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Associations Between Social Network Components and Cognitive Domains in Older Adults

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Abstract

Previous research shows that social network components are associated with cognitive function later in life. However, fewer studies consider different cognitive domains or disaggregate the social network by relationship type. Using data from 2,553 participants aged 65 or older in the Health and Retirement Study's Harmonized Cognitive Assessment Protocol, this study examined relationships between social network structure (i.e., size, contact frequency) and quality (i.e., support, strain) and performance in five cognitive domains (i.e., episodic memory, executive function, visuoconstruction, language, and processing speed) two to four years later, controlling for sociodemographics and previous global cognition. Separate linear regressions were conducted for each cognitive outcome. When averaged across relationship types, network size was not associated with any domain. Contact frequency was positively associated with all domains except episodic memory. Support and strain were negatively associated with all cognitive domains. When considering individual relationship types, larger friend networks were positively associated with visuoconstruction, and greater contact frequency with friends was positively associated with all cognitive domains. Larger family networks were associated with worse executive function, visuoconstruction, and speed. Strain from friends had a negative relationship with every domain except episodic memory. Support from family was negatively associated with episodic memory, executive function, and language. These associations were equivalent to one to 3.5 years of cognitive aging. These results showed that both social network structure and quality may be consequential for cognitive functioning and that links between social relations and cognition differ across domains and as a function of relationship type.

Keywords

social network; cognitive aging

Cognitive decline and dementia are major public health concerns. Rising cases and a lack of disease-modifying therapies highlight the need for studies focused on modifiable factors that

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promote healthy cognitive aging (Livingston et al., 2017). This knowledge is necessary to design and implement more targeted interventions to prevent, halt, or even reverse pathological cognitive aging, as well as to improve and maintain trajectories for healthy cognitive aging. Growing research has found that social networks may have protective effects on health and cognition in later life (Berkman et al., 2000).

Theoretical Framework

A considerable amount of research has examined the effects of social relationships on health and cognition (Amieva et al., 2010; Crooks et al., 2008). The social convoy model breaks down social networks into multiple component parts and highlights the complexity of social networks (Antonucci et al., 2014; Antonucci et al. 1987; Fiori et al., 2006). An individual’s social network can be composed of several relationships of varying closeness, structure, function, and quality. Relationships can serve different purposes in one’s life, and the composition of social networks can vary widely from individual to individual.

Social Networks

A previous study applying the convoy model to cognitive aging considered the structural versus quality components of social networks (Zahodne et al., 2019). Structural components can refer to both the number and type of members in a network (children, friends, a spouse, and other family) and the frequency with which one interacts with members of their network. Quality components can refer to the perceived support and strain of relationships within the social network. Support indicates how much an individual feels they are understood and cared for by members of their social network, whereas strain indicates a lack of understanding and the presence of conflict. Social network structure and quality provide useful ways to dissect the complex nature of social networks into more specific components that may be separately relevant to cognitive aging and could be targeted by different interventions.

Social Network Structure.—Various aspects of social network structure have been associated with cognitive aging. Network structure can be separated into network size (i.e., how many people corresponding to various relationship types are in a network) and contact frequency (i.e., how often one interacts with members of their social network). Previous research has identified the importance of structural aspects such as network size (Crooks et al., 2008) and contact frequency (Zahodne et al., 2019) as it relates to cognition. For example, having a larger social network was found to be a protective factor against the cognitive manifestations of Alzheimer’s disease pathology (Bennett et al., 2006) and has protective implications for physical health and cognitive ability overall (Ellwardt et al., 2015). More recent research has revealed that the frequency of contact with network members may be even more important for aspects of cognitive functioning than social network size (Zahodne et al., 2019). Based on these findings, it is apparent that social network structure, including both size and the frequency of contact with network members, may play a role in cognitive aging over time.

It has been theorized that the apparent protective cognitive effects of social engagement operate through a mechanism involving mental stimulation, based on the use-it-or-lose-it

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hypothesis that states that mental function can be better maintained with continued use (Hertzog et al., 2008). Based on this hypothesis, it may be that cognitive domains that are most directly engaged during social interactions (i.e., executive function, episodic memory, language, processing speed) are most likely to show associations with social network structure (Zahodne et al., 2019; Bourassa et al., 2017; Ellwardt et al., 2015; Kelly et al., 2017). Specifically, executive function refers to decision making, considering options and challenges, and staying focused in a goal-directed manner (Friedman et al., 2017). Executive function is engaged when encountering novel situations and challenges, both of which naturally occur within social relationships over time. Episodic memory is characterized by the remembrance of specific events and is a facet of long-term memory (Tulving, 1972). Episodic memory is used in social interactions when recalling shared experiences. Language is reflected in speech proficiency and understanding and is critical to human interaction. Processing speed refers to the rate by which one can complete a variety of cognitive tasks, including tracking conversation and making prompt, high-quality verbal responses.

Social Network Quality.—On the other hand, some research has argued that structural aspects of social networks may be less influential, and that social network quality may have a greater impact on cognitive outcomes in older age. For example, in their longitudinal 2010 study, Amieva et al. found that greater support from social networks decreased the sample's risk of developing dementia. They characterized support as satisfaction and reciprocity within relationships and found that these aspects of relationships lessened risk for dementia development to a greater degree than structural aspects of relationships such as network size and marital status (Amieva et al., 2010). In their cross-sectional study, Gow et al. (2013) also found social network support to have a positive relationship with cognitive outcomes.

Not only is the presence of support important for cognitive outcomes, but the absence of strain may be uniquely important as well (Zahodne et al., 2019). Previous cross-sectional research has shown that high levels of strain from relationships, especially when coupled with lower levels of support, contribute to lower cognitive performance (Tun et al., 2013). Thus, social network quality may have a relationship with cognitive functioning later in life, and different aspects of social network quality such as support and strain may make independent contributions.

It has been theorized that the apparent protective cognitive effects of social network quality and support operate through mechanisms involving stress and psychological well-being (Seeman et al., 2001). Indeed, previous research indicates that the negative effects of stress on psychological well-being may be moderated by social support (Sicorello et al., 2020). Based on the hypothesis that quality components of social networks may affect cognition through a stress mechanism, it is reasonable to expect that cognitive domains tied to stress (i.e., episodic memory, executive function, and processing speed) would be most likely to have associations with social network quality (Tun et al., 2013; Zahodne et al., 2019; Lupien et al., 2007; Arnsten, 2009; Goldwaser et al., 2021; Siehl et al., 2018).

Relationship Types.—Social network characteristics can be separated not only by structure and quality aspects, but also by relationship type. Often, members of a social network do not all occupy the same role, and social networks can be composed of a

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spouse, children, other family, and/or friends. Aspects of the structure and quality of these relationship types may be differently related to cognitive aging.

Previous research has shown that a greater proportion of friends within a social network may be positively associated with cognition, whereas a greater proportion of family within a social network appears to be negatively related to cognition (Sharifian et al., 2019). Not only is the number of friends important, but the frequency of positive interactions with friends in particular may be important (Windsor et al., 2014; Sharifian et al., 2020). Being married has also been shown to lessen cognitive decline with aging (Gow et al., 2016). Greater contact frequency with family (Béland et al., 2005) and children (Zahodne et al., 2019) may also have potentially beneficial effects. There is also support for positive relationships between the number of non-central family members an individual contacts and cognitive outcomes (Ying et al., 2020).

As for social network quality, previous research has shown that less strain across relationship types may have a positive relationship with measures of cognition (Seeman et al., 2011). Additionally, although somewhat counterintuitive, less support from family has shown a positive relationship with cognition (Zahodne et al., 2019). However, more research addressing the relationship between cognition and specific relationship types is needed.

The Present Study

The separation of cognition into separate cognitive domains is essential to examine the relationship between social networks and the aging brain. It is not necessarily true that only structure or only quality affects cognition, but perhaps both structure and quality play a role in cognition, only through different mechanisms. Along with greater specificity in terms of relationship types and components of social network structure versus quality, the examination of multiple cognitive domains allows for increased specificity in the understanding of how social networks may affect cognition. It is important to separate cognition into separate domains to shed light on differing mechanisms by which certain social network characteristics may affect cognitive aging.

The current study examined relationships between specific aspects of social networks and five domains of cognition. The first aim was to identify relationships between social network structure versus quality and cognition, regardless of relationship types. Based on the hypothesis that more frequent interaction with larger social networks provides increased opportunities to encounter novel situations and challenges and to exercise verbal communication, we expected associations involving social network structure to be detectable for executive functioning, episodic memory (Zahodne et al., 2019), language (Bourassa et al., 2017), and processing speed (Ellwardt et al., 2015). Based on the hypothesis that social support and strain are linked to stress, we expected associations involving social network quality to be detectable for the cognitive domains of executive functioning, processing speed (Tun et al., 2013), and episodic memory (Zahodne et al., 2019; Kelly et al., 2017) because these domains are most commonly implicated in studies on the negative cognitive effects of stress and depressive symptoms.

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The second aim of this study further disaggregated social network structure and quality variables by individual relationship types. Based on existing literature regarding friendships and cognition, we expected support from friends to have positive relationships with cognition (Sharifian et al., 2019), and strain from both friends and family members to have negative relationships with cognition (Zahodne et al., 2019).

By separating social networks into aspects of structure and quality and further by relationship type, this study has the potential to reveal with greater specificity which modifiable social factors are most likely to affect cognitive aging. By using a comprehensive neuropsychological battery to examine five separate domains of cognitive function, this study also has the potential to shed light the different mechanisms at play in the relationships between social network characteristics and cognitive functioning. Finally, this study's lagged design strengthens inferences that can be drawn from associations between social networks and cognitive aging over time.

Method

Transparency and Openness

We report inclusion criteria for the analytic sample and detail the variable creation process and all data manipulation. Stata was used to create social network structure and quality variables and perform analysis (see supplemental materials). This study was not pre-registered. Psychosocial variables and covariates are publicly available on the HRS website (Smith et al., 2017). Covariate data prepared by RAND is also publicly available on the HRS website (https://hrsdata.isr.umich.edu/data-products/rand). Sensitive cognitive outcome data is available by request through the HRS website (Weir et al., 2016).

Participants and Procedure

The sample included 2,553 participants aged 65 years or older who participated in the Health and Retirement Study (HRS). Conducted at the University of Michigan, the HRS began in 1992 with a cohort of individuals born in 1931–1941 with the intent to study aging in the United States in the form of a longitudinal study. It has since grown to include over 37,000 participants aged 50 or older (Sonnega et al., 2014). The core HRS battery includes brief cognitive measures administered in person or over the phone. More detailed information about the HRS and its component parts can be found on the HRS website (https://hrsonline.isr.umich.edu).

Beginning in 2006, participants in the HRS were asked to complete a Psychosocial Wellbeing Questionnaire. Every two years, alternating random subsets of the larger HRS sample complete this leave-behind questionnaire, which collects information regarding their well-being, lifestyle, social relationships, personality, work, and self-related beliefs (Smith et al., 2017). The first subset began completing this questionnaire every four years starting in 2006, and the second subset began in 2008.

In 2016, a subset of HRS participants aged 65 and older who had completed the 2016 core interview participated in the Harmonized Cognitive Assessment Protocol (HCAP). The goal of HCAP was to better understand dementia risk and cognitive aging in the

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U.S. population (Langa et al., 2020). 3,496 participants completed a three-hour, in-person neuropsychological battery to measure their cognitive abilities.

The present study included individuals who participated in the 2016 HCAP, which is where cognitive outcomes were obtained. Social predictors were obtained from the most recent previous wave at which the leave-behind questionnaire was administered (2012 for half the sample and 2014 for the other half). Sample characteristics can be found in Table 1.

Measures

Cognitive Outcomes—Cognition was operationalized by using five factor scores obtained from a published confirmatory factor analysis (CFA) of the HCAP neuropsychological battery (Zahodne et al., 2020). Factor scores indexed the following domains: episodic memory, executive function, visuoconstruction, processing speed, and language.

Episodic Memory.: Episodic memory was measured using four indicators from the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) including the Immediate, Delayed, and Recognition trials from the Word List subtest, the Delayed trial from the Constructional Praxis subtest, Immediate and Delayed trials from the Wechsler Memory Scale-IV (WSM-IV) Logical Memory subtest, and Delayed Word Recall from the Mini Mental State Exam (MMSE).

Executive Function.: Executive function was measured using the Number Series test, Raven's Standard Progressive Matrices, and Trail-Making Test Part B (time).

Visuoconstruction.: Visuoconstruction was measured using CERAD Constructional Praxis (copy) and polygons from the MMSE.

Language.: Language was measured using the sum of two dichotomous items testing verbal description naming from the Telephone Interview for Cognitive Status (TICS), the sum of two dichotomous items testing visual confrontation naming from the MMSE, and a single dichotomous item assessing sentence writing from the MMSE.

Processing Speed.: Processing speed was measured using the Symbol Digit Modalities Test (SDMT), Trail-Making Test Part A (time), Backwards Counting from the Midlife in the United States (MIDUS) project (Kimhy et al., 2013; Tun et al., 2008), and Letter Cancellation as used in the English Longitudinal Study of Ageing (more information can be found on their website: https://www.elsa-project.ac.uk/study-documentation).

Social Network—Social network structure and quality were assessed using participant responses from the most recent HRS Psychosocial and Lifestyle Questionnaire completed prior to 2016. Participant responses were drawn from either the 2012 wave (HRS-wide response rate: 72.7%) or the 2014 wave (HRS-wide response rate: 77.8%), depending on when they received the survey (Smith et al., 2017). Participants answered questions about relationships with their spouse, children, other family, and friends in the form of a paper survey.

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Network Size.: Participants indicated how many children, family, and friends they had a close relationship with. Network size was calculated by adding the number of people reported for each of these relationship types. After examining frequency distributions of network size scores, it was top coded at 50, which is in line with prior work in the HRS (e.g., Zahodne et al., 2019).

Marital Status.: Participants indicated their marital status by answering the question: *Do you have a husband, wife, or partner with whom you live?* Marital status was dichotomized to include married or partnered individuals (coded as 1) and unmarried and unpartnered individuals (coded as 0).

Contact Frequency.: Separated by relationship type (but not including spouse), participants indicated how often they did each of the following with network members who did not live with them: *Meet up (included both arranged and chance meetings)*, *Speak on the phone*, and *Write or email*. Response options included: *Three or more times a week, Once or twice a week, Once or twice a month, Every few months, Once or twice a year*, or *Less than once a year or never*. Responses were coded on a scale of 1–6 and then reverse coded so that more frequent contact was indicated by a higher score. Scores on each item were averaged within each type of social relationship (i.e., children, other family, friends). Overall contact frequency was then computed as the average score across relationship types if at least two relationship types were represented. The 2014 version of the survey included one additional question within the section used to measure contact frequency (*Communicate by Skype, Facebook, or other social media)*, but this question was excluded from analysis in order to maintain consistency between waves.

Support.: Separated by relationship type (spouse, children, other family, friends), questions to measure perceived support included: *How much do they really understand the way you feel about things?*, *How much can you rely on them if you have a serious problem?*, and *How much can you open up to them if you need to talk about your worries?* Response options included: *a lot*, *some*, *a little*, or *not at all*. Each response was coded on a scale of one to four, respectively, and then reverse coded so that greater perceived support was indicated by a higher score. Responses to the three support items were averaged for each type of social relationship. Internal consistency of support measures ranged from Cronbach's $\alpha = .81$ for spousal support to Cronbach's $\alpha = .86$ for support from family members other than spouses or children. Overall support was then computed as the average across relationship types if at least two relationship types were represented.

Strain.: Separated by relationship type (spouse, children, other family, friends), questions to measure perceived strain included *How often do they make too many demands on you?*, *How much do they criticize you?*, *How much do they let you down when you are counting on them?*, and *How much do they get on your nerves?* Response options included, *a lot*, *some*, *a little*, or *not at all*. Each response, coded on a scale of one to four, respectively, was reverse coded so that greater perceived strain was indicated by a higher score. Responses to the four strain items were averaged for each type of social relationship. Internal consistency of strain measures ranged from Cronbach's $\alpha = .74$ for strain from friends to Cronbach's

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α=.79 for spousal strain and strain from other family members not including children. Overall strain was then computed as the average across relationship types if at least two relationship types were represented.

Covariates

Social network characteristics may vary across sociodemographic factors. Because these factors can also be related to cognitive aging, all models controlled for age at the time of HCAP, sex/gender, race/ethnicity, income, wealth, and education (years in school). Sex/gender was dummy coded with women as the reference group. Information about race/ethnicity, income, wealth, and years in school were drawn from RAND, a corporation that creates derived variables from HRS data fit for analysis (covariate information can be found at https://www.rand.org/well-being/social-and-behavioral-policy/centers/aging/dataprod/hrs-data.html). Race/ethnicity was separated into four mutually exclusive categories (Hispanic, Non-Hispanic White, Non-Hispanic Black, and Non-Hispanic other) and dummy coded with Non-Hispanic White as the reference group. Income represented total household income, and wealth represented the difference between total assets and total debts for each participant. Participants were given the Psychosocial Questionnaire either in 2012 or 2014, depending on their HRS cohort, resulting in a dichotomized variable with the year 2012 as the reference group. Years in schools were self-reported (0–17).

One limitation of some previous research on social network characteristics and cognitive aging is the use of predictors and outcomes measured on the same occasion. In order to reduce the likelihood that associations reflect reverse causation, one would ideally control for premorbid cognitive ability, such as cognitive performance in young adulthood (Gow et al., 2011). Because such measures are rarely available in studies of aging such as the HRS, we covaried for cognitive ability at the visit prior to that in which the HCAP cognitive outcome measures were obtained. Specifically, baseline cognitive ability was operationalized as the sum of four measures from the Telephone Interview for Cognitive Status (immediate and delayed recall of a 10-word list, Serial 7s, and Backwards Counting tests). Scores could range from 0 to 27 (Crimmins et al., 2011). Because the only available prior cognitive measure (i.e., TICS) differs from the comprehensive cognitive outcomes (i.e., HCAP), residual variance in the dependent variables cannot be interpreted as a pure measure of cognitive change.

Analytic Strategy

Stata was used to conduct separate regressions for each cognitive outcome variable. The first aim examined associations between social network predictor variables averaged across relationship types (see Figure 1) and each cognitive outcome. The second aim examined associations between each social network predictor variable separated by relationship types and each cognitive outcome. The analyses completed for both aims included all covariates. Only participants with complete data for all variables were included in the analytic sample.

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Results

Intercorrelations among the variables of interest are shown in Table 2. Bivariate correlations between the social predictors revealed that, according to Pearson's r guidelines, all the correlations between predictors fall in the small to moderate range. There were no large correlations between any two predictor variables.

Likewise, all correlations between social variables and cognition variables, if significant, were small. Contact frequency with children was positively correlated with every cognitive domain, as was contact frequency with friends. Spousal support was positively correlated with episodic memory, executive function, and processing speed, but negatively correlated with language and visuoconstruction. Support from children was negatively correlated with all cognitive domains, as was support from family members other than spouses and children (other family). Support from friends had positive correlations with episodic memory, processing speed, and language. Negative correlations were revealed between spousal strain and executive function, processing speed, and visuoconstruction. Similarly, negative correlations were revealed between strain from other family, executive function, and visuoconstruction. Negative correlations were also revealed between strain from friends and all cognitive domains.

Aim 1: Social Network Structure and Quality

Results from the linear regressions showed that both structure and quality variables were associated with cognitive performance (see Table 3). Regarding social network structure, more frequent contact with social network members was associated with better performance in all cognitive outcomes except episodic memory. Neither social network size nor marital status was uniquely associated with any cognitive outcome. Regarding relationship quality, greater social support and greater strain were each associated with worse cognitive outcomes in all five cognitive domains (see Figure 2).

A sensitivity analysis was conducted to determine whether the pattern of results changed if global cognition at baseline was removed as a covariate. This analysis revealed an additional positive association between contact frequency episodic memory (see Supplemental Material, Table S1). Additionally, the magnitude of associations between contact frequency, support, strain, and every cognitive domain increased following the removal of baseline cognition. This stronger pattern of results supported the decision to covary for previous cognition, as the additional and stronger associations between social network variables and cognitive domains may be more likely to reflect reverse causation.

An additional sensitivity analysis added baseline measures of physical and mental health as covariates. These variables were not included in primary models because they could potentially mediate the relationship between social network variables and cognitive outcomes (Cohen et al., 2004; Vanderhorst et al., 2005). Therefore, controlling for them could result in underestimation of the effects of the social network variables on cognition. Depression was operationalized as the sum of responses to an eight-item version of the Center for Epidemiological Studies- Depression Scale (CES-D). Physical health was operationalized as the sum of chronic diseases the participant had. In models that included

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chronic health disease burden and depressive symptoms at baseline as covariates, patterns of significance between social network variables and cognitive outcomes were identical to the primary model, with minimal changes in the magnitude of associations (see Supplemental Material, Table S2).

Aim 2: Social Network Structure and Quality by Relationship Type

Friends—When considering individual relationship types (see Table 4), larger friend networks were associated with better performance only in visuoconstruction. More frequent contact with friends was associated with better performance in all cognitive domains (see Figure 3). Greater support from friends was not associated with performance in any of the five cognitive domains, whereas greater strain from friends was associated with worse performance in every domain except for episodic memory.

Family—Larger family networks (not including children or spouse) were related to worse performance in executive function, visuoconstruction, and processing speed, but not in episodic memory or language. Neither contact frequency with family nor strain from family was associated with any of the five cognitive domains. More support from family was associated with worse performance in episodic memory, executive function, and language, but not visuoconstruction or processing speed.

Regarding children, none of the structure or quality variables were associated with performance in any of the five cognitive domains. In separate models restricted to individuals who were married, neither spousal support nor strain were associated with any of the five cognitive outcomes (see Table 5).

Age Moderation

Because social network characteristics and functions can change with age (Carstensen et al., 1999), we explored whether patterns of association were different as a function of age. We stratified each regression model by age group (under 75 versus 75 and older). Interestingly, negative associations between social network quality variables (i.e., support and strain) and cognitive domains were numerically larger in the older age group than the younger age group (See Table 6). In contrast, positive associations between social network structure (i.e., contact frequency) and cognitive domains were numerically larger in the younger age group than the older age group.

Discussion

This study refines our understanding of links between social networks and cognitive aging by providing evidence that both social network structure and quality predict cognitive outcomes in older adults. Further, links between social network components and cognition differed as a function of relationship type and cognitive domain. Overall, these findings support previous research (Zahodne et al., 2019) that highlights the importance of both social network structure and quality for cognitive aging, as well as the potentially beneficial role of friend networks. In contrast, several aspects of family networks, including the number of and the level of support obtained from non-central family members, were

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negatively associated with cognitive function. Overall, these findings are important not only because they help to narrow the search for modifiable factors that affect cognitive ability, but also because patterns of domain-specific effects point to different mechanisms by which social networks may influence cognitive aging.

Aim 1: Structure Versus Quality

Increased contact frequency across relationship types was positively associated with every cognitive domain aside from episodic memory. These findings support existing literature that contact frequency with network members is more consequential for cognitive aging than the absolute size of the social network (Zahodne et al., 2019). Findings also support the social convoy model (Antonucci et al., 2001) and the “use it or lose it” hypothesis (Hultsch et al., 1999) by showing that the more one interacts with their network members, the more they may get to exercise different cognitive capacities and stimulate their skills, in this case bolstering their ability in executive function, visuoconstruction, language, and processing speed. When interacting with a social network, it may be possible to exercise more skills pertaining to executive function: balancing tasks, encountering novel situations, and problem solving. Additionally, much literature in language learning emphasizes the importance of being surrounded by other individuals to practice language skills in casual settings (Carvalho et al., 2016; Lee et al., 2015). While language maintenance in late life has not been studied as much as language learning in early life, this could potentially support the idea that increased frequency of contact with network members not only helps to learn language, but to maintain it. Additional links between contact frequency and cognitive domains of processing speed and visuoconstruction may point to the idea that mental stimulation gained from increased contact with a social network may be important for increased cognitive efficiency, which can extend to visuo-motor tasks with organizational demands.

Interestingly, positive associations between contact frequency and cognition were stronger in younger participants (i.e., under age 75) than older participants (i.e., age 75 and older). This pattern of results may suggest that the beneficial effects of mental stimulation derived through social interactions may be greater when the brain is more plastic. Indeed, neuroplasticity declines with age and reduced neuroplasticity may limit the extent to which mental stimulation can strengthen and/or re-organize neural networks in order to improve brain and cognitive aging.

Regarding social network quality, strain had a negative relationship with every domain. These relationships may highlight the detrimental effects of interpersonal stress on brain and cognitive health. Substantial literature demonstrates how glucocorticoids involved in chronic stress responses may have a detrimental impact on brain regions with a high density of glucocorticoid receptors, such as the hippocampus and the prefrontal cortex (Conrad et al., 2010; de Souza-Talarico et al., 2011; Hasan et al., 2012). These brain regions provide critical support for episodic memory (Lupien et al., 2007) and executive function, respectively (Diamond et al., 2013). Processing speed is also susceptible to the detrimental effects of stress (Tun et al., 2013), possibly because stress can damage the structural integrity of white matter tracts.

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However, the domain-general findings from this study suggest that stress pathways may have more widespread effects on the brain (Vyas et al., 2016). Interestingly, negative associations between strain and cognition in this study were strongest for older participants (i.e., age 75 and older), whose brains may be more vulnerable to the neurotoxic effects of stress as the result of normative and/or pathological brain aging. Thus, the contrasting pattern of results for contact frequency versus strain in age-stratified models supports hypotheses that social network structure may influence cognition through mental stimulation, whereas social network quality may influence cognition through stress mechanisms.

While the effect sizes observed were relatively small, it is important to conceptualize their meaning in practical terms. For example, the difference between reporting "a little" strain versus "a lot" of strain across relationships was equivalent to about 7.42 years of aging in processing speed performance. Likewise, the difference between contact with social network members "once or twice per month" versus "once or twice per year" was equivalent to about 3.28 years of aging in executive function performance. Positioning these findings within the appropriate context of cognitive aging may be a useful tool to help understand the real-world significance of their effect sizes.

Contrary to our hypothesis based on literature showing benefits of perceived social network quality on mental and physical health (Ellwardt et al., 2015), support was negatively associated with every cognitive domain. While this finding may seem counterintuitive, it is also supported by previous literature (Zahodne et al., 2019). This finding could indicate a couple of potential explanations. First, it is possible that too much support from the social network, even if perceived as positive, could be detrimental to an individual's functioning by limiting individuals' own autonomy, responsibility, and ultimately opportunities to consistently stimulate their cognitive abilities (the "lose it" part of "use it or lose it"; Hultsch et al., 1999). This concept has been referred to as "excess disability" (Bolger et al., 2007). Second, it is possible that participants who had lower cognitive abilities to begin with may have been receiving a greater amount of support. While predictors and outcomes were not drawn from the same assessment wave, there was a relatively short amount of time that passed between social network data collection and cognitive data collection. While we controlled for cognition at the time of the social network data collection, only a coarse measure of global cognition was available.

Additionally, previous literature highlighting the potential stress reducing effects of social networks emphasizes that it may not be simply one's own relationships that are related to stress reduction. Instead, relationships between individuals composing one's social network may also have an effect on one's own stress (Ellwardt et al., 2020). For example, if an individual has two very positive, very close relationships with members of their social network, that individual may not experience stress-related benefit from those relationships unless those two network members also have positive relationships with each other. These findings imply that future research should account not only for the individual's direct relationship to others, but the relationships among others in the social network, adding an additional layer of nuance to the study of social relationships and cognition that could not be examined in the current study. Understanding nuance such as this could help to explain the

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negative and nonexistent relationships between social network support and cognition in our study.

Aim 2: Relationship Types

Positive associations between contact frequency with friends and cognition were also domain general. Since contact frequency with other types of social network members did not have significant associations with any cognitive outcomes, it appears that contact frequency with friends was the driving factor in the overall positive contact frequency results observed in the aim one analyses that aggregated social network characteristics across relationship types. In an attempt to understand these findings within the context of cognitive aging, a one-unit decrease on the scale of contact frequency with friends was equivalent to about 8.43 years of aging for executive functioning performance, which was the domain that showed the largest numerical association with contact frequency with friends. In other words, if participants were in contact with their friends once or twice a week instead of three or more times a week, on average, this was equivalent to about 8.43 years of aging in executive functioning performance.

These findings provide further support for separating the study of social networks by relationship type to reveal more specific associations between social relationships and cognitive function. Substantial previous literature has highlighted the unique effects of friendships on cognition compared to other relationship types (Fiori et al., 2012; Sharifian et al., 2019; Zahodne et al., 2019; Sharifian et al., 2020a; Sharifian et al., 2020b), and these findings provide further support. The concept of social pruning posits that as an individual ages, they maintain fewer friendships than younger individuals (Carstensen et al., 1999). This could imply that the friendships that are maintained are those that are particularly beneficial and rich in cognitive stimulation (Huxhold et al., 2014). In contrast, family relationships are more obligatory and are less likely to be pruned, which may help to explain the discrepancy between positive friend findings and negative or absent family findings (Lee et al., 1987; Wang et al., 2015).

Other characteristics of friend networks showed more domain-specific effects. Specifically, the number of friends had a positive relationship only with visuoconstruction. Additionally, strain from friends had negative relationships with visuoconstruction, language, and processing speed, but not episodic memory or executive function. While it is not exactly clear why only visuoconstruction would benefit from a greater number of friends (and only friends), or why visuoconstruction, language, and processing speed could be potentially more damaged by strain with friends than other domains, this could open the door to further study looking at more specific mechanisms of mental stimulation and stress pathways and their relationship with cognition.

The number of family members other than children and spouse showed negative associations with executive function, visuoconstruction, and processing speed. This finding contrasts somewhat with some previous research showing positive relationships between the number of non-central family members and cognitive outcomes (Ying et al., 2020). However, it should be noted that siblings were included in the “other family member” category in the current study but were excluded in the “other family member” category in the study

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by Ying et al. (2020), which posited that contact with a greater number of peripheral family members may be mentally stimulating in a way similar to friendships. Additionally, children were included as “other family” members in the study conducted by Ying et al. (2020) but not ours. Which network members are classified as non-central or other family members may change the nature of support received from “other family” and whether it is likened to voluntary friendships or obligatory familial relationships (Huxhold et al., 2014). Future studies should disaggregate categories like “other family members” to clarify these mixed findings and determine whether, for example, interacting with children may be more cognitively beneficial than interacting with siblings.

Negative relationships were also present between support from other family members and language, executive function, and episodic memory. These findings imply that it was support from non-central family members, not other relationship types, that accounted for the negative relationships between support and cognition in Aim 1, which did not disaggregate by relationship type. This study is not the first to find negative relationships between support and cognitive outcomes (Bolger et al., 2007; Zahodne et al., 2019) but does not necessarily imply that support from family is detrimental.

The specificity of the negative support-cognition associations to non-central family members may point to reverse causation. For example, an individual who was starting to experience cognitive decline could have been starting to utilize more support from siblings and other family members at the time of social network assessment. Indeed, previous literature has shown that other family members become a primary source of support when individuals experience health challenges (Schulz et al., 2016). Of note, age group-stratified models revealed that negative support-cognition associations were largest for the oldest participants (i.e., aged 75 and older), who may also be most likely to be experiencing health challenges. Future studies with larger samples should explore whether this reverse causation may be particularly plausible for certain subsets of participants. Additionally, the possibility of reverse causality should be examined not only with regard to the unexpected family support findings, but also with regard to findings that highlighted the potentially beneficial nature of contact frequency with friends.

Strengths, Limitations, and Future Directions

The HRS strives to study a nationally representative sample, as opposed to a racially balanced sample. This means that racial minority groups (i.e., Hispanic and Black Americans) have less representation in the data than the racial majority (i.e., White Americans). Therefore, in randomly sampled subsets of the HRS data such as with the HCAP, even smaller numbers of racial minorities are represented in a way that is proportionally similar to the larger sample. Previous literature has shown that social network factors may differ across racial groups, and likewise be differently related to cognition (Arjouch et al., 2001; Sharifian et al., 2019). Moving forward, it would be beneficial to examine racially balanced samples in studies of cognition to accurately represent differences across groups, as well as group-specific resilience factors. Of note, HCAP only included individuals who were 65 or older, while the larger HRS sample is representative of US

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adults aged 51 and older. Given that social networks can change with age (Carstensen et al., 1999), current findings with the HCAP sample may not be generalizable to the larger HRS.

An additional limitation is the availability of only one time point of comprehensive cognitive data. While we attempted to control for previous cognitive levels by utilizing the limited cognitive data available for each participant at the time of social network data collection, these data were not as detailed as the HCAP neuropsychological battery conducted in 2016. Therefore, our ability to partial out previous cognitive abilities was limited. Additional longitudinal data are needed to fully examine the possibility of reverse causation.

Conclusion

The numerous associations between specific social network characteristics and cognition observed in this study provide support for existing literature on the importance of social networks in cognitive aging. This study extends previous literature showing that both network structure and quality could be influential by detailing how links between social network characteristics and cognition differ across relationship types and cognitive domains, leading to more specific hypotheses about differential mechanisms (e.g., mental stimulation and stress). The combination of detailed cognitive data as well as detailed social network data helped to reveal more specific relationships between the two that can fuel future research looking for specific modifiable factors that may affect cognition.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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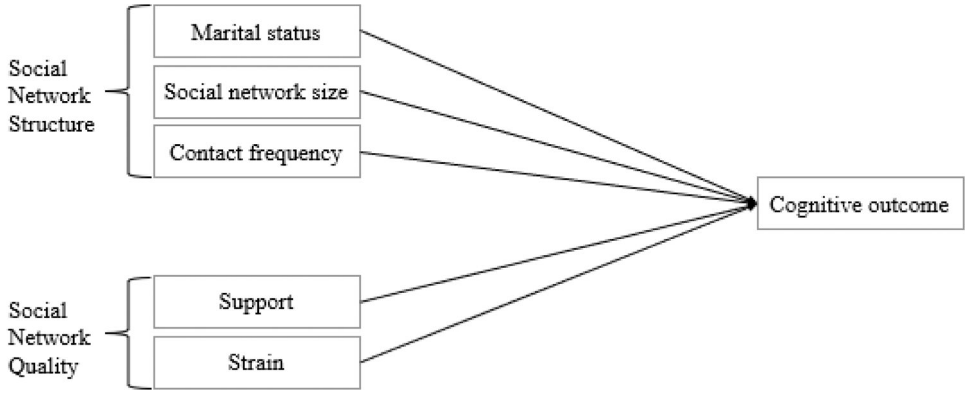

Figure 1.
Aim 1 Analytic Strategy
Note. The second aim of the study followed the same conceptual strategy, and further parsed each social predictor group (aside from marital status) by relationship type.

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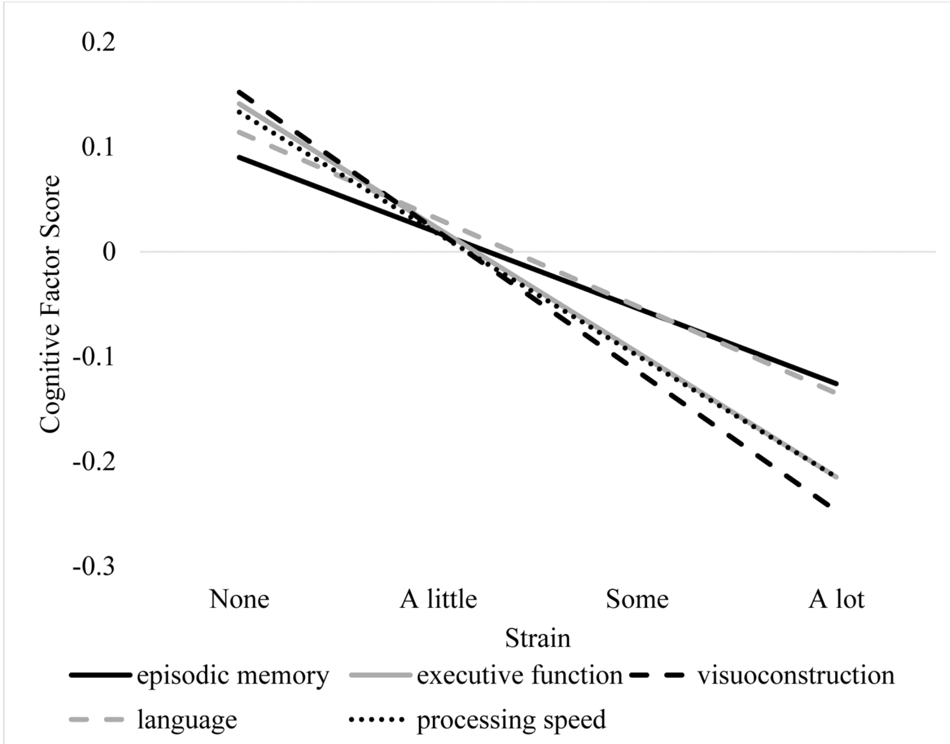

Figure 2.
Associations Between Strain and Cognitive Domains

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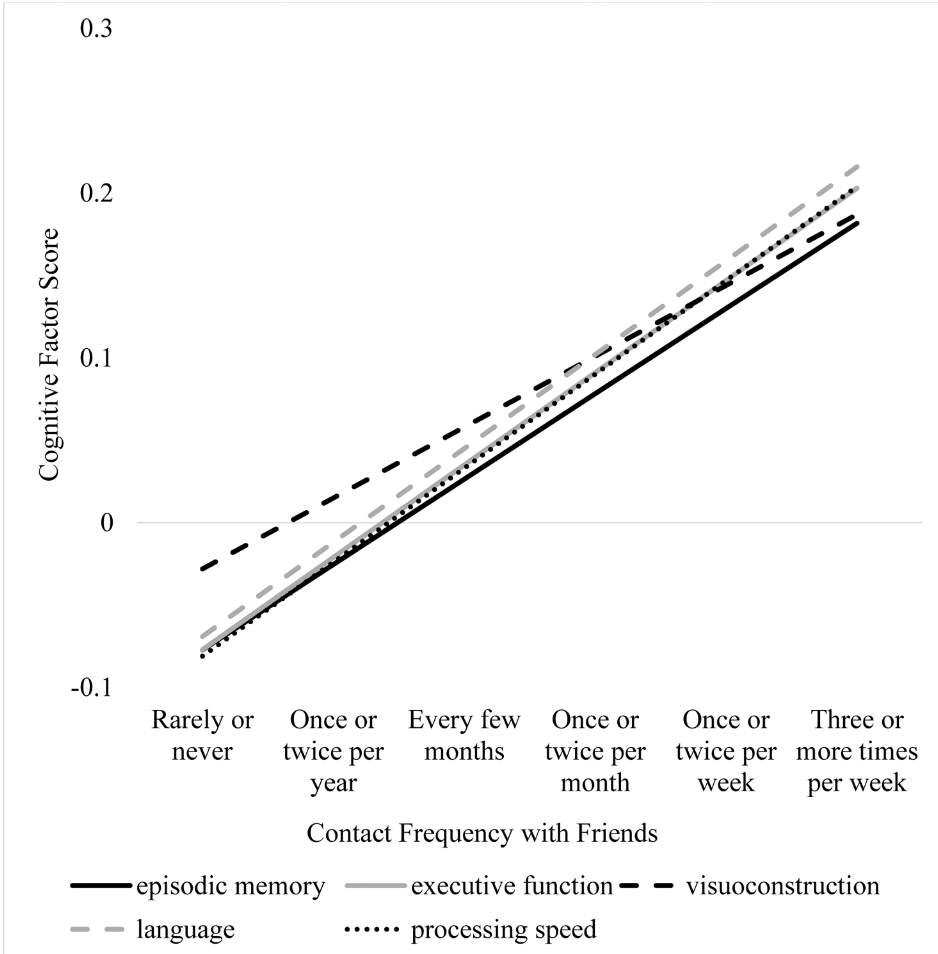

Figure 3.
Associations Between Contact Frequency with Friends and Cognitive Domains

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Table 1

Sample Characteristics

Characteristic (*n* = 2,553)	***M (SD) or %***
Age (years) in 2016	76.63 (7.47)
Gender (% men)	39.66
Race/ethnicity (%)	
Non-Hispanic White	71.24
Non-Hispanic Black	15.69
Hispanic (any race)	10.86
Other	2.21
Income (US dollars) in 2012/2014	61,534.98(116,169.20)
Wealth (US dollars) in 2012/2014	503,892(1,079,451)
Baseline year (% 2012)	47.41
Education (years)	12.75 (3.17)
Cognitive ability (0–27) in 2012/2014	15.15 (4.33)
Social Network Structure in 2012/2014	
Married/Partnered (%)	63.90
Number of children (0–30)	2.81 (4.02)
Number of other family (0–30)	4.02 (5.96)
Number of friends (0–30)	4.86 (7.30)
Contact frequency with children (1–6)	3.96 (1.03)
Contact frequency with other family (1–6)	3.37 (1.08)
Contact frequency with friends (1–6)	3.79 (1.06)
Relationship Quality in 2012/2014	
Support from spouse (1–4)	3.48 (.65)
Support from children (1–4)	3.30 (.70)
Support from other family (1–4)	2.89 (.87)
Support from friends (1–4)	3.06 (.74)
Strain from spouse (1–4)	1.95 (.67)
Strain from children (1–4)	1.65 (.62)
Strain from other family (1–4)	1.53 (.61)
Strain from friends (1–4)	1.38 (.47)

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Table 2

Bivariate Correlations

Variable		Contact frequency			Support				Strain				Cognitive Domain			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Network size	1.00															
Contact frequency																
2.Children	0.19*	1.00														
3. Other Family	0.21*	0.45*	1.00													
4. Friends	0.10*	0.32*	0.32*	1.00												
Support																
5. Spouse	0.06*	0.06*	0.06*	0.07*	1.00											
6. Children	0.23*	0.40*	0.22*	0.05*	0.21*	1.00										
7. Other Family	0.24*	0.14*	0.48*	0.08*	0.10*	0.39*	1.00									
8. Friends	0.16*	0.12*	0.19*	0.39*	0.12*	0.25*	0.32*	1.00								
Strain																
9. Spouse	−0.10*	−0.06*	−0.03	−0.03	−0.50*	−0.18*	−0.10*	−0.05*	1.00							
10. Children	−0.10*	−0.12*	−0.06*	−0.04*	−0.16*	−0.39*	−0.16*	−0.03	0.39*	1.00						
11. Other Family	−0.05*	−0.08*	−0.02	−0.02	−0.12*	−0.22*	−0.22*	−0.03	0.34*	0.49*	1.00					
12. Friends	−0.02	−0.03	−0.00	−0.05*	−0.09*	−0.16*	−0.07*	−0.08*	0.27*	0.38*	0.43*	1.00				
Cognitive Domain																
13. Episodic Memory	0.00	0.12*	0.00	0.22*	0.05*	−0.06*	−0.11*	0.06*	−0.02	0.02	−0.01	−0.04*	1.00			
14. Executive Function	−0.01	0.13*	0.01	0.24*	0.14*	−0.08*	−0.14*	0.03	−0.07*	−0.01	−0.05*	−0.08*	0.81*	1.00		
15. Processing Speed	−0.01	0.14*	0.02	0.24*	0.12*	−0.07*	−0.12*	0.04*	−0.06*	0.01	−0.03	−0.07*	0.83*	0.94*	1.00	
16. Language	0.00	0.13*	0.01	0.24*	−0.06*	−0.06*	−0.12*	0.06*	−0.04	0.00	−0.02	−0.06*	0.94*	0.89*	0.89*	1.00
17. Visuoconstruction	−0.01	0.11*	0.01	0.21*	−0.08*	−0.08*	−0.11*	0.02	−0.08*	−0.03	−0.06*	−0.10*	0.73*	0.93*	0.88*	0.84*

* $p < .05$

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Table 3

Aim 1 Regression Results, Social Network Characteristics Aggregated Across Relationship Types

Variable	Episodic Memory	Executive Function	Visuoconstruction	Language	Processing
	Estimate (*SE*), *β*	Estimate (*SE*), *β*	Estimate (*SE*), *β*	Estimate (*SE*), *β*	Estimate (*SE*), *β*
Social Network Structure					
Network Size	−0.00 (0.01), −0.00	−0.01 (0.01), −0.02	−0.00 (0.00), −0.02	−0.00 (0.01), −0.01	−0.02 (0.02), −0.02
Contact frequency	0.11 (0.08), 0.02	0.23 (0.06), 0.06*	0.09 (0.03), 0.05*	0.22 (0.09), 0.04*	0.76 (0.20), 0.06*
Marital Status	0.05 (0.13), 0.01	−0.04 (0.09), −0.01	0.02 (0.05), 0.01	−0.00 (0.14), −0.00	−0.22 (0.33), −0.01
Social Network Quality					
Support	−0.30 (0.11), −0.05*	−0.32 (0.08), −0.07*	−0.13 (0.04), −0.05*	−0.33 (0.13), −0.04*	−0.99 (0.29), −0.06*
Strain	−0.30 (0.13), −0.04*	−0.37 (0.09), 0.06*	−0.21 (0.05), −0.07*	−0.35 (0.15), −0.04*	−1.33 (0.34), −0.06*
Covariates					
Age	−0.17 (0.01), −0.33*	−0.14 (0.01), −0.34*	−0.06 (0.00), −0.28*	−0.20 (0.20), −0.34*	−0.57 (0.02), −0.39*
Baseline year	0.34 (0.11), 0.04*	0.29 (0.08), 0.05*	0.15 (0.04), 0.05*	0.46 (0.13), 0.05*	0.95 (0.29), 0.05*
Race					
Black	−0.90 (0.18), −0.08*	−1.90 (0.13), −0.22*	−0.86 (0.07), −0.20*	−1.78 (0.20), −0.14*	−5.60 (0.46), −0.18*
Hispanic	−0.66 (0.22), −0.05*	−0.86 (0.15), −0.08*	−0.33 (0.08), −0.07*	−0.67 (0.24), −0.04*	−3.35 (0.55), −0.09*
Other	−0.90 (0.41), −0.03*	−0.99 (0.29), −0.05*	−0.36 (0.16), −0.03*	−1.79 (0.45), −0.06*	−3.37 (1.04), −0.04*
Income	0.00 (0.00), 0.03	0.00 (0.00), 0.03	0.00 (0.00), 0.04	0.00 (0.00), 0.02	0.00 (0.00), 0.02
Wealth	0.00 (0.023), 0.03	0.00 (0.00), 0.05*	0.00 (0.00), 0.04*	0.00 (0.00), 0.05*	0.00 (0.00), 0.04*
Education	0.20 (0.015), 0.15*	0.25 (0.02), 0.25*	0.12 (0.01), 0.24*	0.30 (0.03), 0.20*	0.83 (0.06), 0.23*
Baseline cognitive ability	0.37 (0.123), 0.40*	0.22 (0.01), 0.31*	0.10 (0.01), 0.28*	0.40 (0.02), 0.38*	0.82 (0.04), 0.32*
Gender	0.91 (0.603), 0.12*	−0.14 (0.09), −0.02	−0.09 (0.05), −0.03	0.45 (0.14), 0.05*	0.91 (0.32), 0.04*

Note. Estimates represent *b*. *SE* = standard error of *b*. The episodic memory model $R^2 = 0.47$. The executive function model $R^2 = 0.55$. The visuoconstruction model $R^2 = 0.44$. The language model $R^2 = 0.51$. The processing speed model $R^2 = 0.54$.

* $p < .05$

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Table 4

Aim 2 Regression Results, Disaggregated by Relationship Type

Variable	Episodic Memory	Executive Function	Visuoconstruction	Language	Processing
	Estimate (*SE*), *β*	Estimate (*SE*), *β*	Estimate (*SE*), *β*	Estimate (*SE*), *β*	Estimate (*SE*), *β*
Social Network Structure					
Network Size					
Children	0.00 (0.02), 0.00	0.01 (0.02), 0.02	0.00 (0.01), 0.00	0.01 (0.03), 0.01	0.03 (0.06), 0.01
Other family	0.00 (0.01), 0.01	−0.03 (0.01), 0.06*	−0.02 (0.01), −0.07*	−0.02 (0.02), −0.03	−0.08 (0.04), −0.05*
Friends	0.01 (0.01), 0.01	0.01 (0.01), 0.02	0.01 (0.00), 0.04*	0.02 (0.01), 0.03	0.04 (0.03), 0.03
Contact frequency					
Children	−0.02 (0.08), −0.01	0.01 (0.06), 0.00	0.01 (0.03), 0.01	0.01 (0.09), 0.00	−0.01 (0.21), −0.00
Other family	−0.11 (0.08), −0.05	0.05 (0.06), 0.02	0.00 (0.03), 0.00	−0.07 (0.09), −0.07	0.16 (0.21), 0.02
Friends	0.21 (0.08), 0.06*	1.18 (0.06), 0.06*	0.07 (0.03), 0.05*	0.24 (0.09), 0.06*	0.65 (0.20), 0.06*
Marital Status	0.03 (0.15), 0.00	−0.04 (0.11), −0.01	0.01 (0.06), 0.00	0.02 (0.17), 0.00	−0.31 (0.40), −0.01
Social Network Quality					
Support					
Children	0.02 (0.12), 0.00	−0.03 (0.09), −0.01	−0.05 (0.05), −0.03	−0.02 (0.14), 0.00	−0.12 (0.31), −0.01
Other family	−0.21 (0.10), −0.05*	−0.16 (0.07), −0.05*	−0.02 (0.04), −0.02	−0.28 (0.11), −0.05*	−0.46 (0.25), −0.04
Friends	−0.08 (0.11), −0.02	−0.13 (0.08), 0.03	−0.06 (0.04), −0.05	−0.02 (0.12), −0.00	−0.41 (0.27), −0.03
Strain					
Children	0.01 (0.14), 0.00	−0.10 (0.10), 0.02	−0.09 (0.05), −0.04	−0.05 (0.15), −0.01	−0.32 (0.34), −0.02
Other family	−0.13 (0.14), −0.02	−0.11 (0.10), −0.02	−0.05 (0.05), −0.02	−0.06 (0.15), −0.01	−0.39 (0.35), −0.02
Friends	−0.29 (0.16), −0.04	−0.30 (0.12), −0.05*	−0.13 (0.06), −0.04*	−0.38 (0.18), −0.04*	−1.10 (0.42), −0.05*
Covariates					
Age	−0.18 (0.01), −0.33*	−0.14 (0.01), −0.34*	−0.06 (0.00), −0.28*	−0.20 (0.01), −0.33*	−0.58 (0.03), −0.39*
Baseline year	0.29 (0.13), 0.04*	0.23 (0.09), 0.04*	0.12 (0.05), 0.04*	0.43 (0.15), 0.05*	0.89 (0.34), 0.04*
Race					
Black	−0.99 (0.21), −0.09*	−1.99 (0.15), −0.22*	−0.88 (0.08), −0.21*	−1.89 (0.23), 0.15*	−7.07 (0.53), −0.20*
Hispanic	−0.70 (0.26), −0.05*	−0.90 (0.18), −0.09*	−0.36 (0.10), 0.07*	−0.68 (0.28), −0.04*	−3.39 (0.65), −0.05*
Other	−1.10 (0.50), 0.04*	−1.10 (0.35), 0.05*	−0.38 (0.19), −0.03*	−1.80 (0.56), −0.05*	−3.59 (1.27), −0.04*

Variable	Episodic Memory	Executive Function	Visuoconstruction	Language	Processing
	Estimate (*SE*), β	**Estimate (*SE*), β**	**Estimate (*SE*), β**	**Estimate (*SE*), β**	**Estimate (*SE*), β**
Income	0.00 (0.00), 0.02	−0.00 (0.00), 0.01	0.00 (0.00), 0.02	−0.00 (0.00), −0.02	0.01 (0.00), 0.00
Wealth	0.00 (0.00), 0.00	0.00 (0.00), 0.04*	0.00 (0.00), 0.04	0.00 (0.00), 0.04*	0.03 (0.00), 0.00
Education	0.21 (0.03), 0.16*	0.27 (0.02), 0.26*	0.12 (0.01), 0.24*	0.30 (0.03), 0.20*	0.84 (0.07), 0.03*
Baseline cognitive ability	0.38 (0.02), 0.35*	0.20 (0.01), 0.29*	0.09 (0.01), 0.27*	0.39 (0.02), 0.36*	0.80 (0.05), 0.31*
Gender	0.11 (0.15), 0.88*	−0.06 (0.10), 0.01	−0.07 (0.06), −0.03	0.44 (0.16), 0.05*	1.04 (0.37), 0.05*

Note. Estimates represent *b*. *SE* = standard error of *b*.The episodic memory model R^2 = 0.46. The executive function model R^2 = 0.54. The visuoconstruction model R^2 = 0.45. The language model R^2 = 0.50. The processing speed model R^2 = 0.54.

* $p < .05$

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Table 5

Aim 2 Regression Results, Selected Results from Models Restricted to Married/Partnered Participants (n = 1,232)

Variable	Episodic Memory	Executive Function	Visuoconstruction	Language	Processing
	Estimate (*SE*), *β*	**Estimate (*SE*), *β***	**Estimate (*SE*), *β***	**Estimate (*SE*), *β***	**Estimate (*SE*), *β***
Spousal support	−0.04 (0.16), −0.01	0.20 (0.12), 0.04	0.08 (0.07), 0.03	0.12 (0.19), 0.02	0.62 (0.43), 0.04
Spousal strain	−0.04 (−0.04), −0.01	−0.04 (0.12), −0.01	−0.02 (0.06), −0.01	0.04 (0.19), 0.01	−0.04 (0.42), −0.00

Note. Estimates represent *b*. *SE* = standard error of *b*. The episodic memory model R^2 = 0.49. The executive function model R^2 = 0.55. The visuoconstruction model R^2 = 0.44. The language model R^2 = 0.50. The processing speed model R^2 = 0.54.

* = $p < .05$

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Table 6

Aim I Stratified by Age (younger than 75 n = 1059; 75 or older n = 1494)

Variable	Episodic Memory		Executive Function		Visuoconstruction		Language		Processing	
	β		β		β		β		β	
	Under 75	**75 +**	**Under 75**	**75+**	**Under 75**	**75+**	**Under 75**	**75+**	**Under 75**	**75+**
Social Network Structure										
Network Size	−0.02	−0.00	−0.01	−0.01	−0.04	−0.01	−0.02	−0.00	−0.04	−0.01
Contact frequency	0.04	0.01	0.08*	−0.02*	0.06*	0.05*	0.06*	0.04	0.08*	0.05*
Marital Status	0.01	−0.00	0.08	0.06	0.01	−0.00	−0.02	0.00	−0.02	−0.01
Social Network Quality										
Support	−0.03	−0.06*	−0.05	−0.08*	−0.03	−0.07*	−0.02	−0.06*	−0.03	−0.07*
Strain	−0.03	−0.04	−0.05	−0.07*	−0.06*	−0.23*	−0.02	−0.05*	−0.05*	−0.07*
Covariates										
Age	−0.12*	−0.25*	−0.12*	0.32*	−0.10*	−0.23*	−0.11*	−0.25*	−0.15*	−0.28*

Note. Additional covariates were left out of the table for simplicity, although included in the model. The episodic memory model R^2 = 0.44 for under75, and 0.40 for 75 and older. The executive function model R^2 = 0.55 for under75, and 0.47 for 75 and older. The visuoconstruction model R^2 = 0.45 for under75, and 0.38 for 75 and older. The language model R^2 = 0.47 for under75, and 0.44 for 75 and older. The processing speed model R^2 = 0.49 for under75, and 0.47 for 75 and older.

* $p < .05$