support	20.60	616	
High support	52.51	1570	2990
Level of family support			
Low	5.68	160	
Medium	27.30	769	
High	67.02	1888	2817
Level of friend support			
Low	9.32	255	
Medium	47.68	1305	
High	43.00	1177	2737
Social strain			
Level of strain in relationship with partner			
No partner	26.89	804	
Low level of social strain	51.14	1529	
High level of social strain	21.97	657	2990

*N does not sum to 3,005 and percentages do not add up to 100% because only participants without missing data are considered for each variable

Note. Percentages and N are presented for categorical variables and Means and Standard Deviations are presented for age (continuous variable).

Table 2.3 Social Network Type Prevalence and Item-Response Probabilities for the 5-class Latent Class Analysis Model (N=3,005)

Latent network types	Diverse, supportive network with partner	Average network with partner	Partner-centered network	Large, supportive network without partner	Restrcited, family-centered network without partner
Latent class prevalences	0.32	0.27	0.15	0.16	0.11
Item-response probabilities					
Network size					
Small	0.03	0.19	0.30	0.11	0.41
Medium	0.36	0.47	0.41	0.33	0.34
Large	**0.61**	0.35	0.28	**0.56**	0.25
Network diversity					
Low	0.05	0.18	**0.76**	0.35	**0.84**
Medium	0.31	**0.57**	0.18	0.43	0.15
High	**0.64**	0.25	0.06	0.22	0.02
Frequency of contact					
Low	0.10	0.24	**0.75**	0.22	**0.72**
Medium	0.29	0.49	0.23	0.32	0.27
High	**0.61**	0.27	0.02	0.46	0.01
Involvement of network members in health related discussions					
Low	0.00	0.12	**0.94**	0.01	**0.76**
Medium	0.07	**0.69**	0.06	0.35	0.24
High	**0.93**	0.20	0.00	**0.64**	0.00
Emotional closeness					
Low	0.00	0.09	**0.99**	0.01	**0.82**
Medium	0.07	**0.80**	0.01	0.40	0.18
High	**0.93**	0.12	0.00	**0.59**	0.00
Partner support					
No partner	0.00	0.00	0.00	1.00	1.00
Partner - low support	0.22	0.33	0.34	0.00	0.00
Partner - high support	**0.78**	**0.67**	**0.66**	0.00	0.00
Family support					
Low	0.01	0.05	0.15	0.02	0.14
Medium	0.18	0.31	**0.50**	0.18	0.34
High	**0.81**	**0.64**	0.39	**0.80**	**0.52**
Friends support					
Low	0.03	0.12	0.18	0.04	0.16
Medium	0.39	**0.56**	**0.58**	0.41	0.49
High	**0.57**	0.32	0.23	**0.56**	0.35
Partner strain					
No partner	0.00	0.00	0.00	1.00	1.00
Partner - low strain	**0.74**	**0.67**	**0.65**	0.00	0.00
Partner - high strain	0.26	0.33	0.35	0.00	0.00

Note. Probabilities greater than or equal to 0.50 are printed in bold.

Table 2.4 Sociodemographic Predictors of Membership in Latent Classes of Social Network Types (N=2,720)

	Diverse, supportive network with partner	Average network with partner	Partner-centered network	Large, supportive network without partner	Restrcited, family-centered network without partner
	OR (95% CI)		OR (95% CI)	OR (95% CI)	OR (95% CI)
Age	0.99 (0.97, 1.00)	ref	1.00 (0.99, 1.01)	**1.03 (1.01, 1.04)**	**1.04 (1.02, 1.05)**
Gender *(ref: male)*	**2.00 (1.59, 2.52)**	ref	**0.31 (0.24, 0.39)**	**5.50 (4.39, 6.90)**	**2.31 (1.82, 2.93)**
Race *(ref: White)*					
Black	**0.61 (0.44, 0.85)**	ref	0.69 (0.47, 1.00)	0.91 (0.69, 1.19)	0.95 (0.68, 1.34)
Hispanic	**0.48 (0.33, 0.68)**	ref	**1.55 (1.15, 2.09)**	**0.39 (0.27, 0.56)**	0.93 (0.67, 1.30)
Other	0.83 (0.54, 1.26)	ref	1.08 (0.65, 1.79)	1.34 (0.83, 2.16)	**2.53 (1.40, 4.57)**
Education *(ref: Bachelor's or more)*					
Less than high school	0.86 (0.63, 1.16)	ref	**1.94 (1.34, 2.80)**	**0.55 (0.41, 0.75)**	0.97 (0.64, 1.47)
High school or equivalent	**0.72 (0.57, 0.91)**	ref	**1.55 (1.06, 2.27)**	**0.52 (0.39, 0.71)**	0.82 (0.55, 1.22)
Vocational, some college, or associate's	0.88 (0.69, 1.11)	ref	1.33 (0.94, 1.89)	**0.68 (0.51, 0.91)**	0.86 (0.59, 1.25)
Income *(ref: > $100,000)*					
<$25,000	0.87 (0.60, 1.27)	ref	1.02 (0.72, 1.45)	**12.53 (7.87, 19.9)**	**12.22 (7.08, 21.07)**
$25,000 - <$50,000	1.01 (0.72, 1.41)	ref	0.79 (0.57, 1.11)	**4.10 (2.63, 6.41)**	**3.19 (1.88, 5.41)**
$50,000 - $100,000	1.01 (0.72, 1.42)	ref	0.96 (0.71, 1.31)	**2.39 (1.47, 3.87)**	1.50 (0.88, 2.53)

Note. OR = Odds ratio; 95% CI = 95% confidence interval
Effect estimates with p-values < 0.05 are printed in bold.

Supplementary Material

Table SM 2.1 Model Fit Comparison of Unweighted 3-, 4-, and 5-Class LCA Models

Model	*LL*	*G-squared*	*AIC*	*BIC*	*aBIC*	*CAIC*	*Entropy*	*df*
3-class	-23218.81	7007.87	7119.87	7456.30	7278.37	7512.30	**0.94**	19626.00
4-class	-22525.37	5620.99	5770.99	6221.57	5983.27	6296.57	0.93	19607.00
5-class	-22044.47	4659.20	**4847.20**	**5411.92**	**5113.25**	**5505.92**	0.91	19588.00

Note. AIC = LL = Log Likelihood; Akaike information criterion; BIC = Bayesian information criterion; aBIC = adjusted Bayesian information criterion; df = degrees of freedom

Lower values of AIC, BIC, and aBIC indicate a better model fit. Higher values of entropy indicate better class separation.

CHAPTER 3

Cohort Differences in Social Network Types of Older Adults

Introduction

In a rapidly changing society, individuals from different birth cohorts are exposed to different historical conditions. Dominant socio-cultural conditions of a particular period can influence the composition and nature of social networks of older adults born during that period. Changes in cultural norms and behavioral patterns have led to smaller and geographically dispersed families, higher rates of divorce, lower rates of marriage and childbirth, and an increased reliance on non-kin relationships for support among later cohorts.[1] Therefore, social networks of older adults from later cohorts are likely to be different in composition and nature to networks older adults from earlier cohorts.

Our aim was to determine cohort differences and similarities in the social network types of older adults in a nationally-representative sample. To disentangle cohort effects from age effects, we examine social network types among the same age group (76- to 85-years old) but in different birth cohorts. Specifically, we provide a descriptive comparison of the social networks of older adults born between 1920-1929 versus individuals born between 1930-1939. We expect that a number of changes in social structure and cultural norms, such as changes in women's social roles, decline in marital and birth rates, changes in living arrangements, geographical dispersion of social networks, and economic shifts, would result in different network types among those born in the 1920s versus 1930s.

The 1920s are considered the decade of optimism in America as it was a time of economic growth. Advancements in the automobile industry increased human mobility, allowing individuals the freedom to relocate for employment or personal reasons resulting in more geographically dispersed networks. At the same time, it increased individuals' ability to maintain social interactions with family and friends who were previously geographically inaccessible. Along with industrial advancement, another prominent change of the 1920s was women being granted the right to vote in national politics which increased their political participation.[2] Women's role in society was in a flux during this decade. Social expectations of women changed to some extent following WWI, when women started entering into occupational fields in various businesses and industries; however, they still bore a larger share of the domestic responsibilities compared to men.[2]

In contrast to the 1920s, the 1930s was the decade of depression. Following the stock market crash of October 1929, there was deep national despair. By 1933, 14 million Americans were unemployed, national income had dropped by more than half, and industrial production also declined rapidly.[3] This placed great economic, social, and psychological strains upon American families resulting in major shifts in family organization. Despite widespread unemployment, the number of women in the workforce increased particularly in low paying and less socially acceptable jobs. Marital rates declined initially following the stock market crash and so did divorce rates, while marital strain increased during this period.[4] The trend toward decreasing birth rates accelerated during the 1930s and family members were more likely to live together in a single home due to financial strain.[5]

In addition to the year of birth, cohort effects also consider the influence of early life conditions, population shifts, and continuous exposure to sociohistorical factors among

individuals born during a specific period.[6] From this perspective, in addition to the period in which individuals were born, the historical period during which these individuals matured also plays an important role in shaping their social values and the structure and composition of their social networks. Individuals from the earlier cohort were in their 20s during the 1940s, while individuals from the later cohort were in their 20s during the 1950s. The first half of the 1940s was marked by WWII which transformed the country socially, economically, and politically. Men and women born in the 1920s were forced into new employment patterns and altered social roles during WWII. In contrast, during the 1950s the US experienced marked economic growth following WWII. However, culturally, views of conformity and social conservatism dominated in the 1950s. As a result, men and women born in the 1930s were forced into traditional gender roles which had been reaffirmed following WWII.[7]

Taken together, older adults who grew up during the different decades most likely place different value on various relationship roles (e.g., family vs. friends), have different expectations of types of support offered by specific relationships (e.g., spouse, parent, child), and distinct perspectives on marriage, divorce, and cohabitation. Hence, we would expect the social network types of older adults born in the 1920s to be different from the network types of older adults born in the 1930s.

Methods

Sample and data collection

Data for this analysis were taken from the National Social Life, Health, and Aging Project (NSHAP). NSHAP is a longitudinal, population-based study focused on the health, well-being, and social lives of community-dwelling older Americans. A complex, multi-stage area probability sample was employed to recruit participants in 2005-2006 for the first wave. African

Americans, Latinos, men, and the oldest old (75-85 years at the time of screening) were oversampled. Data collection consisted of a face-to-face interview including a brief self-administered questionnaire, in-home collection of biomeasures, and a leave-behind questionnaire. A total of 3,005 participants aged 57 to 85 years were interviewed during the first wave for a weighted response rate of 75.5%. 4,777 participants were interviewed during the third wave (2015-2016), including 1,592 (53%) respondents from the original cohort. Our analysis used data from an earlier birth cohort of participants aged 76-85 years at Wave 1 (N = 801, born 1920-1929) and a later birth cohort of participants aged 76-85 at Wave 3 (N = 847, born 1930-1939).

Operationalization of network types

NSHAP collected social network and social support data from all respondents during the in-home interview and leave-behind questionnaire using a name generator. Specifically, respondents were asked to name the individuals with whom they discussed things that were important to them over the last 12 months. For each network member identified by the respondent, additional data were collected including the type of relationship and frequency of contact between the respondent and each network member. Respondents were also asked to report on the level of support and strain experienced in relationships with partner, family, and friends. Some social network questions asked of participants in Wave 1 were not repeated in Wave 3. For example, in Wave 1 for each confidant identified using the name generator participants were asked how emotionally close they felt and whether they discussed health problems with the confidant. However, in Wave 3 data were not collected on emotional closeness or likelihood of discussing health problems. We restricted our analysis to only those social network variables for which data were collected in both waves.

Observed variables. Network types were derived through application of latent class analysis (LCA) using observed variables that reflect both structural and functional components of the social network. We applied LCA to seven observed variables for which data were collected in both waves. These included items representing structural aspects: network size, diversity, and frequency of contact; items representing functional aspects: social support from partner, family, and friends; and an item indicating experience of strain in relationship with partner.

Network size. Network size was determined by summing the number of contacts reported by a respondent across three broad relationship types (partner, family, friends) using an ordinal scale: *none* (0), *one* (1), *two to three* (2), *four to nine* (3), *ten to twenty* (4), *and more than twenty* (5). The overall size of the network was then recoded into three categories (1=*small*, 2=*medium*, 3=*large*) using tertiles.

Network diversity. Network diversity was assessed by counting the number of different relationship roles in an individual's confidant network. Respondents identified their relationship to each confidant using 17 options consisting of five broad relationship roles: *spouse/partner* (spouse, ex-spouse, romantic or sexual partner), *family* (parent, parent in-law, child, step-child, brother or sister, other relative of yours, other in-law), *friends*, *neighbors*, *other* (co-worker or boss; minister, priest, or other clergy; psychiatrist, psychologist, counselor, or therapist; caseworker or social worker; housekeeper or home health care provider). The diversity variable captured the extent to which an individual's network was diverse on a scale of 0-17. The final score for network diversity was recoded into three categories (1=*low*, 2=*medium*, 3=*high*) using tertiles.

Frequency of contact. For each confidant, respondents were asked how often they talked to them, including face-to-face, via telephone and email. Potential responses included: *less than once a year* (1), *once a year* (2), *a couple times a year* (3), *once a month* (4), *once every two weeks* (5), *once a week* (6), *several times a week* (7), *every day* (8). Responses were scored according to the approximate number of times per year the respondent interacted with each confidant (e.g., "once a month" = 12; "every day" = 365) and then summed across all network members to obtain a measure of overall volume of contact. The overall volume of contact was then recoded into three categories (1=*low*, 2=*medium*, 3=*high*) using tertiles.

Social support. For three separate relationship types (partner, family, and friends) respondents were asked: (a) "How often can you open up to [partner/ members of your family/ friends] if you need to talk about your worries? Would you say *hardly ever* (1), *some of the time* (2), or *often* (3)?" and (b) "How often can you rely on [partner/ members of your family/ friends] for help if you have a problem? Would you say *hardly ever* (1), *some of the time* (2), or *often* (3)?" Responses to these two questions were combined into a single social support variable for each of the relationship types, resulting in three categorical latent class observed variables. For family and friends, the support variables were coded as follows: (1) *low*, (2) *medium*, (3) *high support*. For partner, the support variable was a combination of the presence of a partner (i.e., whether one has a partner or not) and level of support received (low versus high support): (1) *partner absent*, (2) *partner present, low support*, (3) *partner present, high support*.

Social strain. Social strain in relationship with a partner was assessed by asking respondents: (a) "How often does partner make too many demands on you?" and (b) "How often does partner criticize you?" The response categories were *hardly ever* (1), *some of the time* (2), or *often* (3). Similar to the social support variable, social strain from partner was a combination

of the presence of a partner and the level of strain experienced (low versus high strain): (1) *partner absent,* (2) *partner present, low strain,* (3) *partner present, high strain.*

Statistical analysis

We used LCA to determine the number and nature of network types. In LCA, respondents with similar network patterns are grouped into classes, such that each class represents a distinct social network type. We ran separate latent class models for the later and earlier cohorts to determine potential differences in the network types across the two cohorts. The social network types were derived using unweighted latent class models with 7 polytomous observed variables, or items. For each cohort, starting from a single-class model we stepwise increased the number of classes until the model fit leveled off and we obtained conceptually distinct and meaningful network types. Model fit was assessed using information criteria and entropy. The final model for each cohort with the optimal number of classes was chosen on the basis of a combination of model fit, parsimony, and interpretability. Network type labels were assigned to latent classes based on the overall pattern and distribution of the item-response probabilities for that class. A descriptive comparison was performed of the similarities and differences in social network types and their prevalences for the two birth cohorts.

Results

Baseline characteristics

Baseline sociodemographic and social network characteristics by cohort are presented in Tables 3.1 and 3.2. In each cohort, the mean age of the participants was approximately 80 years (SD=3); more than 50% in each cohort were female; more than 70% were White; and approximately 90% were unemployed. The later cohort was more educated and had a higher income: 80% of the later cohort compared to 69% of the earlier cohort had at least a high school

education; almost half of the earlier cohort had an annual income of less than $25,000 compared to only 29% of the later cohort. Additionally, a bigger proportion of the later cohort was married (62%) compared to the earlier cohort (44%), whereas a smaller proportion of the later cohort was widowed (27%) compared to the earlier cohort (43%). A bigger proportion of those in the earlier cohort did not have a partner (51% vs. 34%) and reported high support from family (65% vs. 40%) rather than low or medium levels of support, compared to the later cohort.

Cohort comparison of network types

A four-class solution adequately captured the social networks of both cohorts and was concordant with the social network types observed in the total sample at Wave 1 (see results of Chapter 2). The four network types observed in the two cohorts were: *large, supportive network without partner*; *large, supportive network with partner*; *restricted, partner-centered network*; and *restricted network without partner*. We observed differences in the prevalence of specific network types and the distribution of responses to the observed network characteristics for each type across the two cohorts. The later cohort had fewer members in the *large, supportive network without partner* (14%) compared to the earlier cohort (33%). Instead, the later cohort had a higher prevalence of the *restricted, partner-centered network* (32%) compared to the earlier cohort (20%). The differences in prevalence of the *large, supportive network with partner* and the *restricted network without partner* between the two cohorts were minor.

Large, supportive network without partner. Those in the *large, supportive network without partner* had relatively large networks, with high support from family and friends, and no partner. Network diversity and frequency of contact were not important characteristics of this network type. One of the distinguishing features of this network type among the later cohort was high support from friends; 71% of those in the later cohort reported high perceived support from

friends. In contrast, support from friends did not emerge as a distinguishing feature of this network type among the earlier cohort, with 49% reporting high and 46% reporting medium levels of perceived support from friends.

Large, supportive network with partner. Those in the *large, supportive network with partner* were similar to those in the *large, supportive network without partner* in all respects, except they had a partner. Individuals in this type had a large network and high support from partner, family, and friends. They also reported experiencing low rather than high strain from partner. The prevalence of this network type was not too different for the earlier (29%) and later cohorts (35%). However, among network members of this type, high frequency of contact with confidants was a distinguishing characteristic for the earlier cohort but not the later cohort. Another distinguishing feature of this type was support from friends: in the later cohort 52% of the members in this type reported high support from friends; in contrast, among the earlier cohort 50% of the members in this type reported medium level of support from friends and only 40% reported high support from friends.

Restricted, partner-centered network. Those in the *restricted, partner-centered network* had low diversity in relationship roles, low frequency of contact, and experienced low to medium levels of support from family and friends. Partner appeared to be a major source of support for these individuals as well as a source of strain. The defining characteristics of this network differed slightly between the earlier and later cohorts. Specifically, the earlier cohort reported medium levels of support from both family (50%) and friends (59%), whereas, the later cohort reported low levels of support from family (57%) and friends (69%). Additionally, members of this type from the earlier cohort mostly reported experiencing low levels of strain in the partner

relationship (67%); in contrast, members of this type from the later cohort were equally likely to report low (50%) and high (50%) levels of strain with partner.

Restricted network without partner. Similar to the previous network, those in the *restricted network without partner* had low diversity in relationship roles and low frequency of contact with network members, except they had no partner. At least half of the members of the *restricted network with partner* from the earlier cohort reported a small network (54%) and medium levels of support from friends (56%), making them distinguishing features of this network type. In contrast, network size and perceived support from friends did not emerge as distinguishing features of the *restricted network with partner* among the later cohort.

Discussion

We examined cohort differences in the defining characteristics and prevalence of social network types in a large, nationally-representative study of older adults in the United States. Using latent class analysis, we identified four discernable network classes or types in each cohort: *large, supportive network without partner*; *large, supportive network with partner*; *restricted, partner-centered network*; and *restricted network without partner*. These network types were appreciably different in terms of network size, perceived support from various relationship roles, and presence versus absence of a partner. In general, older adults in the two *large, supportive* types had more resourceful and supportive networks compared to older adults in the two *restricted* types. The network types of older adults in the two birth cohorts are mostly similar to the main types that were identified in the full NSHAP sample (N=3,005) at Wave 1 in Chapter 2. The 5-class network typology derived at Wave 1 in the full sample had an additional network type, *average network with partner*, which was in between the most resourceful (*large, supportive network with partner*) and least resourceful (*restricted network without partner*)

network types. Individuals in this network were most likely to report average or medium levels of network size, support, and other individual network characteristics. This network type did not emerge in the 4-class typology obtained in the two birth cohorts. The similarity observed in the network types of the full sample and of each birth cohort suggests that network typology has the potential to be used as an assessment measure for characterizing the social lives older adults.

Although the nature of the network types across cohorts was mostly similar, we did observe some cohort differences in the prevalence of certain network types and in the distinctive characteristics of network types. Prevalence of the *large, supportive network without partner* declined from the earlier to later cohort, whereas, the prevalence of the *restricted, partner-centered network* increased from the earlier to the later cohort. This may be, in part, due to increased survival from one cohort to the next; life expectancy at birth increased by 6 years from 54 years in 1920 to 60 years in 1930 in the United States.[8] As a result, partners of older adults in the later cohort were more likely to have survived compared to partners of older adults in the earlier cohort. Among the later cohort individuals were almost equally likely to be in one of the two partner networks: *large, supportive network with partner* (35%) and *restricted, partner-centered network* (32%). However, compared to the earlier cohort, a greater proportion of individuals from the later cohort were in the *restricted, partner-centered network* (an additional 12%) compared to the *large, supportive network with partner* (an additional 6%), suggesting the emergence of smaller and more family-oriented networks in the later cohort, at least among those with a partner. Previous studies of cohort differences in social networks find that the salience of friends as sources of support among older adults has increased over time.[1] This suggests that larger and more diverse network types would be more common in later cohorts due to the increased salience of friends as an additional source of support beyond partner and family.

Although our results were in contrast to previous findings, they were not entirely unexpected. The later cohort in our study was born in the 1930s when traditional gender roles and family structure had been reestablished following WWI; and these individuals came of age during the 1950s when views of conformity and social conservatism dominated the culture which reinforced traditional family values in this cohort.[2,7] Given this historical context, we would expect older adults of the later cohort to rely more on their partner and family compared to other sources of support, which might explain the higher prevalence of the *restricted partner-centered network* in this group. In fact, low support from friends was a distinctive characteristic of this network type in our study for the later, but not the earlier, cohort.

However, the later cohort did not consistently report low support from friends across network types. In fact, high support from friends emerged as a distinctive feature of the later cohort in the two *large, supportive* network types; whereas, high friend support was not a distinctive feature of any of the network types for members of the earlier cohort. The earlier cohort consistently reported a medium level of support across the network types. This suggests that, at least in our study, there is more variation in the relevance of friends as a source of support for the later cohort compared to the earlier cohort.

Unlike the earlier cohort, individuals in the later cohort were more likely to report high levels of strain in the partner relationship among members of the *restricted partner-centered* network. The 1930s, compared to the 1920s, were a time of higher marital strain and dissatisfaction due to the economic recession.[3,4] The theory of intergenerational transmission suggests that interaction patterns can transmit across generations leading to similarities in the emotional experience among family members.[9] This would suggest that if parents of individuals born in the 1930s had negative feelings regarding their marriage, individuals born in the 1930s

may themselves also foster feelings of negativity with their spouses, which would explain the higher level of partner strain reported by the later cohort.

Although the *restricted partner-centered* network was less prevalent in the earlier cohort, the *large, supportive network without partner* was more prevalent in the earlier cohort compared to the later cohort. Once again, based on previous findings which emphasize the relevance of friendship networks in later cohorts, we would have expected the opposite – a lower prevalence of the *large, supportive network without partner* in the earlier cohort. One possible explanation for this unexpected finding may be the shorter life expectancy of the earlier cohort compared to the later cohort. Another explanation is that individuals born in the 1920s were age-eligible to be recruited for WWII during the 1940s. As a result, many unmarried women from that cohort may have never been married with most of the age-eligible men away at war. Similarly, for many married women, their spouses may not have survived the war leaving them widowed. This would explain why a larger proportion of the earlier cohort was in a network type without a partner. This explanation is also consistent with the baseline characteristics of the sample – we observe a higher rate of never married and widowed individuals in the earlier cohort relative to the later cohort. Those from the earlier cohort appear to have compensated for the lack of a partner by reaching out to their family for support - 84% in this network type report high support from family – which explains why despite the absence of a partner these individuals had a large and supportive network.

A key strength of this study is that it examines multiple indicators of social networks of older adults representing both the structure and function of the network which has been lacking in previous typology studies. NSHAP provides comprehensive measurement of older adults' social lives which made it possible to take a pattern-centered multidimensional approach to

construct the social networks of older adults. Additionally, NSHAP collected data on a nationally representative sample of older adults over three waves spanning 10 years allowing us to perform a cohort comparison of the social network types of older adults.

Despite these strengths, the results of the study should be interpreted in view of its limitations. First, true cohort comparisons can only be made when the effects of age and period are also accounted for. In this case, although we compare two cohorts of the same age group accounting for the effect of age, we do not control for the effect of time. Ideally, we would compare two cohorts of the same age, over historical time; however, given the age range of the participants and the follow-up duration of the NSHAP study, this was not possible. Instead, we compared network types constructed in 2005-06 for the earlier cohort (i.e., older adults age 76-85 in 2005-06) to network types constructed in 2015-16 for the later cohort (i.e., older adults aged 76-85 in 2015-16). As a result, it is not possible to rule out potential confounding by period effects. It should also be noted that the analysis presented here is truly descriptive in nature. We did not perform any statistical test of the age-period-cohort effect. Second, reliance on self-reported measures of social network and social support raises concerns about inaccurate recall by the respondents. Although NSHAP excluded people with a history of dementia, it is not uncommon for early cognitive impairment to go undiagnosed among older adults in the community. Third, the analysis is based upon available measures in the NSHAP dataset. Unlike Wave 1, data on emotional closeness of respondents with their network members and the likelihood of discussing health problems with confidants were not collected in Wave 3. As a result, we were unable to include these network characteristics in the construction of network types. However, the constraint of available measures is inherent in most secondary analyses and is not unique to our study. Despite changes in social network measurement across waves,

NHSAP has detailed data on a number of relevant social network indicators in both waves which made it possible to conduct this cohort analysis.

Findings from this study indicate that social and structural changes can influence the types of social networks adults have in later life and potentially lead to differences in social networks across birth cohorts. Future studies should examine cohort effects in network types over multiple age groups and time periods, utilizing statistical methods that go beyond simple descriptive comparisons.

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Tables

Table 3.1 Sociodemographic Characteristics by Birth Cohort

Sociodemographic characteristics	Earlier Cohort (1920-1929)			Later Cohort (1930-1939)		
	% (Mean)	N (S.D.)	Sum	% (Mean)	N (S.D.)	Sum
Age	79.71	2.82	801	79.90	2.78	847
Gender						
Male	43	343	801	47	398	847
Female	57	458		53	449	
Education						
Less than high school	31	252	801	20	168	847
High school or equivalent	31	245		25	208	
Vocational certificate / some college or associate's degree	24	190		32	268	
Bachelors or more	14	114		24	203	
Household income in the previous year						
Less than $25,000	51	359	708	29	220	771
$25,000 - $49,999	32	226		32	247	
$50,000 - $99,999	12	88		28	218	
$100,000 or more	5	35		11	86	
Currently working						
Yes	9	79	800	10	85	846
No	90	721		90	761	
Race/Ethnicity						
White	77	612	798	71	603	845
Black	15	118		15	128	
Hispanic, non-Black	7	56		11	91	
Other	2	12		3	23	
Marital Status						
Married	44	351	801	62	526	847
Living with a partner	1	9		1	6	
Separated	1	8		1	10	
Divorced	7	54		8	64	
Widowed	43	348		27	229	
Never married	4	31		1	12	

Note. Percentages are calculated using only those respondents without missing data.
Percentages and N are presented for categorical variables and Means and Standard Deviations are presented for age (continuous variable).

Table 3.2 Social Network Characteristics by Birth Cohort

	Earlier Cohort (1920-1929)			Later Cohort (1930-1939)		
Structural social network variables	% (Mean)	N (S.D.)	Sum	% (Mean)	N (S.D.)	Sum
Network size						
Small (*0-<9*)	20	148	745	21	159	758
Medium (*9-<22*)	37	276		38	286	
Large (*22-42*)	43	321		41	313	
Network diversity (*number of different relationship roles*)						
Low (*0-<2*)	47	377	795	45	375	840
Medium (*2-<4*)	35	276		35	291	
High (*4-6*)	18	142		21	174	
Volume of contact (*number of times contacted ties in a year*)						
Low (*0-<625.5 times*)	39	308	792	36	301	837
Medium (*625.5-<990.5 times*)	32	257		35	291	
High (*990.5-2190 times*)	29	227		29	245	
Functional social network variables						
Level of partner support						
No partner	51	404	795	34	283	840
Low support	18	147		22	181	
High support	31	244		45	376	
Level of family support						
Low	8	56	739	34	249	736
Medium	27	202		26	192	
High	65	481		40	295	
Level of friend support						
Low	14	97	711	37	282	755
Medium	51	365		29	217	
High	35	249		34	256	
Level of strain in relationship with partner						
No partner	51	404	795	34	283	838
Low social strain	34	270		38	318	
High social strain	15	121		28	237	

Note. Percentages are calculated using only those respondents without missing data.
Percentages and N are presented for categorical variables and Means and Standard Deviations are presented for age (continuous variable).

Table 3.3 Prevalence and Item-Response Probabilities for Social Network Types by Birth Cohort

Social Network Types	Large, supportive network without partner		Large, supportive network with partner		Restricted, partner-centered network		Restricted network without partner	
Cohort	**Earlier**	**Later**	**Earlier**	**Later**	**Earlier**	**Later**	**Earlier**	**Later**
Network type prevalence	0.33	0.14	0.29	0.35	0.20	0.32	0.18	0.20
Item-response probabilities								
Network size								
Small	0.08	0.00	0.09	0.05	0.25	0.37	**0.54**	0.37
Medium	0.39	0.41	0.34	0.35	0.45	0.37	0.30	0.41
Large	**0.53**	**0.59**	**0.57**	**0.59**	0.29	0.26	0.16	0.23
Network diversity								
Low	0.49	0.49	0.12	0.21	**0.64**	**0.50**	**0.85**	**0.71**
Medium	0.40	0.34	0.44	0.46	0.30	0.30	0.15	0.24
High	0.11	0.17	0.45	0.34	0.06	0.18	0.01	0.04
Frequency of contact								
Low	0.22	0.28	0.15	0.15	**0.66**	**0.50**	**0.79**	**0.56**
Medium	0.42	0.37	0.32	0.40	0.32	0.34	0.14	0.26
High	0.36	0.36	**0.52**	0.45	0.02	0.16	0.07	0.18
Partner support								
No partner	**1.00**	**1.00**	0.00	0.00	0.00	0.00	**1.00**	**1.00**
Low support	0.00	0.00	0.33	0.29	0.44	0.36	0.00	0.00
High support	0.00	0.00	**0.67**	**0.71**	**0.56**	**0.64**	0.00	0.00
Family support								
Low	0.00	0.08	0.02	0.17	0.15	**0.57**	0.22	0.44
Medium	0.16	0.15	0.22	0.29	**0.50**	0.24	0.32	0.32
High	**0.84**	**0.77**	**0.76**	**0.55**	0.34	0.19	0.46	0.25
Friend support								
Low	0.05	0.04	0.10	0.15	0.25	**0.69**	0.25	0.47
Medium	0.46	0.24	**0.50**	0.33	**0.59**	0.27	**0.56**	0.28
High	0.49	**0.71**	0.40	**0.52**	0.16	0.04	0.19	0.25
Partner strain								
No partner	**1.00**	**1.00**	0.00	0.00	0.00	0.00	**1.00**	**1.00**
Low strain	0.00	0.00	**0.71**	**0.64**	**0.67**	**0.50**	0.00	0.00
High strain	0.00	0.00	0.29	0.36	0.33	**0.50**	0.00	0.00

Note. Probabilities greater than or equal to 0.50 are printed in bold.

CHAPTER 4

Types of Social Networks and Their Association with Physical Function and Disability in Late Life

Introduction

Disability and physical mobility limitations are prevalent aging related conditions that lead to increased dependence among older adults and a diminished quality of life. As of 2016, 35% of people aged 65 and older in the US were living with some type of disability with ambulatory difficulty (23%) and independent living difficulty (15%) being among the most common.[1] Physical functioning difficulties tend to increase with age. In 2016, 44.3% of people aged 75 and over reported having difficulty in physical functioning. This percentage is more than twice as large as for the age group 45 to 64 (19.7%)[1] Mobility and other functional impairments are associated with risk of additional loss of function, including loss of muscle mass and strength, falls, long hospital stays, and nursing home placement.[2] Although physical functional impairments are often misconstrued as an inevitable part of aging, many physical functioning deficits can be delayed, if not prevented.[3] Additionally, there is significant heterogeneity among older adults in the rate of decline in functional ability; some older adults remain stable in their functional ability, others experience a general decline in functional ability, and many recover from a state of disability.[3,4]

Social Networks and Functional Health

It is widely observed that social relationships have a beneficial effect on functional health of older adults.[5] Several studies note the favorable effects of structural characteristics of the social network, particularly network size, frequency of contact with social ties, and social participation, on disability in mobility and activities of daily living.[4,6–11] However, the role of specific types of ties in protecting against disability remains unclear with some evidence for the protective effect of contact with friends and family[8,9,11] but no effect of contact with children and confidants.[9,11] Other studies claim that functional characteristics of the social network such as social support are more protective for onset and changes in functional ability.[12,13] However, findings of studies examining social support in relation to functional health are unclear. Some studies found no effect of social support as a risk factor of functional decline, some found a harmful effect of instrumental support on functional decline, and others found that under certain circumstances, a lack of social support in late life may actually promote mobility improvement.[4,9,11,14,15]

Network typology

The body of research on social networks and health has primarily been restricted to isolated aspects of social relationships. Among those that consider multiple individual aspects simultaneously, the focus has been either on structural aspects or functional aspects, but not both.[16] There is an increasing acknowledgement that social network is a complex phenomenon, representing a collection of distinct social network types, each of which may have a different association with health outcomes.[17] The construct of network type, particularly one that combines multiple aspects of the network including its structure, function, and quality, may provide a more comprehensive and nuanced understanding of the relationship between social

networks and health. It may also clarify the varied and sometimes contradictory nature of the findings regarding social networks and health. The relationship between social networks and health as captured by simple measures of size and support is likely not the same as that captured by network types. This is because network typologies capture systematic variation in multiple structural and functional elements of social networks and are therefore able to take into account the complexity of one's interpersonal environment.

Network types and age-associated health outcomes

Social network types have been examined in relation to mortality, emotional health, and health-related behaviors. Restricted social network types, which indicate limited engagement in social relationships, in particular, have been associated with higher mortality risk across various settings.[18,19] Litwin & Shiovitz-Ezra (2006) found that older Israeli adults in the *diverse* and *friend-focused* network types, and to a lesser degree those in the *community-clan* network type, had a lower risk of mortality compared to individuals belonging to *restricted* networks.[18] In a more recent survey of six Latin American countries, as well as India, and China, Santini et al., (2015) observed that older adults in restricted social networks (i.e., *locally self-contained, family dependent,* and *private* network types) had a significantly higher mortality risk compared to the *locally integrated* social network type. Belonging to different network types is also related to depressive symptomology,[20] morale,[21] and subjective well-being.[22,23] Additionally, social network types have been shown to predict the risk of alcohol abuse,[24] engagement in physical activity,[24] and utilization of health and social services.[25] Initial evidence from these studies indicates that social network types can be used to predict mortality, mental health, and behavioral health outcomes. However, there is little reported research on the association between social

network types and the physical health outcomes of disability and physical mobility among older adults.

Network types and functional health

Preliminary evidence suggests that social network types may have a differential effect on physical functional health in old age. In a population of community-dwelling Jewish Israelis, Litwin (1998) observed that older adults in *diversified*, *friend*, and *neighbor* network types had, on average, a lower rate of disability in basic ADLs; whereas, older adults in the *religious family* and *attenuated* networks had higher than average rates of disability.[26] Corroborating these findings, in a subsequent study Litwin (2003) found that older adults in *family* and *restricted* networks had a significantly higher degree of disability compared to other network types.[27] However, in contrast to the previous study, Litwin (2003) observed that individuals in the *neighbor* network, in fact, had a higher degree of disability compared to other network types. Data from an older Mexican population suggests that older adults belonging to *widowed* and *restricted* networks have a higher proportion of functional dependency in basic and instrumental activities of daily living relative to older adults belonging in more diverse network types.[28] It remains unclear if social network types are also associated with changes in mobility over time in old age.

Scope of current study

Multidimensional social network types, unlike isolated measures of social networks, provide a more complete picture of the interpersonal environments in which older adults are embedded as well as of the function and quality of these environments. Given that individual aspects of social networks operate through different, albeit sometimes overlapping, pathways to impact health, network typologies can better represent multiple potential pathways that operate

simultaneously to influence health. They therefore provide a more comprehensive assessment of the overall effect of social networks, as opposed to just one aspect of the network, on physical functional health of older adults.

Existing research on network typology has primarily used either structural or functional network characteristics, but not both, and rarely has it included a measure of social strain in the construction of network types. For instance, Litwin's network types were defined based primarily on structural features of the social network and social participation.[26,27] Although Doubova et al (2010) did include a measure of support in constructing their typology, respondents were specifically asked about instrumental support and emotional support was not measured.[28] Another major concern with existing studies is their reliance on cross-sectional data. Social networks both influence health, and are shaped by health status.[29,30] Previous studies, using cross-sectional data, are unable to determine whether it is social network types that affect older adults' health, or whether it is the functional and cognitive health of older adults that leads them to cluster into different social network types.[20,22,26–28] Although researchers have constructed network typologies and examined their association with mortality in the United States, studies examining functional health in relation to network types have primarily been conducted in populations outside the United States, including Israel[26,27] and Mexico.[28]

The main purpose of the present study is to examine the association of previously derived social network types, representing the structure, function, and quality of relationships, with physical functional health in a nationally representative sample of older adults in the United States. The use of longitudinal data in this study allows us to ensure, to some extent, that the social network types that older adults cluster into precede any changes in health status. Individually, larger network size, high diversity, and high social support have been linked to

improved functional health. Studies examining isolated measures, such as size, inherently assume that larger networks are also more diverse and supportive. However, a large network could be restricted (i.e., have low diversity) and unsupportive, in which case the functional health effects may be null or negative. Using network types to simultaneously capture the effect of multiple individual aspects of social networks, we hypothesized that elderly in larger, diverse, and more supportive network types would be at a lower risk of decline in functional health.

Methods

Sample and data collection

Data for the study came from the National Social Life, Health, and Aging Project (NSHAP). NSHAP is a longitudinal, population-based study of health and social factors, designed to understand the well-being of community-dwelling older Americans. Participants aged 57 to 85 years at baseline were recruited using a complex, multi-stage area probability sample with oversampling of African Americans, Latinos, men, and the oldest old (75-84 years at the time of screening). 3,005 participants completed interviews at baseline or wave 1 (2005-2006). In wave 2 (2010-2011), 3,377 respondents were interviewed of whom 2,261 respondents were from wave 1 and the remaining were non-interviewed respondents who had declined to participate in wave 1 but agreed to participate in wave 2, and the spouses or cohabiting romantic partners of the respondents. In wave 3 (2015-2016), all surviving respondents from the previous waves (N = 2,409) were interviewed again and a new cohort of respondents born between 1948 and 1965 was added along with their spouses or partners, totaling 4,777 participants. Data collection comprised of a face-to-face interview including a brief self-administered questionnaire, in-home collection of biomeasures, and a leave-behind questionnaire. For this study, we restricted our sample to the 3,005 participants who were interviewed at baseline and

therefore had complete exposure data. The analysis for each outcome was conducted using data on the individuals out of these 3,005 for whom the specific outcome measures were available.

Social network type

The exposure variable was the social network type assigned to individuals at baseline in a previous analysis.[31] Five network types were derived by means of a latent class analysis: *diverse, supportive network with partner*; *average network with partner*; *partner-centered network*; *large, supportive network without partner*; and *restricted, family-centered network without partner*. The criterion variables used for the delineation of the network types included nine observed variables representing network structure (network size, diversity, and frequency of contact), network function (involvement of network members in health discussions, emotional closeness, social support from partner, social support from family, and social support from friends) and relationship quality (social strain from partner).

Diverse, supportive network with partner (31%). Respondents in this type had a large and diverse network with frequent contact with social ties. Older adults reported a high level of emotional closeness, a high likelihood of discussing health problems with confidants, and high support from all three major relationship types: partner, family, and friends. Compared to other network types, a smaller proportion of respondents in this type reported experiencing high strain in the partner relationship.

Average network with partner (27%). Respondents in this type reported medium levels of diversity, emotional closeness, and likelihood of discussing health problems with their confidants, hence the name average network. Although older adults in this type were more likely to experience high rather than low levels of support from partner and family, they reported experiencing medium levels of support from friends.

Partner-centered network (16%). Respondents in this type reported low levels of network diversity, low frequency of contact, and a low likelihood of discussing health problems with confidants. A distinctive feature of this type was the high levels of support received from partner compared to other relationships. At the same time, respondents in this type were more likely to report experiencing high strain in the partner relationship compared to the other network types.

Large-supportive network without partner (16%). Respondents in this type had a large network and reported high levels of emotional closeness and high likelihood of discussing health problems with confidants. Respondents in this network did not have a partner and relied heavily on family and friends for support.

Restricted, family-centered network without partner (11%). Respondents in this type did not have a partner and had very little diversity in their network. Older adults reported low frequency of contact, low emotional closeness, and low likelihood of discussing health problems with confidants. A distinctive feature of this type was the increased reliance on family, but not friends, for support.

Disability

Disability was operationalized as impairment in activities of daily living (ADL) and was assessed at all three waves. Participants were asked to report on how much difficulty they experience in performing six ADLs: walking across a room; dressing oneself, including putting on shoes and socks; bathing or showering; eating, such as cutting up one's food; getting in or out of bed; and using the toilet, including getting up and down. Ability to perform these six activities is commonly used to determine ADL disability[26] and they appear on the 7-item modified Katz ADL scale and the Physical Self-Maintenance Scale.[32,33] Each item was measured on a 3-point

scale: 0 (no difficulty), 1 (some difficulty), 2 (much difficulty). Respondents were asked to exclude any difficulties that they expected to last less than three months. Any difficulty in performing a task was scored as a disability. Disability in carrying out any of the 6 ADLs was used to identify respondents who experienced disability, consistent with previous studies using dichotomous measures of disability.[11] Individuals with any ADL disability at baseline were excluded from the analysis so that only those at-risk of developing a disability remained in the sample. Then among those at-risk of disability, anyone who developed one or more ADL disabilities after baseline was counted as having experienced disability onset.

Mobility

Mobility-related function in older adults was assessed using a timed walk test. In wave 1, approximately half of the respondents (N = 1,506) were randomly assigned to complete the "get-up-and-go" task[34] where they stand up from a chair without using any support, walk 3 meters, turn around, walk back 3 meters toward the chair and sit down. Participants were allowed to use their walking aid if they normally used one for the 6-meter walk. The time that it took for the respondent to perform each task: (a) stand, (b) walk 3 meters, (c) turn around, (d) return 3 meters, and (e) turn and sit was recorded in seconds. In waves 2 and 3, physical function was assessed using a separate timed walk and repeated chair stands. For the timed walk, derived from the Short Physical Performance Battery,[35] the time that it took for the respondent to (a) walk 3 meters, and (b) return 3 meters was recorded in seconds. For wave 1, the overall time of the walk adding up the times of stages (b), (c), and (d) was used. For waves 2 and 3, the total time it took the respondents to complete the timed walk was used.

Covariates

In order to control for potential confounding, baseline data for age (in years), sex (male, female), race/ethnicity (White; Black; Hispanic, non-Black; Other), educational attainment (less than high school; high school diploma or equivalent; vocational, some college, or associate's degree; bachelor's degree or higher), employment status (employed, unemployed), physical activity (0=*never*, 1=*less than once a month*, 2=*1-3 times per month*, 3=*1-2 times per week*, 4=*3 or more times per week*), current smoking status (smoker, non-smoker), comorbidities (0 to 6 conditions), Body Mass Index (BMI), and cognitive function (score of 0-10 on the Short Portable Mental Status Questionnaire) were included.

Statistical analysis

Social network types and ADL disability. Social network types were used to predict risk of ADL disability onset using a logistic regression model where the outcome, onset of disability, was binary. The five social network types were entered in the model as four dummy variables, with *diverse, supportive network with partner* serving as the reference group. Disability status at baseline was used to identify respondents at risk; we excluded individuals who had a disability at baseline ($N = 820$). Then, among those at risk ($N = 2{,}185$) we modeled the odds of developing a disability at either of the two follow-up waves. Confounders were entered into the models in stages: the initial regression model was unadjusted; the next model adjusted for demographic covariates of age, sex, and race/ethnicity; the following model adjusted for educational attainment; and the final model additionally adjusted for physical activity, comorbidities, and cognitive function.

Social network types and mobility. To estimate the longitudinal association between social network types previously identified and mobility, we employed a generalized linear mixed

model. The independent variable, social network types, were modeled as dummy variables and the dependent variable, time to complete a 6-meter walk, was modeled as a continuous variable. Time to walk which was originally right-skewed was log-transformed in order to better fit the normal distribution. Confounders were entered into the models in stages: the initial regression model included the main effects for time and network types as well as age and sex; the second model included time interactions with network types; the third model adjusted for sociodemographic variables of race/ethnicity, education, and employment status; and the final model additionally adjusted for health-related variables of physical activity, comorbidities, BMI, and cognitive function.

Sensitivity analysis. To determine the robustness of our findings, we conducted four sets of sensitivity analyses. In the first set of analyses, we examined the association between social network types and all-cause mortality. This analysis was done primarily to replicate the well-established relationship between network types and mortality. Even if network types did not predict the risk of ADL disability or changes in mobility, based on previous findings we expected network types to predict mortality. Living status of the participants was assessed at each of the follow-up waves. The final disposition of each respondent was coded as: *interviewed*, *deceased*, *in poor health*, *in nursing home*, *other-known/presumed alive,* or *other-not known if alive*. All participants without a final disposition of *deceased* were considered to be alive. Data on cause of death were not collected; therefore, all-cause mortality was used as the outcome. Additionally, information on date of death of the participants was not available as living status was assessed via proxy interviews rather than by linking NSHAP data to vital statistics records. The analysis was restricted to participants from wave 1 who were still in the study at wave 3 (10-year follow-up), and for whom living status was available. Given the absence of date of death

among the deceased, instead of a time to event analysis we used logistic regression to examine whether living status at wave 3 differed between social network types in our sample. Analyses were adjusted for age, sex, race/ethnicity, education, comorbidities, smoking status, and cognitive function in stages.

In LCA, every respondent receives a posterior probability of membership in each of the latent classes based on their observed characteristics. Each respondent is then assigned to the class for which they have the highest posterior probability of membership. In our study, the maximum probabilities for belonging to a class were generally high (Mean = 0.95), indicating high certainty in the assignment of respondents to a class. In the second set of sensitivity analyses, we excluded 663 (22%) respondents for whom the highest probability of membership in their respective assigned class was less than 0.95 to get an even more well-determined class assignment. We re-ran the regression models with the restricted sample to determine whether the association between network types and each of the health outcomes remains unchanged.

In the third set of sensitivity analyses, we modeled the risk of ADL disability onset at wave 2 (5-year), and separately at wave 3 (10-year) ignoring disability status at wave 2. Similarly, we ran a sensitivity analysis modeling the 5-year risk of mortality in contrast to a 10-year risk of mortality. Our goal was to determine if the effect of network types on disability and mortality is relevant in the short-term (5 years) or the long-term (10 years). The primary analysis did not allow us to make this distinction. Previous studies of social relationships show both short- and long-term effects on health, with intervention studies primarily showing short-term beneficial effects of social relationships on health.[36,37]

In the fourth sensitivity analysis, we examined the association of network types with general attrition, due to mortality or other loss to follow-up, to determine if selective attrition may be a source of bias.

All statistical analyses accounted for stratification and clustering of the NSHAP sample design, unequal probabilities of selection, and nonresponse to calculate weighted, nationally representative population estimates and standard errors. Analyses were conducted in SAS 9.4.

Results

Baseline characteristics

Table 4.1 presents the weighted (i.e., adjusted for non-response and non-random attrition) background characteristics and distribution of health outcomes and demographic covariates by social network type. The distribution of the network types reveals that the *diverse, supportive network with partner* (31%) and the *average network with partner* (27%) were the most prevalent network types. The remaining network types each accounted for less than a fifth of the sample. The average age of the sample at baseline was 69 years (SD=8) and approximately half of the sample was female (51%). Of the 3,005 participants interviewed at baseline, 2,253 (75%) were disability free and therefore at risk of developing ADL disability. 496 (22%) of those at risk developed disability in at least one ADL during follow-up. Participants took an average of approximately 10 seconds (SD=7) to complete the 6-meter walk. At wave 3, living status was available for 2,421 (81%) participants from the original sample, of whom 412 (17%) were deceased.

Among those who experienced disability at one of the follow-up waves, a greater proportion were assigned to the *diverse, supportive network with partner* (38%), and *average network with partner* (24%) at baseline, compared to the *large, supportive network without*

partner (16%), *partner-centered network* (13%) and *restricted, family-centered network without partner* (9%). Similarly, among those who were deceased at W3, a greater proportion were assigned to the *diverse, supportive network with partner* (30%) and *average network with partner* (23%) at baseline, compared to the other three network types. Older adults in the two network types without a partner took longer on average to complete the 6-meter walk, compared to the three network types with a partner.

Please see supplementary Table 4.1 (Table SM 4.1) for more detailed characteristics of the sample broken down by network type, including socioeconomic and health related variables that were included in the analyses.

ADL disability onset by social network type

Table 4.2 presents results of the logistic regression models with ADL disability as the outcome variable and the network types as the predictor variable. There was no statistically significant association between network type and ADL disability onset at the two follow-up waves. Among background variables, age, physical activity, and comorbidities were important predictors of ADL disability onset. In the fully-adjusted model (Model 3), a one-year increase in age was associated with 3% (95% CI: 1.02, 1.06) higher odds of ADL disability onset and those with one additional comorbid condition had 42% (95% CI: 1.25, 1.60) higher odds of ADL disability onset. In contrast, increase in physical activity was associated with 14% (95% CI: 0.76, 0.97) lower odds of ADL disability onset.

Mobility by social network type

As Model 1 in Table 4.3 indicates, social network type had a cross-sectional association with mobility such that older adults in the *large, supportive network without partner* (ß = 0.08; $p < .001$) and those in the *restricted, family-centered network without partner* (ß = 0.18; $p < .001$)

took significantly longer to complete the 6-meter walk compared to older adults in the *diverse, supportive network with partner.* Respondents in the two networks with partner, *partner-centered network* (ß = 0.03; $p = 0.158$) and *average network with partner* (ß = 0.02; $p = 0.347$) did not have significantly different walking times compared to the reference network type. Model 2 includes interaction terms between each of the social network types and time, to test the longitudinal association between social network type and change in mobility over time. We found no evidence that social network type at baseline alters the course of mobility over time. Model 3 shows that the cross-sectional association between the two social network types without partner and mobility persists after controlling for sociodemographic confounders. Finally, model 4 adds health-related confounders which attenuates the cross-sectional association between *restricted, family-centered network* and mobility by 18.75 % and renders the association between the *large, supportive network without partner* and mobility insignificant. All background variables, except sex, had a statistically significant association with walking time. In the fully adjusted model (Model 4), a one-year increase in age was associated with slower walking time (ß = 0.01; $p < .001$). Blacks (ß = 0.14; $p < .001$) and Hispanic, non-Blacks (ß = 0.06; $p < .01$) had significantly slower walking times compared to Whites. Similarly, those with less than high school education (ß = 0.13; $p < .001$) and high school or equivalent education (ß = 0.07; $p < .001$) had significantly slower walking times compared to those with a Bachelor's degree. Increase in comorbidities (ß = 0.04; $p < .001$) and BMI (ß = 0.01; $p < .001$) was also associated with a significantly slower walking time. In contrast, current employment (ß = -0.07; $p < .001$), engagement in more frequent physical activity (ß = -0.04; $p < .001$), and a higher cognitive functioning score (ß = -0.07; $p < .01$) were associated with significantly faster walking times.

Sensitivity analysis

In the first sensitivity analysis, examining the association between social network types and mortality, individuals in the *partner-centered network* (OR: 1.49; 95% CI: 1.00, 2.21), the *large, supportive network without partner* (OR: 1.44; 95% CI: 1.04, 1.99) and the *restricted, family-centered network without partner* (OR: 1.91; 95% CI: 1.26, 2.89) had significantly higher odds of mortality at the 10th year of follow-up (wave 3) compared to individuals in *diverse, supportive network without partner* in the unadjusted analysis (not shown). As shown in supplementary table SM 4.2, this association disappeared after inclusion of demographic covariates (Model 1). The association remained insignificant after additional adjustment of socioeconomic (Model 2) and health-related confounders (Model 3). Age, sex, education, comorbidities, and smoking status were important predictors of mortality. In the fully adjusted model (Model 3), a one-year increase in age was associated with 13% (95% CI: 1.11, 1.15) higher odds of mortality. Females, compared to males, were half as likely to die (OR: 0.51; 95% CI: 0.37, 0.69). Those with a vocational, some college, or associate's degree had 50% (95% CI: 1.03, 2.15) higher odds of mortality compared to those with a Bachelor's degree. Individuals with one additional comorbidity had significantly higher odds of mortality (OR: 1.34; 95% CI: 1.21, 1.50) and smokers, compared to non-smokers, were more than twice as likely to die (OR: 2.68; 95% CI: 1.84, 3.91).

In the second sensitivity analysis, focusing on participants with well-determined network type membership, for ADL disability onset the ORs were slightly attenuated for each of the network types except the *restricted, family-centered network without partner* for which the effect estimates were slightly stronger. However, similar to the main analysis, there was no statistically significant association between any of the network types and ADL disability onset. Age and

comorbidities continued to have a significant positive association with ADL disability onset; however, physical activity which had a significant negative association in the main analysis was no longer associated with onset of ADL disability. For mobility models, the association between network types and walking time remained statistically significant although the effect estimates for network types were somewhat stronger in the sensitivity analysis. Older adults in the *large, supportive network without partner* (ß = 0.09; $p < .001$) and *restricted, family-centered network without partner* (ß = 0.19; $p < .001$) had significantly longer walking times. For the *restricted, family-centered network without partner* (ß = 0.16; $p < .001$) this association attenuated slightly but remained statistically significant even after controlling for sociodemographic and health covariates. However, for the *large, supportive network without partner* (ß = 0.06; $p = 0.067$) adjustment for health confounders rendered the association insignificant. Similar to the primary analysis, all background variables, except sex, had a statistically significant association with walking time. For mortality models, the results removing those with a posterior probability of membership less than 0.95 were very similar to the results of the analysis including the full sample. The ORs were slightly attenuated for each of the network types except the *restricted, family-centered network* for which the effect estimates were slightly stronger, however, network type was not associated with 10-year risk of mortality. Age, sex, smoking status, and comorbidities remained important predictors of mortality status. Supplementary tables SM 4.3, SM 4.4 and SM 4.5 present results of the second set of sensitivity analyses for ADL disability, mobility, and mortality, respectively.

In the third sensitivity analysis, modeling the 5-year risk of ADL disability onset, the *partner-centered network* (OR: 0.60; 95% CI: 0.37, 0.99) and the *average network with partner* (OR: 0.59; 95% CI: 0.41, 0.86) had significantly lower odds of disability onset compared to the

diverse, supportive network with partner (see supplementary table SM 4.6). This association remained statistically significant even after controlling for sociodemographic and health-related confounders. As in the primary analysis, age, comorbidities, and physical activity were significant predictors of 5-year risk of disability onset. As shown in supplementary table SM 4.7, in the 10-year risk of ADL disability onset models which ignored the 5-year disability status, network type was not associated with disability onset although age, comorbidities, and physical activity continued to be significantly associated with disability onset.

For the mortality models, which contrasted the 5- to the 10-year risk of mortality, the two network types without a partner, *large, supportive network without partner* (OR: 2.13; 95% CI: 1.42, 3.20) and the *restricted, family-centered network without partner* (OR: 3.21; 95% CI: 2.22, 4.63) had significantly higher odds of mortality compared to the reference type at the 5-year mark. These associations attenuated but remained statistically significant after inclusion of sociodemographic and health-related confounders. Age, sex, education, comorbidities, and smoking status remained important predictors of mortality in the 5-year models. Unlike the 10-year models, those with higher cognitive function had significantly lower odds of mortality (OR: 0.73; 95% CI: 0.66, 0.80) in the 5-year model. Supplementary table SM 4.8 presents results of the sensitivity analysis for 5-year risk of mortality.

Models of the fourth sensitivity analysis examining dropout (results not shown), found no statistically significant association between network types and general dropout minimizing the possibility of bias due to selective attrition. Therefore, we did not employ inverse probability weighting in any of our analyses.

Discussion

We investigated the prospective association between social network types and functional health, determined by ADL disability and mobility, in a large cohort of older adults. Our findings indicate that the association between network types and functional health is somewhat equivocal. In contrast to our hypothesis that larger, more diverse, and more supportive network types would have a significantly lower risk of disability onset, there was no association between social network types and risk of ADL disability onset at wave 2 or 3 in the primary analysis. However, in the sensitivity analysis we observed a protective effect of the *partner-centered network* and the *average network with partner* on a 5-year risk of disability onset. Similarly, we observed an association between network type and mobility, such that older adults in the *restricted, family-centered network without partner* had significantly slower walking times than those in the *diverse, supportive network with partner* over time. These network types, however, did not have a longitudinal effect on change in mobility. In the sensitivity analysis, we observed no association between baseline network type and 10-year mortality risk in later life. However, in the analysis modeling the short- and long-term risk of mortality separately, older adults in the *restricted, family-centered network without partner* had a higher risk of mortality over the first 5 years of follow-up (wave 2).

Consistent with previous research in which *restricted* network types have been associated with increased disability and a higher risk of mortality whereas *diversified* network types have been associated with decreased disability,[19,26] we observed that the *restricted, family-centered network without partner* had significantly poor mobility and higher risk of mortality compared to the *diverse, supportive network with partner*. A major concern in existing studies of social networks and functional health is the lack of a clear unidirectional association due to use of

cross-sectional data.[38,39] Although social support is known to lower the risk of functional decline, disability and mobility limitations have also been shown to influence network formation.[40] Thus, while individuals in a *restricted* network may have worse health due to lack of support, it may also be the case that the poor health of individuals in the *restricted* network prevents them from maintaining extensive social ties. In an attempt to get around the problem of bi-directionality, we used longitudinal data where we established network types at baseline and measured the outcomes at follow-up waves. Specifically, for disability models we excluded individuals with ADL disability at baseline and modeled the risk of transition to initial onset of disability. For mobility models, to better maintain the integrity of the cohort we included mobility assessments at all three waves including the baseline wave. As a result, for mobility models there may be a greater chance of reverse causality, whereby baseline mobility may have influenced baseline network types.

The fact that we observe an effect of network type on risk of disability onset and mortality over a 5-year follow-up (i.e., at wave 2) but not a 10-year follow-up (i.e., at wave 3) might suggest that the health benefits or drawbacks of social networks are more pertinent during the short-term. It is also likely that the social networks of older adults have changed over the study period, such that the network types derived at baseline do not accurately reflect the network types older adults are embedded in at the 10th year of follow-up; assuming that the effect of one's social network is relatively short-lived, we would expect the baseline network types to be associated with health at 5th year of follow-up but not necessarily the 10th year of follow-up.

Another possible explanation for observing an effect of network types at a 5-year follow-up but not a 10-year follow-up may be that the association between functional health and network types has already played itself out. There may be a countervailing effect of support,

making network types an indicator of previously declining health in our study. In other words, previously declining health, such as preclinical disability, may have increased the dependence of individuals on their social networks for support, influencing the network types we observe at baseline. In particular, instrumental support appears to have an adverse effect on disability status such that older adults with more instrumental support exhibit a more rapid increase in disability risk over time.[41] Individuals in supportive network types may partly reflect a state of preclinical disability that precedes development of manifest disability in ADLs. Individuals with preclinical disability may reach out to their social ties for support with daily activities, which may gradually weaken their ability to perform these tasks on their own.[41] Reliance on others, particularly in an individualistic society like the United States, may also foster a sense of dependency and undermine an older adult's confidence in their ability to perform ADLs without assistance. An extension of this work may wish to consider the association between network type and disability in instrumental activities of daily living which reflect preclinical disability and are a risk factor of ADL disability.

Finally, perhaps the disability process itself is driven by disease rather than social networks such that the initial onset of disability is driven primarily by the biological mechanisms at the cellular level. Although behavioral adaptations, such as support from social networks, can slow down disability accumulation or severity progression, perhaps they do not play a crucial role in onset of functional disability. Certain isolated social network measures, such as increased diversity, have been associated with less decline in physical function over time lending support to the argument that social networks may be particularly relevant for progression of physical decline.[31] Future research should examine network types in relation to both accumulation (i.e., number of disabilities) as well as severity of disability.

Our study addresses one of the most important methodological challenges in social networks and health research – reverse causality. Studies using cross-sectional data may not be able to establish a causal association between network types and health status because of the reciprocal nature of the relationship. We used longitudinal data where network types were assessed at baseline and outcomes were measured over two follow-up waves spanning 10 years. The use of NSHAP data is another important strength of this analysis, as NSHAP provides rich subjective and objective social network data in a large, nationally representative sample of community-dwelling older adults. Detailed assessment of social networks in NSHAP allowed us to construct a multidimensional typology of social networks that provides a more nuanced and complete picture of the social networks of older adults. It also consists of a more recent sample of older adults in the US compared to previous studies of network types and health. A greater proportion of older adults live in isolation today as family networks have become smaller and more geographically dispersed. These secular trends have resulted in social networks among older adults that did not exist in prior cohorts, prompting the need to use more current data to examine the influence of social network patterns on health in old age.

Despite these strengths, the study involves a number of limitations that need to be considered. An important design issue is that attrition due to mortality or other forms of dropout during follow-up may produce biased estimates of the association between network type and functional health outcomes. In sensitivity analyses, we examined the association between network type and loss to follow-up and found that network types were not predictive of attrition. However, it should be noted that participants who dropped out of the NSHAP study after the first wave were less educated and more functionally impaired at baseline compared to the individuals who were included in follow-up waves.[42] Although NSHAP offers detailed social network data,

this advantage was offset by the relatively poor measurement of physical functioning in the study. Given the reciprocal nature of the association between social relationships and health, few waves of measurement (only 2 follow-up waves in NSHAP) conducted every 5 years may be insufficient to detect the complex relationship between social networks and functional health. The measurement of ADL disability was rather imprecise as the sample was restricted to at-risk individuals (i.e., those who were not disabled at baseline) and disability was treated as a dichotomous outcome (no disability vs any disability). This crude characterization may have masked the residual heterogeneity within finer disability categories that represent accumulation and severity of disability. Ideally, frequent repeated measurements over many years would allow us to appropriately detect subtle changes in physical function. There was also inconsistency in measurement of mobility across baseline and the follow-up waves which may have contributed partly to the lack of an association between network types and change in mobility over time.

Despite these limitations, this work adds to the current literature on social networks and functional health. Although our findings suggest that the effects of network types on functional health might not persist for up to 10 years, in the short term, consideration of social network resources may still offer opportunities for the prevention and postponement of common functional limitations in old age. Future studies should treat social network types as a time-varying exposure and examine its effect with functional decline outcomes to confirm whether social networks are indeed more relevant in the short-term.

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Tables

Table 4.1 Weighted Baseline Characteristics of the Total Sample and By Network Type

Network Types	*Total sample* N=3,004	*ADL disability onset** N=496	*Time to complete 6-meter walk (in seconds)* (Mean=10.3; SD=6.9)	*Deceased by W3* N=412	*Age* (Mean=69.3; SD=7.9)	*Female* N=1,547
	N (%)	*N (%)*	*Mean (S.D)*	*N (%)*	*Mean (S.D)*	*N (%)*
Diverse, supportive network with partner	933 (31)	186 (20)	9.8 (6.4)	122 (13)	67.5 (7.3)	523 (56)
Average network with partner	795 (27)	120 (15)	10.0 (7.6)	93 (12)	68.1 (7.5)	332 (42)
Partner-centered network	469 (16)	65 (14)	9.8 (4.9)	75 (16)	68.3 (7.6)	93 (20)
Large, supportive network without partner	474 (16)	79 (17)	11.5 (6.9)	71 (15)	71.9 (7.9)	384 (81)
Restricted, family-centered network without partner	332 (11)	46 (14)	12.5 (8.4)	50 (15)	72.6 (7.9)	215 (65)

* ADL disability onset at W2 or W3 among those at risk (N=2253) at W1.

Note. Other than the first column, row percentages are presented.

Table 4.2 Regression Models of Activities of Daily Living (ADL) Disability Onset by Network Type

	Model 1 (N = 1,759)		Model 2 (N = 1,759)		Model 3 (N = 1,756)	
Network types (*ref*: *Diverse, supportive network with partner*)	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	0.80	(0.58, 1.12)	0.79	(0.56, 1.10)	0.78	(0.54, 1.11)
Average network with partner	0.75	(0.54, 1.05)	0.74	(0.53, 1.03)	0.72	(0.52, 1.01)
Large, supportive network without partner	0.86	(0.57, 1.30)	0.84	(0.55, 1.26)	0.79	(0.52, 1.20)
Restricted, family-centered network without partner	1.00	(0.65, 1.55)	0.97	(0.62, 1.52)	0.95	(0.59, 1.53)
Sociodemographic covariates						
Age	1.04*	(1.02, 1.06)	1.04*	(1.02, 1.06)	1.03*	(1.02, 1.06)
Female	1.11	(0.84, 1.46)	1.11	(0.83, 1.47)	1.06	(0.79, 1.43)
Race/ethnicity (*ref: White*)						
Black	1.54	(0.95, 2.50)	1.37	(0.80, 2.35)	1.15	(0.63, 2.08)
Hispanic, non-Black	1.07	(0.64, 1.77)	0.88	(0.52, 1.50)	1.01	(0.58, 1.76)
Other	0.70	(0.33, 1.52)	0.68	(0.31, 1.50)	0.61	(0.26, 1.39)
Education (*ref: Bachelor's degree*)	.	.				
Less than high school			1.66	(1.00, 2.73)	1.45	(0.80, 2.63)
High school or equivalent			0.81	(0.52, 1.28)	0.73	(0.44, 1.21)
Vocational, some college, or associate's degree			1.05	(0.71, 1.54)	0.96	(0.66, 1.39)
Physical activity	.	.	.	.	0.86*	(0.76, 0.97)
Comorbidities (0-6)	.	.	.	.	1.42*	(1.25, 1.60)
Cognitve function	.	.	.	.	1.01	(0.85, 1.20)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.

*p-value $< .05$

Table 4.3 Longitudinal Regression Models of Walking Time by Network Type

	Model 1 (N=2,514)		Model 2 (N=2,514)		Model 3 (N=2,501)		Model 4 (N=2,377)	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Time (months since baseline) x 10^{-3}	0.22	0.34	0.41	0.37	0.51	0.37	0.63	0.37
Social Network Types (*ref: Diverse, supportive network with partner)*								
Partner-centered	0.03	0.02	0.06*	0.03	0.03	0.03	0.02	0.03
Average network with partner	0.02	0.02	0.02	0.02	0.01	0.02	-0.01	0.02
Large, supportive network without partner	0.08***	0.02	0.10***	0.03	0.07*	0.03	0.05	0.03
Restricted, family-centered network without partner	0.18***	0.03	0.21***	0.04	0.16***	0.03	0.13***	0.03
Partner-centered*Time x 10^{-3}	.	.	-0.51	0.33	-0.45	0.33	-0.43	0.33
Average network with partner*Time x 10^{-3}	.	.	-0.06	0.27	-0.06	0.26	0.06	0.26
Large, supportive network without partner*Time x 10^{-3}	.	.	-0.35	0.34	-0.31	0.34	-0.38	0.34
Restricted, family-centered network without partner*Time x 10^{-3}	.	.	-0.45	0.42	-0.48	0.42	-0.29	0.42
Covariates								
Age x 10^{-2}	1.04***	0.13	1.01***	0.13	0.76***	2.30	0.80***	0.13
Female	0.06***	0.02	0.06***	0.01	0.03*	0.01	0.02	0.01
Age*Time x 10^{-3}	0.08***	0.02	0.08***	0.02	0.08***	0.02	0.08***	0.02
Time (squared) x 10^{-5}	0.56*	0.25	0.56*	0.25	0.49	0.25	0.43	0.25
Age (squared) x 10^{-3}	0.23	0.13	0.22	0.13	0.38**	0.12	0.36**	0.12
Race/ethnicity (*ref: White*)								
Black	.	.	.	.	0.17***	0.02	0.14***	0.02
Hispanic, non-Black	.	.	.	.	0.05*	0.03	0.06**	0.02
Other	.	.	.	.	0.04	0.04	0.01	0.04
Education (*ref: Bachelor's degree*)								
Less than high school	.	.	.	.	0.18***	0.02	0.13***	0.02
High school or equivalent	.	.	.	.	0.10***	0.02	0.07***	0.02
Vocation, some college or associate's degree	.	.	.	.	0.05**	0.02	0.03	0.02
Employed	.	.	.	.	-0.08***	0.01	-0.07***	0.01
Physical activity	.	.	.	.	.	.	-0.04***	0.01
Comorbidities (0-6)	.	.	.	.	.	.	0.04***	0.01
BMI	.	.	.	.	.	.	0.01***	0.00
Cognitive function	.	.	.	.	.	.	-0.07**	0.02

Note. Partner-centered; Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.

*p-value < .05, **p-value < .01, ***p-value <.001

Supplementary Materials

Table SM 4.1 Weighted Baseline Sociodemographic and Health Characteristics by Network Type

Variable	*Total sample* N=3,004	*Diverse, supportive network with partner* N=933	*Average network with partner* N=795	*Partner-centered network* N=469	*Large, supportive network without partner* N=474	*Restricted, family-centered network without partner* N=332
	N (%) Mean (S.D.)	*N (%) Mean (S.D.)*	*N (%) Mean (S.D.)*	*N (%) Mean (S.D.)*	*N (%) Mean (S.D.)*	*N (%) Mean (S.D.)*
Time since baseline (in months)	66.12 (47.36)	66.48 (50.55)	67.68 (48.36)	65.01 (46.36)	66.79 (43.40)	60.12 (43.67)
Education						
Less than high school	557 (19)	106 (11)	120 (15)	105 (22)	119 (25)	108 (32)
High school or equivalent	810 (27)	229 (25)	214 (27)	129 (28)	135 (28)	102 (31)
Vocational certificate / some college or associate's degree	902 (30)	311 (33)	242 (30)	132 (28)	137 (29)	80 (24)
Bachelors or more	736 (25)	288 (31)	219 (28)	103 (22)	84 (18)	42 (13)
Currently employed						
Yes	1050 (35)	353 (38)	316 (40)	176 (38)	122 (26)	83 (25)
No	1954 (65)	580 (62)	478 (60)	293 (62)	353 (74)	249 (75)
Race/Ethnicity						
White	2416 (81)	807 (87)	643 (81)	357 (77)	372 (79)	235 (71)
Black	300 (10)	65 (7)	79 (10)	41 (9)	66 (14)	50 (15)
Hispanic, non-Black	205 (7)	41 (4)	56 (7)	54 (12)	21 (4)	32 (10)
Other	74 (2)	19 (2)	15 (2)	3 (3)	11 (2)	16 (5)
Physical Activity						
Never	260 (9)	59 (6)	44 (5)	33 (7)	59 (12)	66 (20)
Less than 1 time per week	196 (7)	59 (6)	45 (6)	34 (7)	36 (8)	23 (7)
1-2 times per week	187 (6)	60 (6)	65 (8)	18 (4)	23 (5)	22 (6)
3 or more times per week	2357 (79)	755 (81)	639 (81)	385 (82)	355 (75)	222 (67)
Smoking Status						
Current smoker	457 (15)	115 (12)	120 (15)	77 (16)	81 (17)	64 (19)
Non-smoker	2546 (85)	818 (88)	675 (85)	392 (84)	393 (83)	267 (81)
Number of comorbid conditions (0-6)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)
BMI (kg/m2)						
Underweight (< 18.5)	29 (1)	7 (1)	6 (1)	2 (0)	3 (1)	11(4)
Normal weight (18.5 - 24.9)	693 (25)	243 (27)	172 (23)	89 (21)	110 (24)	77 (26)
Overweight (25 - 29.9)	1013 (36)	314 (35)	288 (39)	157 (37)	157 (35)	97 (33)
Obese (> 30)	1072 (38)	337 (37)	271 (37)	172 (41)	180 (40)	111 (38)
Mild cognitive impairment	222 (7)	42 (4)	52 (7)	43 (9)	32 (7)	50 (15)

*denominator for the calculation of % does not include respondents with missing data on the variable.

Note: Percentages and N are presented for categorical variables and Means and Standard Deviations are presented for continuous variables.

Table SM 4.2 Regression Models of Mortality (10-year risk) by Network Type

	Model 1 (N = 2,337)		Model 2 (N = 2,337)		Model 3 (N = 2,334)	
Network types (*ref*: Diverse, supportive network with partner)	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	1.22	(0.77, 1.94)	1.19	(0.75, 1.90)	1.12	(0.70, 1.80)
Average network with partner	0.81	(0.58, 1.12)	0.80	(0.57, 1.11)	0.77	(0.55, 1.08)
Large, supportive network without partner	1.06	(0.73, 1.55)	1.04	(0.70, 1.54)	0.93	(0.61, 1.42)
Restricted, family-centered network without partner	1.35	(0.86, 2.12)	1.28	(0.81, 2.03)	1.16	(0.71, 1.88)
Sociodemographic covariates						
Age	1.13*	(1.11, 1.15)	1.13*	(1.11, 1.15)	1.13*	(1.11, 1.15)
Female	0.53*	(0.39, 0.73)	0.50*	(0.37, 0.68)	0.51*	(0.37, 0.69)
Race/ethnicity (*ref: White*)						
Black	1.25	(0.87, 1.80)	1.19	(0.81, 1.76)	1.01	(0.67, 1.53)
Hispanic, non-Black	0.76	(0.52, 1.10)	0.71	(0.47, 1.06)	0.75	(0.49, 1.15)
Other	1.00	(0.44, 2.24)	1.00	(0.45, 2.23)	0.92	(0.40, 2.12)
Education (*ref: Bachelor's degree*)						
Less than high school	.	.	1.63*	(1.15, 2.32)	1.53	(0.97, 2.42)
High school or equivalent	.	.	1.37	(0.95, 1.99)	1.33	(0.87, 2.05)
Vocational, some college, or associate's degree	.	.	1.68*	(1.18, 2.39)	1.49*	(1.03, 2.15)
Comorbidities (0-6)	.	.	.	.	1.34*	(1.21, 1.50)
Current smoker	.	.	.	.	2.68*	(1.84, 3.91)
Cognitve function	.	.	.	.	0.92	(0.79, 1.06)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.

*p-value < .05

Table SM 4.3 Regression Models of Activities of Daily Living (ADL) Disability Onset by Network Type Removing Respondents with Posterior Probability <0.95

	Model 1 (N = 1,350)		Model 2 (N = 1,350)		Model 3 (N = 1,347)	
Network types (*ref*: *Diverse, supportive network with partner*)	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	0.69	(0.47, 1.01)	0.68	(0.46, 0.99)	0.66	(0.44, 1.00)
Average network with partner	0.82	(0.57, 1.17)	0.81	(0.56, 1.17)	0.77	(0.54, 1.11)
Large, supportive network without partner	0.83	(0.52, 1.30)	0.82	(0.52, 1.29)	0.77	(0.48, 1.22)
Restricted, family-centered network without partner	1.03	(0.66, 1.61)	1.00	(0.64, 1.58)	0.96	(0.58, 1.58)
Sociodemographic covariates						
Age	1.05***	(1.03, 10.07)	1.05***	(1.03, 1.07)	1.04**	(1.02, 1.06)
Female	1.13	(0.82, 1.56)	1.13	(0.81, 1.59)	1.07	(0.75, 1.53)
Race/ethnicity (*ref: White*)						
Black	1.50	(0.93, 2.43)	1.35	(0.80, 2.29)	1.13	(0.63, 2.03)
Hispanic, non-Black	1.14	(0.57, 2.26)	0.95	(0.45, 1.99)	1.05	(0.47, 2.31)
Other	1.01	(0.42, 2.41)	1.01	(0.43, 2.38)	0.85	(0.34, 2.13)
Education (*ref*: *Bachelor's degree*)						
Less than high school	.	.	1.58	(0.91, 2.75)	1.55	(0.78, 3.10)
High school or equivalent	.	.	0.83	(0.52, 1.33)	0.79	(0.46, 1.34)
Vocational, some college, or associate's degree	.	.	1.07	(0.73, 1.57)	1.02	(0.71, 1.46)
Physical activity	.	.	.	.	0.90	(0.78, 1.04)
Comorbidities (0-6)	.	.	.	.	1.41***	(1.22, 1.61)
Cognitve function	.	.	.	.	0.96	(0.78, 1.18)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.
*p-value < .05, **p-value < .01, ***p-value < .001

Table SM 4.4 Longitudinal Regression Models of Walking Time by Network Type Removing Respondents with Posterior Probability <0.95

	Model 1 (N= 1944)		Model 2 (N= 1944)		Model 3 (N= 1934)		Model 4 (N = 1846)	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Time (months since baseline) x 10^{-3}	-0.02	0.39	0.21	0.02	0.28	0.41	0.39	0.05
Social network types (*ref: Diverse, supportive network with partner*)								
Partner-centered	0.02	0.02	0.06	0.03	0.03	0.03	0.03	0.03
Average network with partner	0.02	0.02	0.03	0.03	0.01	0.03	0.00	0.03
Large, supportive network without partner	0.09***	0.02	0.11**	0.03	0.08*	0.03	0.06	0.03
Restricted, family-centered network	0.19***	0.03	0.23***	0.04	0.18***	0.04	0.15***	0.04
Partner-centered*Time x 10^{-3}	.	.	-0.52	0.35	-0.43	0.35	-0.49	0.36
Average network with partner*Time x 10^{-3}	.	.	-0.12	0.31	-0.09	0.31	-0.07	0.31
Large, supportive network without partner*Time x 10^{-3}	.	.	-0.30	0.37	-0.26	0.36	-0.30	0.36
Restricted, family-centered network without partner*Time x 10^{-3}	.	.	-0.60	0.45	-0.61	0.45	-0.50	0.46
Covariates								
Age x 10^{-2}	1.07***	0.14	1.03***	0.15	0.79***	0.15	0.86***	0.15
Female	0.05**	0.02	0.05**	0.02	0.03	0.02	0.01	0.02
Age*Time x 10^{-3}	0.08***	0.02	0.08***	0.02	0.08***	0.02	0.07***	0.02
Time (squared) x 10^{-5}	0.64*	0.28	0.63*	0.28	0.57*	0.28	0.52	0.28
Age (squared) x 10^{-3}	0.27	0.14	0.27	0.14	0.40**	0.14	0.37*	0.14
Race/ethnicity (*ref: White*)								
Black	.	.	.	.	0.16***	0.02	0.13***	0.02
Hispanic, non-Black	.	.	.	.	0.03	0.03	0.04	0.03
Other	.	.	.	.	0.05	0.05	0.00	0.05
Education (*ref: Bachelors degree*)								
Less than high school	.	.	.	.	0.18***	0.02	0.18***	0.03
High school or equivalent	.	.	.	.	0.08***	0.02	0.09***	0.02
Vocation, some college or associate's degree	.	.	.	.	0.05*	0.02	0.02	0.02
Employed	.	.	.	.	-0.06***	0.02	-0.06***	0.02
Physical activity	.	.	.	.	.	.	-0.04***	0.01
Comorbidities (0 -7)	.	.	.	.	.	.	0.04***	0.01
BMI	.	.	.	.	.	.	0.01***	0.00
Cognitive function	.	.	.	.	.	.	-0.03***	0.01

Notes. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.

**p-value* < .05, ***p-value* < .01, ****p-value* < .001

Table SM 4.5 Regression Models of Mortality (10-year risk) by Network Type Removing Respondents with Posterior Probability <0.95

	Model 1 (N = 1,806)		Model 2 (N = 1,806)		Model 3 (N = 1,803)	
Network types (*ref*: Diverse, supportive network with partner)	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	1.21	(0.70, 2.10)	1.21	(0.70, 2.09)	1.13	(0.65, 1.98)
Average network with partner	0.81	(0.56, 1.17)	0.80	(0.55, 1.16)	0.76	(0.52, 1.13)
Large, supportive network without partner	1.06	(0.71, 1.58)	1.05	(0.70, 1.56)	0.94	(0.61, 1.44)
Restricted, family-centered network without partner	1.49	(0.93, 2.39)	1.45	(0.90, 2.34)	1.35	(0.82, 2.22)
Sociodemographic covariates						
Age	1.13***	(1.11, 1.16)	1.13***	(1.11, 1.15)	1.13***	(1.11, 1.16)
Female	0.54**	(0.38, 0.78)	0.52**	(0.36, 0.73)	0.50**	(0.35, 0.72)
Race/ethnicity (*ref: White*)						
Black	1.41	(0.96, 2.06)	1.36	(0.90, 2.06)	1.17	(0.75, 1.82)
Hispanic, non-Black	0.65	(0.41, 1.03)	0.61	(0.38, 1.00)	0.62	(0.38, 1.00)
Other	1.21	(0.41, 3.55)	1.23	(0.42, 3.58)	1.21	(0.39, 3.75)
Education (*ref: Bachelor's degree*)						
Less than high school	.	.	1.43	(0.95, 2.14)	1.46	(0.87, 2.46)
High school or equivalent	.	.	1.22	(0.77, 1.92)	1.26	(0.75, 2.12)
Vocational, some college, or associate's degree	.	.	1.55*	(1.05, 2.29)	1.44	(0.97, 2.16)
Comorbidities (0-6)	.	.	.	.	1.37***	(1.20, 1.57)
Current smoker	.	.	.	.	2.36***	(1.56, 3.58)
Cognitve function	.	.	.	.	0.90	(0.78, 1.04)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.
*p-value < .05, **p-value < .01, ***p-value < .001

Table SM 4.6 Regression Models of 5-year Risk of Activities of Daily Living (ADL) Disability Onset by Network Type

	Model 1 (N = 1,727)		Model 2 (N = 1,727)		Model 3 (N = 1,724)	
Network types (*ref*: *Diverse, supportive network with partner*)	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	0.60*	(0.37, 0.99)	0.58*	(0.35, 0.97)	0.57*	(0.33, 0.97)
Average network with partner	0.59**	(0.41, 0.86)	0.58*	(0.40, 0.83)	0.58*	(0.40, 0.83)
Large, supportive network without partner	0.81	(0.51, 1.31)	0.78	(0.48, 1.25)	0.75	(0.46, 1.22)
Restricted, family-centered network without partner	1.40	(0.82, 2.38)	1.33	(0.76, 2.33)	1.30	(0.73, 2.31)
Sociodemographic covariates						
Age	1.04***	(1.02, 1.06)	1.04*	(1.01, 1.06)	1.03*	(1.01, 1.05)
Female	1.11	(0.77, 1.59)	1.10	(0.76, 1.59)	1.05	(0.72, 1.54)
Race/ethnicity (*ref: White*)						
Black	1.62*	(1.11, 2.39)	1.40	(0.91, 2.14)	1.15	(0.71, 1.86)
Hispanic, non-Black	0.68	(0.38, 1.220	0.55	(0.29, 1.03)	0.59	(0.30, 1.15)
Other	0.43	(0.13, 1.46)	0.41	(0.11, 1.45)	0.37	(0.10, 1.32)
Education (*ref: Bachelor's degree*)						
Less than high school	.	.	1.93*	(1.12, 3.30)	1.85	(1.00, 3.43)
High school or equivalent	.	.	0.89	(0.53, 1.51)	0.86	(0.49, 1.52)
Vocational, some college, or associate's degree	.	.	1.08	(0.69, 1.68)	0.99	(0.64, 1.53)
Physical activity	.	.	.	.	0.85*	(0.75, 0.98)
Comorbidities (0-6)	.	.	.	.	1.35***	(1.18, 1.54)
Cognitve function	.	.	.	.	0.94	(0.79, 1.13)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.
*p-value < .05, **p-value < .01, ***p-value < .001

Table SM 4.7 Regression Models of 10-yeark Risk of Activities of Daily Living (ADL) Disability Onset by Network Type

	Model 1 (N = 1,264)		Model 2 (N = 1,264)		Model 3 (N = 1,263)	
Network types (*ref*: *Diverse, supportive network with partner*)	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	1.01	(0.66, 1.85)	1.10	(0.64, 1.88)	1.11	(0.61, 2.01)
Average network with partner	0.85	(0.47, 1.54)	0.83	(0.46, 1.51)	0.80	(0.43, 1.47)
Large, supportive network without partner	1.02	(0.56, 1.85)	0.98	(0.53, 1.80)	0.93	(0.50, 1.74)
Restricted, family-centered network without partner	0.85	(0.46, 1.59)	0.82	(0.43, 1.54)	0.74	(0.37, 1.49)
Sociodemographic covariates						
Age	1.07***	(1.05, 1.10)	1.07***	(1.05, 1.10)	1.07***	(1.04, 1.10)
Female	0.95	(0.69, 1.31)	0.92	(0.67, 1.26)	0.87	(0.63, 1.21)
Race/ethnicity (*ref: White*)						
Black	1.41	(0.66, 3.02)	1.29	(0.55, 2.99)	1.01	(0.38, 2.64)
Hispanic, non-Black	1.11	(0.60, 2.08)	0.91	(0.45, 1.84)	1.08	(0.52, 2.22)
Other	0.93	(0.32, 2.66)	0.88	(0.30, 2.58)	0.78	(0.25, 2.45)
Education (*ref: Bachelor's degree*)						
Less than high school	.	.	1.63	(0.87, 3.06)	1.51	(0.70, 3.22)
High school or equivalent	.	.	0.74	(0.44, 1.23)	0.69	(0.39, 1.20)
Vocational, some college, or associate's degree	.	.	1.26	(0.85, 1.88)	1.13	(0.76, 1.67)
Physical activity	.	.	.	.	0.83*	(0.72, 0.96)
Comorbidities (0-6)	.	.	.	.	1.52***	(1.29, 1.80)
Cognitve function	.	.	.	.	0.95	(0.77, 1.16)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.
*p-value < .05, **p-value < .01, ***p-value < .001

Table SM 4.8 Regression Models of Mortality (5-year risk) by Network Type

	Model 1 (N = 2,982)		Model 2 (N = 2,982)		Model 3 (N = 2,979)	
Network types (*ref*: Diverse, supportive network with partner)	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	1.72*	(1.18, 2.50)	1.60*	(1.10, 2.33)	1.37	(0.91, 2.04)
Average network with partner	1.41	(0.96, 2.06)	1.37	(0.93, 2.01)	1.31	(0.88, 1.97)
Large, supportive network without partner	2.13**	(1.42, 3.20)	1.99**	(1.33, 2.98)	1.77*	(1.18, 2.65)
Restricted, family-centered network without partner	3.21***	(2.22, 4.63)	2.85***	(1.95, 4.16)	2.30***	(1.53, 3.44)
Sociodemographic covariates						
Age	1.08***	(1.06, 1.10)	1.07***	(1.05, 1.09)	1.07***	(1.05, 1.09)
Female	0.64**	(0.47, 0.87)	0.60**	(0.43, 0.82)	0.55**	(0.39, 0.78)
Race/ethnicity (*ref: White*)						
Black	1.03	(0.71, 1.50)	0.86	(0.58, 1.29)	0.68	(0.45, 1.02)
Hispanic, non-Black	0.67*	(0.46, 0.97)	0.52*	(0.33, 0.82)	0.51*	(0.29, 0.91)
Other	0.90	(0.42, 1.94)	0.87	(0.42, 1.77)	0.71	(0.35, 1.42)
Education (*ref: Bachelor's degree*)						
Less than high school	.	.	2.52***	(1.66, 3.81)	3.34***	(2.14, 5.21)
High school or equivalent	.	.	1.83**	(1.24, 2.69)	2.11**	(1.41, 3.17)
Vocational, some college, or associate's degree	.	.	1.38	(0.94, 2.01)	1.22	(0.81, 1.83)
Comorbidities (0-6)	.	.	.	.	1.39***	(1.24, 1.56)
Current smoker	.	.	.	.	2.51***	(1.72, 3.67)
Cognitve function	.	.	.	.	0.73***	(0.66, 0.80)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.
*p-value < .05, **p-value < .01, ***p-value < .001

CHAPTER 5

Social Network Typology and Cognitive Impairment Among Older Adults

Introduction

Cognitive change is a common albeit not inevitable part of aging. Certain cognitive abilities do not deteriorate and, in fact, may even improve with age, such as vocabulary.[1] Other abilities tend to decline gradually with age, including conceptual reasoning, memory, and processing speed.[1] Milder forms of certain age-related cognitive change do not impair an individual's ability to perform daily activities.[1] However, some cognitive changes that occur with age can be pre-symptomatic and lead to mild cognitive impairment (MCI). MCI is associated with reduced productivity, independence, and quality of life for older adults, as well as with an increased risk of developing Alzheimer's disease and related dementias (ADRD).[2]

More than 16 million people in the United States are living with cognitive impairment. An estimated 5.1 million Americans aged 65 years or older currently have Alzheimer's disease and this number is expected to rise to 13.2 million by 2050.[3] People with cognitive impairment report more than three times as many hospital-stays as individuals who are hospitalized for some other conditions.[3] Despite increasing concern about the enormous burden of cognitive impairment, there is significant variability in age-related cognitive changes among older adults and the risk of developing dementia among those with MCI is not inevitable. The variability in cognitive change across older adults can be attributed to genetic, environmental, and lifestyle factors that affect the brain across the life course. While some of these factors, such as genetics,

cannot be altered, others, such as lifestyle factors including participation in intellectually engaging activities, physical activity, and social engagement, may be modifiable.[2]

Social networks and cognitive function

Among modifiable risk factors, a growing body of research suggests that older adults' patterns of social engagement protect against cognitive impairments. A larger social network is associated with a lower risk of dementia.[4,5] Similarly, more frequent contact with friends and family, greater community engagement, participation in social and leisure activities, and access to social resources is protective against cognitive impairment[6,7] and dementia.[8–10] In contrast, a smaller network size, a lack of close social ties, and living alone are associated with poorer cognitive function[11–13] and a higher risk of dementia.[5] In addition, neuroimaging studies have shown that older adults with smaller social networks are more likely to have severe ventricular enlargement and white matter hyperintensities, which are considered pathological markers of dementia.[14] Similarly, smaller family networks and less social support are independently associated with severe ventricular enlargement.[14]

The association between perceived emotional support and cognitive decline is less clear with some studies finding evidence for a protective effect of emotional support on cognitive functioning[15] and others finding no such evidence.[16] Similarly, although the association between some structural network features, such as size and contact frequency, and cognitive function appears unequivocal when considered in isolation, that is not necessarily the case. For instance, the ability to call on a diverse set of social relationships in response to specific needs confers long-term benefits, over and above network size. Older adults with more diverse social networks, regardless of network size, have higher cognitive function compared to those with less diverse networks.[17] Additionally, older adults with lower perceived satisfaction, regardless of the

frequency of contact with ties, may have a higher risk of dementia compared to those with higher perceived satisfaction.[5]

Several biological mechanisms have been proposed to explain the protective effects of social networks on cognitive function. One putative mechanism pertains to the degree to which participation in social or leisure activities keeps the brain active and stimulated. According to the notion of "use it or lose it", this helps maintain cognitive reserve and delay cognitive atrophy.[11,18] Social networks can also affect the risk of cognitive decline through cardiovascular mechanisms which are involved in the pathogenesis and progression of dementia. Through the sharing of health behaviors, such as physical activity and obesity, social networks can reduce the risk of not only cardiovascular disease and vascular disorders but also dementia.[11,14,19] Stress is another underlying mechanism through which social networks affect cognitive decline. Individuals with more frequent contact and social integration receive social support and experience more positive emotional states such as self-esteem, social competence, and adequate mood, which can prevent stress-related cognitive decline.[11,14,19]

Network types and cognitive function

Most of what we know about social relationships and their health effects comes from studies that focus on limited, isolated dimensions of social networks rather than using a broad set of interrelated characteristics.[11] A variable-centered approach, focused on specific characteristics of the network, does not comprehensively capture the structure of older adults' social networks.[20] For example, social networks that are similar in size may comprise different levels of diversity and support, which would provide distinct social environments.[17] Although a variable-centered approach is informative, adding up individual network characteristics (e.g., network size) does not equate to the effect of being embedded in a network with a particular array of attributes (e.g.,

small network size with high diversity and high emotional support).[21] Instead, it may be more informative to take a pattern-centered approach and examine types of social networks by grouping people with a similar pattern of network characteristics together, especially among older adults for whom social relationships may be particularly heterotypic.[21] There is likely to be considerable variation in patterns of social relations and their adaptiveness for older adults, and network types allow us to capture this variation. Simultaneous consideration of multiple aspects of social function may also provide a better understanding of the cognitive consequences of lower social connectedness.

Network types have been shown to predict mental health outcomes among older adults such as depressive symptomatology,[21] morale,[22] anxiety, loneliness, and happiness.[23] One common finding is that social network types characterized by access to various social resources, such as a *diverse* network type, are associated with better psychological wellbeing than more *restricted* network types. For example, the prevalence of depressive symptomatology was lowest among older adults with *diverse* networks.[21,24] Compared with a *restricted* network type, *diverse*, *friend-centered*, and *religious activity-centered* network types are associated with lower anxiety and greater happiness among older adults.[23] In contrast, older adults with *restricted* social networks consistently report poorer mental health,[21,24] a lower level of well-being,[23] and a higher likelihood of mortality relative to older adults whose social network types feature greater connectedness with close others.[25] Findings with regard to *family* networks are inconsistent with some studies reporting higher depressive symptoms in the *family* network type[26] and others reporting higher well-being among the *children* and *spouse and children* network types[27] compared to the *non-family* network types.

Most prior research has rarely considered the inclusion of functional characteristics, such as perceived support and relationship satisfaction. Social ties can be supportive and thus buffer the stress of adverse life events; nevertheless, social ties can themselves be a source of stress and may, in turn, contribute to poorer mental health and cognitive function.[26] Furthermore, most network typology studies have been conducted primarily in Europe and Israel. Because social networks are likely shaped by societal structures and culture, we would expect network types and their association with mental health and cognitive function in the United States to be somewhat different from the network types observed elsewhere. Finally, previous studies have relied almost exclusively on cross-sectional data which raise the possibility of reverse causality whereby changes in mental health and cognition produce changes in network type. Given the mental and emotional health effects of network types, we would expect network types to also have an effect on cognitive function. However, no study to our knowledge has evaluated whether social network types are associated with cognitive function among older adults.

Scope of current study

In the current study, we attempt to address these gaps in the literature. Specifically, using data from the National Social Life, Health, and Aging Project, a large nationally-representative sample of community-dwelling older adults in the United States, we examine the association between social network types and cognitive function over a 10-year follow-up period. We posit that the influence of social networks on cognitive function would reflect previous findings which suggest that smaller network size, less diversity, less support, and lower satisfaction in relationships are associated with poorer cognitive function. Specifically, we hypothesize that older adults whose networks are characterized by greater size and diversity, and more social

support would be less likely to develop cognitive impairment over time relative to those whose networks are more restricted in terms of size, diversity, or support.

Methods

Sample and data collection

Data for this analysis come from the National Social Life, Health and Aging Project (NSHAP). NSHAP is a prospective cohort study of a nationally representative sample of community-dwelling adults aged 57-85 years old. Participants were recruited using a complex, multi-stage area probability sample with oversampling of African Americans, Latinos, men, and the oldest old (75-85 years at the time of screening).[28] NSHAP excluded people with known cognitive impairment from participation during the screening. The first examination (Wave 1) took place between 2005 and 2006, and two follow-up examinations occurred in 2010-2011 (Wave 2) and 2015-2016 (Wave 3). A total of 3,005 participants were recruited for the original cohort and completed interviews at Wave 1, for a weighted response rate of 75.5%. Of these, 2,261 (75%) also completed interviews at Wave 2. 430 (14%) of the original cohort were deceased by Wave 2 and the remaining 314 (10%) were lost to follow-up due to poor health or other unknown reasons. 1,592 (53%) of the original cohort completed interviews at Wave 3. Of the surviving Wave 1 respondents, 463 (15%) of the original cohort were deceased by Wave 3 and the remaining 330 (11%) were lost to follow-up. Data collection comprised of a face-to-face interview including a brief self-administered questionnaire, in-home collection of biomeasures, and a leave-behind questionnaire. For this analysis of cognitive impairment onset, we excluded individuals with cognitive impairment, as determined by their results on the cognitive tests, at baseline ($N = 251$, 8%) and those with missing outcome data due to non-response or attrition (22%), leaving 2,163 individuals available for analyses.

Social network types

Social networks of older adults were assessed using network types constructed for individuals at baseline, in a previous analysis.[29] Five network types were derived by means of a latent class analysis: *diverse, supportive network with partner*; *average network with partner*; *partner-centered network*; *large, supportive network without partner*; and *restricted, family-centered network without partner*. The criterion variables used for the delineation of the network types included nine observed variables representing three dimensions of social networks: network structure (network size, diversity, and frequency of contact), network function (involvement of network members in health discussions, emotional closeness, social support from partner, social support from family, and social support from friends) and relationship quality (social strain from partner).

Diverse, supportive network with partner (33%). Respondents in this type had a large and diverse network with frequent contact with social ties. Older adults reported a high level of emotional closeness, a high likelihood of discussing health problems with confidants, and high support from all three major relationship types: partner, family, and friends. Compared to other network types, a smaller proportion of respondents in this type reported experiencing high strain in the partner relationship.

Average network with partner (26%). Respondents in this type reported medium levels of diversity, emotional closeness, and likelihood of discussing health problems with their confidants, hence the name average network. Although older adults in this type were more likely to experience high rather than low levels of support from partner and family, they reported experiencing medium levels of support from friends.

Partner-centered network (14%). Respondents in this type reported low levels of network diversity, low frequency of contact, and a low likelihood of discussing health problems with confidants. A distinctive feature of this type was the high levels of support received from partner compared to other relationships. At the same time, respondents in this type were more likely to report experiencing high strain in the partner relationship compared to the other network types.

Large-supportive network without partner (18%). Respondents in this type had a large network and reported high levels of emotional closeness and high likelihood of discussing health problems with confidants. Respondents in this network did not have a partner and relied heavily on family and friends for support.

Restricted, family-centered network without partner (11%). Respondents in this type did not have a partner and had very little diversity in their network. Older adults reported low frequency of contact, low emotional closeness, and low likelihood of discussing health problems with confidants. A distinctive feature of this type was the increased reliance on family, but not friends, for support.

Cognitive function

In Wave 1, cognitive function was assessed using the Short Portable Mental Health Questionnaire (SPSMQ) in the face-to-face interview. SPMSQ, a 10-question cognitive screening measure, was originally designed to identify organic brain deficiency.[30] Respondents were asked to recall the current date (1 point) and day of the week (1 point), place (1 point), personal address and contact information (1 point), their age (1 point) and date of birth (1 point), current (1 point) and former (1 point) presidents of the United States, and their mother's name (1 point). Next, respondents were asked to subtract 3 from 20 and to keep subtracting 3 from each

new number all the way down (1 point). Number of errors (range: 0-10) across the 10 questions were summed for each participant and the final scoring, accounting for education, was used to classify participants as having: *intact intellectual functioning* (0-2 errors)*, mild intellectual impairment* (3-4 errors)*, moderate intellectual impairment* (5-7 errors)*, and severe intellectual impairment* (8-10 errors).[30] Participants with *intact intellectual functioning* were considered as having no cognitive impairment at baseline.

In Waves 2 and 3, overall global functioning was assessed using the Chicago Cognitive Function Measure (CCFM), which has been adapted from the Montreal Cognitive Assessment (MoCA).[31] The CCFM was available for use in English and Spanish among NSHAP participants. Respondents were evaluated on 8 cognitive domains: Orientation: today's day and month (2 points total); Naming: animal recognition (1 point); Executive function: Trail Making Test Part B (1 point); Visuo-construction skills: clock (3 points); Memory delayed recall: five words (5 points); Attention: forward digit span (1 point), backward digit span (1 point), and serial 7s (3 points); Language: sentence repetition (1 point) and verbal fluency (1 point); and Abstraction: similarity between items (1 point). Summing across different domains of performance, the composite CCFM score can range from 0–20 points, with higher scores indicating better global cognitive functioning.[31] CCFM scores are highly correlated with MoCA scores (Pearson's r = 0.97) and can be projected to MoCA scores using the equation: MoCA = (1.14 × CCFM) + 6.83.[31] MoCA has good internal validity and high test-retest reliability.[32] In this analysis, CCFM scores were projected to MoCA scores and a cut-off score of 26 (on a scale of 0-30) on the MoCA was used to identify individuals who experienced onset of cognitive impairment (i.e., individuals scoring 25 or below) in Waves 2 and 3.[32]

Covariates

Covariates were measured at baseline to control for potential confounding. These included sociodemographic variables: age (in years), sex (male, female), race/ethnicity (White; Black; Hispanic, non-Black; Other), and educational attainment (less than high school; high school diploma or equivalent; vocational, some college, or associate's degree; bachelor's degree or higher); and health variables: disability (0 or 1) in activities of daily living (ADL) and comorbidities (0 to 6 conditions).

Statistical analysis

Social network types were used to predict risk of cognitive impairment onset using a logistic regression model where the outcome, onset of any impairment, was binary. The five social network types were entered in the model as four dummy variables, with *diverse, supportive network with partner* serving as the reference group. Cognitive impairment status at baseline was used to identify respondents at risk; we excluded individuals who had any impairment at baseline ($N = 251$). Then, among those at risk ($N = 2{,}753$) we examined the odds of developing cognitive impairment at either of the two follow-up waves in the same model. Confounders were entered into the models in stages: the initial regression model was unadjusted; the next model adjusted for demographic covariates of age, sex, and race/ethnicity; the following model adjusted for educational attainment; and the final model additionally adjusted for ADL disability and comorbidities.

Sensitivity analysis. To determine the robustness of our findings, we conducted three sets of sensitivity analyses. In the first sensitivity analysis, we examined the association of network types with cognitive impairment onset using a cut-off of 23/30 because some studies, including a

recent meta-analysis, have indicated that the originally suggested MoCA cutoff score of 26/30 leads to an inflated rate of false positives.[34]

In the second set of sensitivity analyses, we restricted the analysis to those respondents who had a relatively high posterior probability of membership for their respective classes. In LCA, every respondent receives a posterior probability of membership in each of the latent classes based on their observed characteristics. Each respondent is then assigned to the class for which they have the highest posterior probability of membership. In our study, the maximum probabilities for belonging to a class were generally high (Mean = 0.95), indicating high certainty in the assignment of respondents to a class. We excluded 663 (22%) respondents for whom the highest probability of membership in their respective assigned class was less than 0.95 to get an even more well-determined class assignment. We re-ran the regression models with the restricted sample to determine whether the association between network types and cognitive impairment onset remains unchanged.

In the third set of sensitivity analyses, we modeled the risk of cognitive impairment onset at Wave 2 (5-year), and separately at Wave 3 (10-year) ignoring cognitive function status at Wave 2. Our goal was to determine if the effect of network types on cognitive impairment is relevant in the short-term (5 years) or the long-term (10 years). The primary analysis did not allow us to make this distinction. Previous studies of social relationships show both short- and long-term effects on health, with intervention studies primarily showing short-term beneficial effects of social relationships on health.[33]

All statistical analyses accounted for stratification and clustering of the NSHAP sample design, unequal probabilities of selection, and nonresponse to calculate weighted, nationally representative population estimates and standard errors. Analyses were conducted in SAS 9.4.

Results

Baseline characteristics

Baseline descriptive data on the distribution of cognitive impairment and demographic covariates by social network type are presented in Table 5.1. The *diverse, supportive network with partner* (33%) and the *average network with partner* (26%) were the most prevalent network types, with the remaining network types each accounting for less than a fifth of the sample. The average age of the sample at baseline was 67 years (SD=8) and approximately half of the sample was female (52%). Of the 3,005 participants interviewed at baseline, 2,753 (92%) had intact intellectual functioning and were therefore at risk of developing cognitive impairment. 1,768 (64%) of those at risk developed cognitive impairment during one of follow-up waves.

Across the five network types a smaller percentage of those in the *diverse, supportive network with partner* (73%), compared to the other network types, experienced cognitive impairment onset at one of the follow-up waves. Individuals in the *diverse, supportive network with partner* were also slightly younger on average (Mean = 66; SD = 7) compared to the other network types. Of the five network types, *large, supportive network without partner* (86%) had the highest proportion of females and the *partner-centered network* (20%) had the lowest proportion of females.

Please see supplementary table SM 5.1 for more detailed characteristics of the sample broken down by network type, including socioeconomic and health related variables that were included in the analyses.

Cognitive impairment onset by network type

Table 5.2 presents results of the logistic regression models examining the association between social network types and cognitive impairment onset. In the unadjusted model (Model

1) older adults in the *partner-centered network* (OR: 1.77; 95% CI: 1.19, 2.61) and the *restricted, family-centered network without partner* (OR: 1.95; 95% CI: 1.27, 2.99) had significantly higher odds of any cognitive impairment onset compared to the *diverse, supportive network with partner.* However, adjustment for baseline age, sex, and race/ethnicity render these associations insignificant (Model 2). Further adjustment for education (Model 3) and health variables (Model 4) attenuated the associations and they remained insignificant. Among background variables, age, sex, race/ethnicity, education, and comorbidities were important predictors of cognitive impairment onset. In the fully-adjusted model (Model 4), a one-year increase in age was associated with 5% (95% CI: 1.03, 1.08) higher odds of impairment onset and those with one additional comorbid condition had 16% (95% CI: 1.02, 1.31) higher odds of cognitive impairment onset. In contrast, females had 48% (95% CI: 0.38, 0.72) lower odds of cognitive impairment onset compared to males. Blacks (OR: 4.15; 95% CI: 2.39, 7.21), Hispanic non-Blacks (OR: 2.55; 95% CI: 1.17, 5.53), and those of Other (OR: 3.22; 95% CI: 1.08, 9.64) racial/ethnic groups also had significantly higher odds of cognitive impairment compared to Whites. Those with less than high school education (OR: 8.15; 95% CI: 3.93, 16.90), high school or equivalent education (OR: 2.03; 95% CI: 1.39, 2.97), and a vocational, some college or associate's degree (OR: 1.96; 95% CI: 1.40, 2.73) also had significantly higher odds of cognitive impairment compared to those with a Bachelor's degree.

Sensitivity analysis

Sensitivity analyses demonstrated qualitatively similar findings when a cut-off of 23/30 was used, when individuals with low class membership probabilities were excluded, and when odds of cognitive impairment onset were modeled separately for Wave 2 and Wave 3 (Tables SM 5.2, 5.3, 5.4, and 5.5 in the Supplement).

Models of the first sensitivity analysis (Table SM 5.2) using a cut-off of 23/30, had results very similar to the primary analysis with the *partner-centered network* (OR: 1.72; 95% CI: 1.25, 2.36) and *restricted, family-centered network without partner* (OR: 2.30; 95% CI: 1.57, 3.39) exhibiting higher odds of cognitive impairment onset in the unadjusted model. However, unlike the primary analysis, the *large, supportive network without partner* (OR: 1.62; 95% CI: 1.22, 2.16) also had significantly higher odds of cognitive impairment onset compared to the *diverse, supportive network with partner.* Once baseline characteristics were included in the models, the association between network types and cognitive impairment was no longer statistically significant. Age, sex, race/ethnicity, and education remained important predictors of cognitive impairment onset, however, number of comorbid conditions was no longer associated with cognitive impairment.

In the second sensitivity analysis (Table SM 5.3), focusing on participants with well-determined network type membership, the ORs were slightly attenuated for the *average network with partner* and the *large, supportive network without partner*, whereas the effect estimates for the *partner-centered network* and the *restricted, family-centered network without partner* were slightly stronger. However, similar to the main analysis, there was no statistically significant association between any of the network types and cognitive impairment onset in the presence of sociodemographic and health-related confounders. Age, sex, race/ethnicity, education, and comorbidities continued to be significantly associated with cognitive impairment onset.

In the third sensitivity analysis, modeling the 5-year risk of cognitive impairment onset (Table SM 5.4), the *partner-centered network* (OR: 1.99; 95% CI: 1.38, 2.85), the *large, supportive network without partner* (OR: 1.74; 95% CI: 1.19, 2.55) and the *restricted, family-centered network without partner* (OR: 1.96; 95% CI: 1.33, 2.88) had significantly higher odds

of cognitive impairment onset compared to the *diverse, supportive network with partner* before adjustment of any covariates. As in the primary analysis, adjustment for baseline age, sex, and race/ethnicity rendered these associations insignificant. In the 10-year risk of cognitive impairment onset models (Table SM 5.5), which ignored the 5-year cognitive impairment status, the *large, supportive network without partner* (OR: 1.67; 95% CI: 1.04, 2.66) had significantly higher odds of cognitive impairment onset. However, the association was no longer statistically significant once baseline sociodemographic variables were included. Age, sex, race/ethnicity, education, and comorbidities continued to be significantly associated with cognitive impairment.

Discussion

In this large, nationally-representative sample, social network types were not associated with onset of cognitive impairment during the 10-year study. Although unadjusted analyses suggested a higher risk of cognitive impairment onset among those in one of the two *restricted* network types: *partner-centered network* and *restricted, family-centered network without partner*, adjustment for sociodemographic and health-related background characteristics rendered these associations insignificant. The results were generally robust to a MoCA cut-off of 23/30, to exclusion of individuals with low class membership probabilities, and to modeling of cognitive impairment onset separately for Wave 2 and Wave 3.

Unlike previous studies of network types focused on outcomes of mental and emotional health, we examined the effect of a multidimensional network typology on cognitive function. Existing work demonstrates that *diverse* network types have better mental and emotional health compared to the *restricted* network types.[21,23,24] Although unadjusted analyses in our study also showed similar results for cognitive function, the association was no longer significant after

adjustment for potential confounding variables. There are a few likely explanations for the discrepancy in findings between the current and prior studies.

First, most previous studies were cross-sectional in nature and therefore unable to exclude the possibility of reverse causation. It is likely that social relationships and mental health are associated bidirectionally: socially well-connected older adults may have better mental health as a result of the support received from connections and through participation in cognitively stimulating relationships; at the same time, older adults with better mental health may be more capable of developing and maintaining social connections. Therefore, it is possible that older adults observed to be in *diverse* networks in prior studies were ones who were less depressed and had higher cognitive function which allowed them to maintain many supportive relationships; in contrast, adults who were more depressed and had lower cognitive function were incapable of maintaining many supportive relationships and therefore had a *restricted* network.

Second, it is possible that the association between cognitive function and network types may have already played itself out. Previously declining health, such as preclinical cognitive decline, may have increased the dependence of older adults on their social networks for support, influencing the network types observed at baseline. As a result, individuals in the *diverse* networks in our study may partly reflect a state of preclinical cognitive impairment that precedes development of manifest impairment. In other words, the potential benefits of being in a *diverse* network are not observed in our sample because at-risk individuals selected into this network type before we could detect signs of impairment.

Lastly, previous studies examined outcomes of mental and emotional health such as depression, morale, well-being, and happiness. It is possible that while social networks are associated with these outcomes, they are not associated with cognitive decline. However, this

seems less likely given that isolated network characteristics, such as network size and diversity, have been associated with cognitive decline, lending support to the notion that social networks are particularly relevant for cognitive function in older adults.[17] Furthermore, mental and emotional health may be potential mediators of the association between social networks and cognitive function.[15] In addition to network types having an influence on mental and emotional health, outcomes of mental and emotional health including self-efficacy and depressive symptomology have been shown to affect cognitive function.[16,35] Given that network types have been associated with mental and emotional health which are potential risk factors of cognitive function, it would be reasonable to assume an association between network types and cognitive function, even if the magnitude of that association is small.

The primary strength of our study is the use of a large, nationally-representative data set with comprehensive assessment of social networks of older adults. Detailed assessment of various aspects of one's network, including characteristics representing structure, function, and quality of relationships allowed the construction of a multidimensional network typology. The use of network types, in turn, allowed us to examine the effect of the network as a whole on cognitive function. Furthermore, use of longitudinal data allowed us to circumvent the issue of reverse causality to some extent. Given that cognitive function can influence one's ability to develop and maintain social relationships, by measuring network types at baseline and cognitive function at follow-up waves among those at-risk, we minimize the possibility that baseline network types were influenced by cognitive function.

The results of this study should be viewed in light of potential limitations. First, although NSHAP has good quality data on social networks, the assessment of cognitive function is inconsistent across waves. At baseline, SPMSQ which is primarily an assessment of memory and

is relatively insensitive to early impairment, was used to measure cognitive function. However, for the follow-up waves cognitive function was measured using CCFM, a modified version of the MoCA. Unlike SPMSQ, MoCA assesses global cognitive function, including domains of orientation, executive function, visuo-construction skills, and attention. Although MoCA has shown excellent performance in discriminating cognitive impairment from normal cognition in older adults[36,37] inconsistent measurement across waves makes it difficult to compare participants' cognitive function over time. We excluded those with any cognitive impairment at baseline on the basis of SPMSQ scores and then used a measure of global cognition to determine cognitive impairment status in waves 2 and 3. It is possible that among those identified as being at-risk for cognitive impairment on the basis of SPMSQ, there were some older adults who had poor function in other domains of cognition besides memory, such as visuo-construction skills and executive function. It is also important to note that questionnaires like SPMSQ and MoCA alone are not sufficient to provide a formal diagnosis of mild cognitive impairment or dementia which would require full neuropsychological testing.

Second, although we used longitudinal data, due to the long prodromal period of cognitive impairment[11] it is still difficult to assess a causal relationship between network types and cognition. We did not have any information concerning the past social life of participants and it is possible that the network types observed at baseline were informed by pre-symptomatic cognitive decline that did not become symptomatic until one of the follow-up waves.

Third, since the data are focused on community-dwelling, high-functioning older adults, this study does not assess the association of social relationships with more profound cognitive impairment. Furthermore, cognitive status likely factors into the ability to participate in a 2-hour survey, and therefore, the exclusion of those unable to do so further limits generalizability.

Finally, of the original NSHAP cohort 15% were deceased and 11% were lost to follow-up by the third wave, raising the possibility of bias due to selective attrition. Dropout, due to death or other loss to follow-up, was not highly patterned by social network type, however, making this bias less likely.

The current analysis has value, nevertheless, in that it makes use of a unique data set that allows the simultaneous consideration of sociodemographic background characteristics, social network type, and cognitive function in a national sample of older Americans. This distinctive study made it possible to examine and to better understand the possible effects of a multidimensional social network typology on cognitive function in late-life. An important step in future research will be to model the association between network types and cognitive function using longitudinal data with more frequent assessments. This would allow modeling of transitions in social network types and simultaneous transitions in cognitive function. Both social networks and cognitive function are complex and dynamic constructs; by treating the two as time-varying, future research can clarify the short- and long-term health effects of network type on cognitive function.

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Tables

Table 5.1 Weighted Baseline Characteristics by Network Type

Network Types	*Total sample*	*Cognitive impairment onset at W2 or W3 among those at risk**	*Age*	*Female*
	N=2,266	N=1,768	(Mean=67; S.D.=8)	N=1,186
	N (%)	*N (%)*	*Mean (S.D.)*	*N (%)*
Diverse, supportive network with partner	741 (33)	544 (73)	66 (7)	416 (56)
Average network with partner	582 (26)	446 (77)	67 (7)	222 (38)
Partner-centered network	322 (14)	268 (83)	67 (7)	63 (20)
Large, supportive network without partner	402 (18)	326 (81)	70 (8)	344 (86)
Restricted, family-centered network without partner	219 (10)	184 (84)	70 (8)	140 (64)

Note. Percentages and N are presented for categorical variables and Means and Standard Deviations are presented for continuous variables. Denominator for the calculation of % does not include respondents with missing data on the variable. Row percentages are presented except for in the first column on the distribution of network types in the sample.

*A MoCA score of less than 26 was used to identify individuals who experience impariment onset.

MoCA - Montreal Cognitive Assessment; W2 - Wave 2 (2010-2011); W3 - Wave 3 (2015-2016)

Table 5.2 Regression Models of Cognitive Impairment Onset (MoCA score <26) by Network Type

	Model 1 (N= 2,163)		Model 2 (N= 2,153)		Model 3 (N= 2,153)		Model 4 (N= 2,153)	
Network types (*ref*: Diverse, supportive network with partner)	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	1.77**	(1.19, 2.61)	1.27	(0.82, 1.97)	1.07	(0.70, 1.64)	1.08	(0.70, 1.67)
Average network with partner	1.21	(0.91, 1.60)	1.00	(0.74, 1.37)	0.95	(0.69, 1.30)	0.95	(0.69, 1.31)
Large, supportive network without partner	1.57	(0.99, 2.50)	1.25	(0.78, 1.99)	1.17	(0.72, 1.91)	1.14	(0.70, 1.87)
Restricted, family-centered network without partner	1.95**	(1.27, 2.99)	1.30	(0.81, 2.09)	1.01	(0.61, 1.67)	1.00	(0.60, 1.66)
Sociodemographic covariates								
Age	.	.	1.07***	(1.05, 1.09)	1.06***	(1.04, 1.08)	1.05***	(1.03, 1.08)
Female	.	.	0.63**	(0.47, 0.84)	0.54***	(0.40, 0.73)	0.52***	(0.38, 0.72)
Race/ethnicity (*ref: White)*								
Black	.	.	5.19***	(3.04, 8.87)	4.37***	(2.51, 7.60)	4.15***	(2.39, 7.21)
Hispanic, non-Black	.	.	3.76**	(1.69, 8.36)	2.49*	(1.14, 5.43)	2.55*	(1.17, 5.53)
Other	.	.	3.14*	(1.04, 9.45)	3.35*	(1.12, 10.01)	3.22*	(1.08, 9.64)
Education (*ref: Bachelors degree)*								
Less than high school	.	.	.	.	8.74***	(4.18, 18.30)	8.15***	(3.93, 16.90)
High school or equivalent	.	.	.	.	2.12***	(1.46, 3.08)	2.03***	(1.39, 2.97)
Vocation, some college or associate's degree	.	.	.	.	2.01***	(1.45, 2.78)	1.96***	(1.40, 2.73)
Activities of daily living disability	.	.	.	.	.	.	1.29	(0.90, 1.87)
Comorbidities (0-6)	.	.	.	.	.	.	1.16*	(1.02, 1.31)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.

**p-value* < .05, ***p-value* < .01, ****p-value* < .001

Supplementary Materials

Table SM 5.1 Weighted Baseline Sociodemographic and Health Characteristics by Network Type

Variable	*Total sample*	*Diverse, supportive network with partner*	*Average network with partner*	*Partner-centered network*	*Large, supportive network without partner*	*Restricted, family-centered network without partner*
	N=2,783	N=741	N=582	N=322	N=402	N=219
	N (%) Mean (S.D.)	*N (%) Mean (S.D.)*	*N (%) Mean (S.D.)*	*N (%) Mean (S.D.)*	*N (%) Mean (S.D.)*	*N (%) Mean (S.D.)*
Race/Ethnicity						
White	1839 (81)	650 (88)	477 (82)	242 (76)	315 (79)	154 (71)
Black	226 (10)	49 (7)	57 (10)	26 (8)	63 (16)	31 (14)
Hispanic, non-Black	142 (6)	25 (3)	37 (6)	42 (13)	16 (4)	21 (10)
Other	52 (2)	16 (2)	8 (1)	9 (3)	6 (2)	12 (6)
Education						
Less than high school	382 (17)	74 (10)	85 (15)	71 (22)	83 (21)	69 (32)
High school or equivalent	598 (26)	177 (24)	142 (24)	92 (29)	119 (30)	68 (31)
Vocational certificate/some college or associate's degree	687 (30)	247 (33)	175 (30)	82 (25)	122 (30)	60 (27)
Bachelors or more	599 (26)	242 (33)	179 (31)	77 (24)	78 (19)	22 (10)
Health status						
Activities of daily living disability	494 (22)	143 (19)	108 (19)	72 (22)	106 (26)	65 (30)
Comorbidities (0-6)	2 (1)	1 (1)	1 (1)	1 (1)	2 (1)	2 (1)

Note. Percentages and N are presented for categorical variables and Means and Standard Deviations are presented for continuous variables.
Denominator for the calculation of % does not include respondents with missing data on the variable. Column percentages are presented.

Table SM 5.2 Regression Models of Cognitive Impairment Onset (MoCA score <23) by Network Type

	Model 1 (N= 2,163)		Model 2 (N= 2,153)		Model 3 (N= 2,153)		Model 4 (N= 2,153)	
Social network types	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	1.72**	(1.25, 2.36)	1.28	(0.90, 1.83)	1.10	(0.77, 1.56)	1.09	(0.77, 1.56)
Average network with partner	1.16	(0.90, 1.50)	0.97	(0.72, 1.31)	0.91	(0.68, 1.22)	0.91	(0.68, 1.22)
Large, supportive network without partner	1.62**	(1.22, 2.16)	1.09	(0.80, 1.48)	0.99	(0.71, 1.38)	0.97	(0.69, 1.36)
Restricted, family-centered network without partner	2.30***	(1.57, 3.39)	1.43	(0.92, 2.21)	1.10	(0.68, 1.77)	1.08	(0.66, 1.77)
Sociodemographic covariates								
Age	.	.	1.10***	(1.08, 1.12)	1.09***	(1.07, 1.11)	1.09***	(1.07, 1.11)
Female	.	.	0.75*	(0.60, 0.95)	0.66***	(0.52, 0.84)	0.65***	(0.51, 0.83)
Race/ethnicity (*ref: White)*								
Black	.	.	8.29***	(5.29, 13.00)	7.31****	(4.41, 12.13)	7.09***	(4.27, 11.77)
Hispanic, non-Black	.	.	4.27***	(2.40, 7.59)	2.83***	(1.74, 4.62)	2.88***	(1.76, 4.72)
Other	.	.	2.09*	(1.05, 4.17)	2.19*	(1.03, 4.68)	2.15	(1.01, 4.59)
Education (*ref: Bachelors degree)*								
Less than high school	.	.	.	.	6.84***	(4.00, 11.69)	6.53***	(3.79, 11.23)
High school or equivalent	.	.	.	.	2.04***	(1.43, 2.92)	1.99***	(1.39, 2.85)
Vocation, some college or associate's degree	.	.	.	.	1.85**	(1.26, 2.71)	1.81**	(1.23, 2.66)
Activities of daily living disability	.	.	.	.	.	.	1.17	(0.84, 1.63)
Comorbidities (0-6)	.	.	.	.	.	.	1.11	(0.98, 1.25)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.

**p-value* < .05, ***p-value* < .01, ****p-value* < .001

Table SM 5.3 Regression Models of Cognitive Impairment Onset by Network Type Excluding Respondents with Membership Probability <0.95

	Model 1 (N= 1,668)		Model 2 (N= 1,160)		Model 3 (N= 1,160)		Model 4 (N= 1,160)	
Network types (*ref*: Diverse, supportive network with partner)	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	1.88**	(1.19, 2.98)	1.37	(0.82, 2.29)	1.19	(0.71, 1.97)	1.18	(0.70, 1.97)
Average network with partner	1.06	(0.75, 1.49)	0.86	(0.59, 1.24)	0.82	(0.55, 1.20)	0.80	(0.54, 1.18)
Large, supportive network without partner	1.39	(0.86, 2.25)	1.14	(0.71, 1.83)	1.10	(0.67, 1.80)	1.05	(0.64, 1.74)
Restricted, family-centered network without partner	2.29**	(1.30, 4.03)	1.59	(0.87, 2.90)	1.22	(0.65, 2.28)	1.19	(0.63, 2.25)
Sociodemographic covariates								
Age	.	.	1.06***	(1.04, 1.08)	1.05***	(1.02, 1.07)	1.04***	(1.02, 1.07)
Female	.	.	0.65*	(0.47, 0.92)	0.57**	(0.40, 0.81)	0.54**	(0.37, 0.78)
Race/ethnicity (*ref: White)*								
Black	.	.	5.04***	(2.87, 8.82)	4.14***	(2.33, 7.33)	3.92***	(2.22, 6.91)
Hispanic, non-Black	.	.	2.59*	(1.17, 5.72)	1.66	(0.76, 3.62)	1.72	(0.79, 3.75)
Other	.	.	2.82	(0.87, 9.14)	3.37*	(1.03, 11.06)	3.22	(0.97, 10.64)
Education (*ref: Bachelors degree)*								
Less than high school	.	.	.	.	8.76***	(3.80, 20.19)	8.06***	(3.53, 18.39)
High school or equivalent	.	.	.	.	1.96**	(1.31, 2.92)	1.90**	(1.27, 2.85)
Vocation, some college or associate's degree	.	.	.	.	1.90***	(1.38, 2.63)	1.86***	(1.34, 2.57)
Activities of daily living disability	.	.	.	.	.	.	1.36	(0.89, 2.07)
Comorbidities (0-6)	.	.	.	.	.	.	1.16*	(1.01, 1.33)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.

**p-value* < .05, ***p-value* < .01, ****p-value* < .001

Table SM 5.4 Regression Models of Cognitive Impairment Onset at Wave 2

	Model 1 (N= 2,126)		Model 2 (N= 2,116)		Model 3 (N= 2,116)		Model 4 (N= 2,116)	
Network types (*ref*: Diverse, supportive network with partner)	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	1.99***	(1.38, 2.85)	1.53	(0.99, 2.38)	1.33	(0.86, 2.07)	1.33	(0.85, 2.08)
Average network with partner	1.18	(0.89, 1.57)	1.00	(0.72, 1.40)	0.95	(0.68, 1.34)	0.95	(0.68, 1.35)
Large, supportive network without partner	1.74**	(1.19, 2.55)	1.25	(0.84, 1.86)	1.17	(0.78, 1.77)	1.15	(0.76, 1.74)
Restricted, family-centered network without partner	1.96***	(1.33, 2.88)	1.25	(0.84, 1.87)	0.99	(0.66, 1.49)	0.98	(0.64, 1.48)
Sociodemographic covariates								
Age	.	.	1.08***	(1.06, 1.10)	1.07***	(1.05, 1.09)	1.07***	(1.05, 1.09)
Female	.	.	0.75*	(0.57, 0.99)	0.67**	(0.50, 0.90)	0.65**	(0.48, 0.89)
Race/ethnicity (*ref: White)*								
Black	.	.	6.96***	(4.55, 10.65)	6.11***	(3.88, 9.62)	5.90***	(3.73, 9.32)
Hispanic, non-Black	.	.	4.22***	(2.14, 8.32)	3.05**	(1.58, 5.92)	3.09**	(1.59, 6.01)
Other	.	.	2.44	(0.96, 6.19)	2.56*	(1.08, 6.09)	2.51*	(1.06, 5.96)
Education (*ref: Bachelors degree)*								
Less than high school	.	.	.	.	5.24***	(3.37, 8.15)	4.93***	(3.18, 7.65)
High school or equivalent	.	.	.	.	2.01***	(1.50, 2.70)	1.95***	(1.45, 2.61)
Vocation, some college or associate's degree	.	.	.	.	1.69***	(1.25, 2.29)	1.65**	(1.21, 2.25)
Activities of daily living disability	.	.	.	.	.	.	1.27	(0.94, 1.71)
Comorbidities (0-6)	.	.	.	.	.	.	1.11	(0.98, 1.26)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.

**p-value* < .05, ***p-value* < .01, ****p-value* < .001

Table SM 5.5 Regression Models of Cognitive Impairment Onset at Wave 3

	Model 1 (N= 1,510)		Model 2 (N= 1,503)		Model 3 (N= 1,503)		Model 4 (N= 1,503)	
Network types (*ref*: Diverse, supportive network with partner)	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Partner-centered network	1.36	(0.94, 1.98)	0.91	(0.61, 1.36)	0.78	(0.53, 1.16)	0.79	(0.53, 1.19)
Average network with partner	1.36	(0.99, 1.87)	1.10	(0.78, 1.55)	1.05	(0.74, 1.50)	1.06	(0.74, 1.50)
Large, supportive network without partner	1.67*	(1.04, 2.66)	1.33	(0.82, 2.17)	1.25	(0.74, 2.11)	1.22	(0.73, 2.05)
Restricted, family-centered network without partner	1.20	(0.72, 2.00)	0.85	(0.50, 1.45)	0.65	(0.36, 1.16)	0.64	(0.35, 1.16)
Sociodemographic covariates								
Age	.	.	1.09***	(1.06, 1.11)	1.08***	(1.06, 1.11)	1.08***	(1.05, 1.10)
Female	.	.	0.60**	(0.43, 0.85)	0.52***	(0.36, 0.74)	0.50***	(0.35, 0.72)
Race/ethnicity (*ref: White)*								
Black	.	.	4.61***	(2.75, 7.72)	4.16***	(2.31, 7.49)	3.89***	(2.19, 6.89)
Hispanic, non-Black	.	.	2.47*	(1.25, 4.90)	1.70	(0.91, 3.16)	1.83	(0.99, 3.39)
Other	.	.	1.69	(0.83, 3.45)	1.80	(0.81, 4.02)	1.65	(0.72, 3.78)
Education (*ref: Bachelors degree)*								
Less than high school	.	.	.	.	5.64***	(2.78, 11.42)	5.24***	(2.58, 10.66)
High school or equivalent	.	.	.	.	2.22***	(1.44, 3.42)	2.17***	(1.39, 3.38)
Vocation, some college or associate's degree	.	.	.	.	2.03***	(1.49, 2.77)	1.98***	(1.45, 2.70)
Activities of daily living disability	.	.	.	.	.	.	0.93	(0.63, 1.37)
Comorbidities (0-6)	.	.	.	.	.	.	1.22**	(1.08, 1.39)

Note. Partner-centered, Average network with partner; Large, supportive network without partner; Restricted, family-centered network without partner represent dummy codes for the network types. Diverse, supportive network with partner is used for the reference group and left out of the analysis.

*p-value < .05, **p-value < .01, ***p-value < .001

CHAPTER 6

Discussion

Summary and Implications of Main Findings

Life expectancy and the proportion of the population aged 65 years and older has been growing at a rapid rate in recent times. Life expectancy at birth has increased from 47.3 years in 1900 to 78.6 years in 2016.[1] Currently, it is estimated that 46 million Americans are 65 years and older and it is predicted that in the 2030s, for the first time in the history of the country, there will be more people aged 65 or older than aged 18 or younger.[2] However, this dramatic increase in the number of years lived has not necessarily come with a proportionate increase in the quality of life for older adults. Along with improved life expectancy, the risk of disability, mobility limitations, and cognitive impairment has also risen.[3] In an attempt to improve not just the length of life but also the quality of life, the focus of public health research has begun to shift from prevention strategies centered on clinical care and health behaviors to modifiable social determinants of health. One potential avenue for improving the functional health, and thereby quality of life, of older adults is by gaining a better understanding of their social networks and how they influence their health. This way, we can identify older adults at risk of poor health trajectories and develop strategies to address social engagement as a potential avenue to improve functional health.

Social networks are critical in maintaining cognitive health, avoiding loneliness, and improving the quality of life of older adults.[2] On the one hand, improvements in communication technologies offer older adults more avenues through which they can stay connected with

members in their social networks. On the other hand, secular trends such as increases in rates of divorce and remarriage, smaller families, geographically dispersed families, and childlessness have resulted in more older adults living in isolation than ever before. Nonetheless, there is a lot of heterogeneity in the nature of social networks of older adults and how they change over time. Unfortunately, existing measures fail to capture this heterogeneity as they primarily focus on isolated dimensions of networks. This approach ignores the multidimensional and complex nature of social networks, and as a result, the health consequences of social networks remain poorly understood. This dissertation provides evidence that a pattern centered approach focused on multiple network dimensions may indeed be helpful in providing a fuller and more nuanced assessment of older adults' social networks. It also assesses the relevance of such an approach to identify individuals at risk of health-related impairments in older age.

The primary goals of this dissertation were to: (1) examine profiles of social networks (i.e., social network types) of older adults using an array of multidimensional network characteristics; (2) identify sociodemographic factors that predict membership in these network types; (3) determine if the structure of the social network typology and the prevalence of the specific network types differ by birth cohort; (4) examine the effect of network types on physical functional health; and (5) determine the impact of network types on cognitive impairment.

In chapter 2, using nine different characteristics of social networks representing the structure, function, and quality of relationships we identified five distinct social network types in a nationally-representative cohort of community-dwelling older adults: *diverse, supportive network with partner* (32%); *average network with partner* (27%); *partner-centered network* (15%); *large, supportive network without partner* (16%); and *restricted, family-centered network without partner* (11%). The network types that emerged in the NSHAP sample correspond

broadly to the four network types commonly found in the literature: *diverse*, *friend-focused*, *family-focused*, and *restricted*.[4–7] With the addition of functional characteristics, compared to previous studies, we identified two, instead of one, 'diverse' network types that differed in the presence versus absence of partner; one restricted network type that was also family-focused; and no friend-focused network type. These findings point to specific characteristics that define the nature of older adults' social networks. In addition to structural characteristics of size and diversity, perceived support and partner status proved to be defining features of social networks; two network types were classified on the basis of social support and all five network types were classified on the basis of partner status. Notably, these very same network features of size, diversity, support, and partner status have shown important relationships with health in old age when examined as isolated measures.

In analyses exploring network type membership by sociodemographic covariates, we found that less educated individuals and Blacks had a low probability of having a highly diverse network. Women, older adults, and those with lower income were more likely to be in a network type without a partner. Taken together, these findings suggest that women, older adults, Blacks, and those with lower socioeconomic status are at a disadvantage as they are more likely to be in restricted network types that are less endowed and offer less support.

These results are an important contribution to the literature on social networks of older adults. In contrast to prior work, results from this study provide evidence that both structural and functional dimensions of social networks play an important role in defining the social lives of older adults. A pattern-centered approach, such as constructing a social network typology, allows us to elucidate the varied interpersonal environments in which older adults are embedded and how these environments can in turn affect their health. Network types can be utilized to identify

the kinds of available resources, such as informal caregiving that older adults may call upon during times of serious illness, hospitalizations, and other difficulties in daily life. This network approach can also prove useful in identifying older adults that are at an increased risk of becoming socially isolated, such as those in restricted networks or networks without a partner. By identifying socially isolated individuals and those lacking sufficient support, we can offer targeted opportunities for social engagement through participation in educational, social, and physical activity programs, thereby improving the quality of life of older adults.

Chapter 4 built upon work from chapter 2 by examining the effect of the multidimensional social network types on ADL disability and mobility. Our findings indicate that the association between network types and functional health is somewhat equivocal. Contrary to our expectation, we observed no effect of network types on ADL disability in the primary analysis. However, modeling the short- and long-term risk of ADL disability separately, we observed a protective effect of the *partner-centered network* and the *average network with partner* relative to the *diverse, supportive network with partner* on a 5-year (i.e., short-term) risk of disability onset. Social network types were associated with mobility, such that older adults in the *restricted, family-centered network without partner* had significantly slower walking times than those in the *diverse, supportive network with partner* over time. These network types, however, did not have a longitudinal effect on change in mobility. Previous studies have shown a well-established association between network types and mortality. In sensitivity analyses performed to replicate these findings, we observed a harmful effect of the *restricted, family-centered network without partner* on a 5-year risk of mortality, but not a 10-year risk. The findings for mobility and mortality are consistent with previous research in which *restricted*

network types have been associated with worse functional health and a higher risk of mortality whereas *diversified* network types have been associated with improved physical function.[8,9]

Although additional replication studies using longitudinal data are needed, findings from this chapter may have implications for future research on health effects of social network types. The fact that we observe a short-term, but not long-term, effect of network types on ADL disability and mortality raises important questions about the duration of exposure to and accumulation of social network benefits that is relevant for functional health in old age. Previous studies of social relationships show both short- and long-term effects on health, with intervention studies primarily showing short-term beneficial effects of social relationships on health.[10] Our findings are most consistent with the literature that emphasizes the short-term health consequences of social networks. Contrary to previous findings and our expectation, the most diverse network type in our study (i.e., *diverse, supportive network with partner*) did not have the lowest risk for ADL disability onset. Instead, the remaining two networks with partner (i.e., *partner-centered network* and *average network with partner*) had a significantly lower risk of disability onset in the short-term relative to the *diverse, supportive network with partner*; whereas, the two networks without a partner (i.e., *large, supportive network without partner* and *restricted, family-centered network without* partner) did not differ significantly from the most diverse network in their risk of disability onset. These findings underscore the relative importance of the partner relationship compared to other kin and non-kin relationships, in particular for disability onset. Rather than having a large and diverse network with many different sources of support, when it comes to ADL disability it appears that the presence of a partner and support from partner are more essential in preventing onset. This is not surprising given the significance of the partner (i.e., spouse or significant other) relationship. Relationship

with a partner is fundamentally different from other relationships as it often involves cohabitation, influences the composition of one's social network, and is a source of various kinds of support including material support, care, reassurance, and emotional closeness in times of illness. Thus, the results from chapter 4 suggest that perhaps a universal protective or beneficial network type does not exist; rather for different health outcomes, different network types may prove to be more or less beneficial.

Chapter 5 evaluated the utility of network types in predicting onset of cognitive impairment among older adults. Given our findings that network types are associated with physical function, even if only in the short-term, and previous findings that social network types are associated with mental health which is a risk factor of cognitive function, we expected network types to also have an impact on cognitive impairment. However, surprisingly in this large, nationally-representative sample, social network types were not associated with onset of cognitive impairment. Although unadjusted analyses suggested a higher risk of cognitive impairment onset among those in the two restricted network types: *partner-centered network* and *restricted, family-centered network without partner*, adjustment for sociodemographic and health-related background characteristics rendered these associations insignificant.

This suggests that perhaps the cognitive impairment process itself is driven by disease rather than social networks such that the initial onset of impairment is driven primarily by biological mechanisms. Although behavioral adaptations, such as support from social networks, may slow down cognitive decline, perhaps they do not play a crucial role in onset of cognitive impairment. If this is the case, then findings from chapter 5 suggest that previous studies of a cross-sectional nature were most likely subject to reverse causality. It is possible that older adults observed to be in *diverse* networks in prior studies were ones who had better mental health and

higher cognitive function which allowed them to maintain many supportive relationships; in contrast, adults who had poor mental health and lower cognitive function were incapable of maintaining many supportive relationships and therefore had a *restricted* network.

It is also possible that social network types do, in fact, impact cognitive function but we failed to detect the association due to poor measurement of cognitive function and the specific study design of NSHAP. So far, only two follow-up waves have been conducted five years apart with the NSHAP cohort. This may be insufficient to detect the effect of network types on cognitive function, given the reciprocal and dynamic relationship between the two. Additionally, the measurement of cognitive function was rather imprecise as the sample was restricted to at-risk individuals (i.e., those who had intact intellectual functioning) and cognitive impairment was treated as a dichotomous outcome (no impairment vs any impairment). This crude characterization may have masked the residual heterogeneity within finer cognitive function categories that represent accumulation and severity of impairment. Additionally, the switch from SPMSQ – a measure of memory – at baseline to a modified version of the MoCA – a measure of global cognitive function – to assess cognition may have contributed partly to the inability to detect an association between network types and cognitive impairment.

Collectively, the results of this dissertation support the premise that social networks of older adults are heterogeneous and adults with different patterns of social networks likely have different health risks. Chapter 2 demonstrated that social networks are multidimensional constructs and consideration of both structural and functional characteristics allows for a more nuanced assessment of the network. The results from chapter 4 and 5 illustrate the potential of the construct of social network types for predicting functional health outcomes. Social network types, at least in the short-term, do have an effect on ADL disability onset, mobility, and

mortality. However, perhaps there is no universally beneficial network type as certain network types appeared to be more or less beneficial for specific outcomes. Furthermore, the relevance of network types seems to vary by health outcome; although network types had some impact on physical functional health, they had no apparent impact on cognitive impairment. Insights from this dissertation can be applied to research on risk factors of other aging-related health outcomes; our findings suggest that there is indeed some value in moving beyond proximate biological risk factors to social networks of older adults as determinants of the onset and progression of functional decline.

Strengths and Limitations

Strengths

The work presented in this dissertation has several strengths. We used a recent, nationally representative sample with detailed information on multiple social network characteristics. Having numerous measures of specific structural and functional characteristics allowed us to explore social network types as a complex and multidimensional construct. It also enabled us to consider the influence of strain in social networks as an important network feature, which has largely been ignored in earlier network typology research. Although strain in relationship with partner did not emerge as an important dimension of network types in our study, we did observe some variation across the five network types in the proportion of older adults reporting social strain with their partner.

Another strength of this study was the use of LCA to derive network types – this is in contrast to the various clustering procedures, such as k-means or hierarchical clustering, employed in previous research.[11,12] Unlike cluster analysis, LCA is based upon a statistical model, and therefore, maximum likelihood estimates can be used to classify respondents based

upon their posterior probability of class membership.[13] Assigning a probability to class membership in LCA, as opposed to a weight of 0 or 1 as in K-means clustering, prevents biasing the estimated class-specific means.[14] LCA also allows inclusion of covariates to predict individuals' latent class membership and the prevalence of each network type in the population.[15]

A major concern in existing studies of social networks and functional health is the lack of a clear unidirectional association due to use of cross-sectional data.[16,17] The use of a prospective study design where we established network types at baseline and measured the outcomes at follow-up waves allowed us to circumvent the issue of reverse causality to some extent. Specifically, for disability and cognitive function models we excluded individuals with ADL disability and any cognitive impairment at baseline and modeled the risk of transition to initial onset of disability and cognitive impairment.

Limitations

Some limitations of the present study should also be acknowledged. Although comprehensive data on various measures are available in NSHAP, the social network data are egocentric and collected through self-report. NSHAP excluded respondents with a history of dementia; however, social network data are measured from the perspective of the 'ego' (i.e., respondent) and may therefore be subject to some degree of unreliable recall and social desirability bias.[18] Additionally, the advantage of detailed social network data was offset by the relatively poor measurement of physical and cognitive functioning in the study. Given the reciprocal nature of the association between social relationships and health, few waves of measurement (only 2 follow-up waves) conducted every 5 years may be insufficient to detect the complex relationship between social networks and functional health. Measurement of mobility and cognitive function was also inconsistent across baseline and follow-up waves which makes it

difficult to make reliable comparisons within participants over time. As in all studies following participants longitudinally, chapters 4 and 5 are susceptible to bias due to selective attrition. Although network types were not predictive of attrition in our study, it should be noted that participants who dropped out of the NSHAP study after the first wave were less educated and more functionally impaired at baseline compared to the individuals who were included in follow-up waves.[19] Finally, although we used longitudinal data, due to the long prodromal period of physical and cognitive impairment[20] it is still difficult to assess a causal relationship between network types and functional health. We did not have any information concerning the past social life of participants and it is possible that the network types observed at baseline were informed by pre-symptomatic physical or cognitive decline that did not become symptomatic until one of the follow-up waves. Therefore, the implications of the observed findings should not be over stated and these results should be interpreted within the context of the broader literature on social networks and health in old age.

Future Directions

The work presented in this dissertation highlights the complexity of the relationship between social networks and health of older adults. In general, findings support the notion that taking a pattern-centered approach of constructing social network types is useful to capturing the complexity and heterogeneity in social networks of older adults. The social network types identified in this study may have implications for understanding the determinants of aging related outcomes and could inform interventions that increase the amounts of available social support and reduce social isolation among older adults. Nonetheless, there are several directions for future research that can further elucidate the nature of the association between social network types and functional health outcomes in old age.

To strengthen causal inference regarding the health effects of social networks in old age, the field of aging epidemiology would benefit from longitudinal studies which treat social network types as a time-varying exposure and examine its association with functional health over time. Neither individuals' social relationships nor their health is static over time; in fact, the relationship between social networks and health is bi-directional such that social networks affect health and health affects social networks as they both change over time. Specifically, within the NSHAP sample the average network size increased between waves 1 and 2. Emotional closeness, frequency of contact with confidants, and respondents' likelihood of discussing health with confidants reportedly declined between the two waves. New ties added by respondents in wave 2 to replace lost ties from wave 1 were often weaker ties. Even among ties that remained stable across waves, there was some weakening of the relationship between the respondents and their confidants. This suggests that older adults do experience changes in social networks over a short period of time which could potentially translate into differences in network types across waves; in the case of the NSHAP sample this involved an expansion of the network accompanied by a weakening of relationship strength and closeness.[21] Ideally, future studies should determine whether the history of network characteristics could predict health outcomes, conditional on health history, and whether the history of health could predict the change in social networks, conditional on network history.[22] This would allow modeling of transitions in social network types and simultaneous transitions in functional health. Both social networks and functional health are complex and dynamic constructs; by treating the two as time-varying, future research can clarify the short- and long-term health effects of network type on functional health in old age and vice versa.

In order to understand the specific role of social networks on functional health, future research should examine network types in relation to both accumulation (i.e., number of disabilities or impairments) as well as severity of disability and cognitive impairments. This would help us determine whether network types are more relevant for onset of functional impairment or the progression of functional decline among those already impaired. Similarly, an extension of this work may wish to consider the association between network type and pre-clinical forms of functional impairment, such as disability in instrumental activities of daily living which reflect preclinical disability and are a risk factor of ADL disability.

Despite detailed assessment of social lives of older adults, the measurement of social networks can be improved further still. Contrary to our expectation, social strain in family relationships did not emerge as a discriminating characteristic of network types and was therefore not included in the analysis. In general, assessing the quality of social relationships using indicators such as 'makes too many demands' and 'criticizes often' presents difficulties among older adults as prevailing social norms in this generation may lead to an underreporting of excessive demands and criticism. In this age group, other measures of strain, such as stress in a relationship due to ineffective helping or excessive helping, unpleasant interactions due to lack of independence, and negative interactions in the context of caregiving may be more relevant. Future studies should assess social strain within specific social relationships (e.g., adult children, grandchildren, and other family member caregivers) rather than assessing negative interactions with one's family in general, to better capture the relationship-specific social strain and its consequences for well-being. Finally, the ego-centered approach employed in this study is a simple assessment of the social networks of older adults as it does not utilize data on ties between all members of a network. Future studies should go beyond the ego-centered approach

employed in this study by taking a socio-centric or whole network approach and by treating social networks as systems of interacting individuals to gain additional information about older adults' social networks and their effects on health.

Conclusion

This dissertation suggests that social network typologies may represent a viable approach to capturing the complex social networks of older adults. Although the association between social networks and health is dynamic and reciprocal, focusing exclusively on individual network characteristics while ignoring the multidimensional nature of social networks is inadequate. Although our findings suggest that the effects of network types on functional health might not persist for up to 10 years, at least in the short term, consideration of social network resources may still offer opportunities for the prevention and postponement of certain functional limitations in old age.

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