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Research Article

Longitudinal Within-Person Associations Between Quality of Social Relations, Structure of Social Relations, and Cognitive Functioning in Older Age

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Abstract

Objectives: Individuals' social connections and interpersonal experiences can both shape and be shaped by cognitive functioning. This study examines longitudinal within-person associations between quality of social relations, structure of social relations, and cognitive functioning in older age.

Methods: We examined 16-year longitudinal data (3 waves) from 497 older adults (M = 66.07 years, SD = 0.83, range = 64–68 years) from the Interdisciplinary Longitudinal Study of Adult Development and Aging. Quality of social relations was measured by scales on perceived emotional support, instrumental support, and social integration. Structure of social relations was measured by self-reported number of leisure time partner types, indicating social network diversity. Cognitive functioning was assessed as a latent construct consisting of five cognitive tests (i.e., Information, Similarities, Letter Fluency, Picture Completion, Block Design). We used a random intercept cross-lagged panel model in the analysis.

Results: At the within-person level, prior quality of social relations, but not structure of social relations, was positively associated with subsequent cognitive functioning. Moreover, prior cognitive functioning was positively associated with subsequent structure of social relations, but not with quality of social relations.

Discussion: Quality of social relations is a protective factor of cognitive aging. Additionally, responding to prior lower cognitive functioning, social network diversity reduced, but quality of social relations did not seem to change. Overall, this study suggested that social relations and cognitive functioning mutually influence each other, but different aspects of social relations (i.e., quality, structure) might have different directional associations with cognitive functioning.

Keywords: Cognitive aging, Longitudinal, Random intercept cross-lagged panel model, Reciprocal association, Social network diversity.

Across the life span, an individual is typically surrounded by a circle of other people, such as spouse, family, and friends. This circle is called a convoy, meaning a protective escort (Antonucci et al., 2014). Maintaining convoys of social relations has been shown to protect against cognitive decline in older age (Evans et al., 2019; Kelly et al., 2017; Kuiper et al., 2015). Most studies thus far have examined unidirectional effects of social relations on cognitive functioning, thereby neglecting the potential reversed directional effects of cognitive functioning on social relations. Life-span developmental theory conceptualizes development as an adaptive process of coordinating, integrating,

and balancing gains and losses of internal and external resources (Baltes et al., 1999, 2007). That is, while environment shapes human development, individuals also shape their own environment, selecting themselves into and out of environments (Wahl & Gerstorf, 2018). If cognitive aging is indeed an ongoing adaptive process, social relations and cognitive functioning should exhibit reciprocal relations over time. The directional effect of cognitive functioning on social relations can reflect how individuals adaptively change their social relations in response to their own cognitive functioning.

Social Relations and Cognitive Functioning in Older Age

Two dimensions of social relations that are pivotal in explaining their influence on cognitive health in older age are their quality and their structure (Antonucci et al., 2019). Quality of social relations refers to an individual's evaluation of their social relationships (Antonucci, 1990; Zahodne et al., 2019). It is typically measured by perceived emotional and instrumental support, satisfaction with social relations, social integration, and social strain (e.g., Seeman et al., 2001). Relationship quality is positively associated with cognitive performance, including visuospatial abilities, language, executive functions, episodic memory, processing speed, and semantic memory (Gow et al., 2013; Kelly et al., 2017). Relationship quality is negatively associated with the likelihood of developing dementia (Fratiglioni et al., 2004; Sörman et al., 2015). It is proposed that positive and supportive social relations can buffer stress and loneliness, preventing cardiovascular and neurological diseases (Antonucci et al., 2019; Fratiglioni et al., 2004).

Structure of social relations refers to objective characteristics (Antonucci, 1990; Zahodne et al., 2019). It is typically measured by the number of social ties, frequency of contacts with social ties, and diversity of social ties (e.g., Ali et al., 2018; Seeman et al., 2001). It is positively associated with cognitive performance, such as executive functions, orientation, episodic memory, and processing speed (Ali et al., 2018; Evans et al., 2019; Kelly et al., 2017; Shankar et al., 2013), and negatively associated with risk of developing dementia (Kuiper et al., 2015; Rafnsson et al., 2017). Researchers on social convoy theory propose that larger social relationship structure offers opportunities for individuals to participate in social interaction and communication, where they engage and stimulate their mental resources (Antonucci et al., 2019). This assumption is in line with the "use it or lose it" hypothesis, positing that performing cognitively demanding activities helps to exercise mental resources and to preserve cognitive functioning in older age (Hertzog et al., 2008).

Recent reviews have pointed out that prevention of cognitive decline and dementia is a lifelong process (Dixon & Lachman, 2019; Fratiglioni et al., 2020). Life-span developmental psychologists propose that human development is the outcome of a lifelong ongoing adaptive process, co-constructed by biology and culture. In this process, individuals respond to changes in their inner biological system and their outer—ecological—environment as they move through life (Baltes et al., 1999, 2007; Wahl & Gerstorf, 2018). The adaptive characteristic implies that not only do social relations contribute to the maintenance (or loss) of cognitive functioning, but cognitive functioning (or decline) may also influence the formation of social relations. In other words, social relations and cognitive functioning may reciprocally influence each other over the whole life span, even in older age. There is evidence from similar lines of research showing that older adults proactively shape their social environment. For instance, older adults maintain emotionally close social relationships and discontinue peripheral social relationships given their perceived limited future lifetime (Lang, 2001; Lang & Carstensen, 2002). Moreover, older adults with better self-reported health have better positional advantages in their social networks, such that they connect more closely to their social ties and extract more information and resources from their network (Schafer, 2013). Older adults who have lower functional health tend to reduce their network size but increase their frequency of contact with their social ties, which, in turn, brings in more support (Cornwell, 2009; Van Tilburg & Broese Van Groenou, 2002). Similar to health and future time perspective, cognitive functioning is likely to influence social relations, because it may influence older adults' capacity and preference in initiating and maintaining social contact.

Thus far, the majority of past studies has focused on a purely unidirectional perspective, which views quality and structure of social relations as predictors of cognitive functioning. Recent studies have started to consider bidirectional characteristics in the examination of associations between relationship quality, relationship structure, and cognitive functioning. For example, Zahodne and colleagues (2019) examined data from the Health and Retirement Study and found that the structure of social relations (i.e., being married, reporting more frequent contacts) was associated with a trajectory of slower decline in episodic memory (i.e., immediate and delayed recall) over 6 years. This study also reported that the quality of social relations (i.e., social support, social strain) was not associated with memory decline and that baseline memory did not predict subsequent changes in structure and quality of social relations. In contrast, Liao and colleagues (2018) examined data from the Whitehall II cohort study and found that prior executive functions and episodic memory (i.e., delayed recall) predicted changes in subsequent relationship quality (i.e., social support) received over 5 years. Li and Zhang (2015) examined data from the Chinese

Longitudinal Healthy Longevity Survey and found that older adults' social network diversity and cognitive impairment (represented by scores of the Mini-Mental State Examination; Folstein et al., 1975) had a reciprocal association over 3 years. In sum, these first findings seem to suggest a mixed picture, where social relations and cognitive functioning can be both, a significant predictor and outcome, of each other.

Moreover, these few bidirectional studies (Li & Zhang, 2015; Liao et al., 2018; Zahodne et al., 2019) have limitations that may have led to incomplete or premature results regarding longitudinal associations between social relations and cognitive functioning in older age. First, these studies focused on a rather narrow selection of specific cognitive functions (i.e., episodic memory, executive functions). It has been shown that a wide range of cognitive functions is associated with the quality and structure of social relations (Evans et al., 2019; Kuiper et al., 2015) and it is thus unclear whether the reported null findings from past studies generalize to other cognitive functions. Second, whereas these prior studies have modeled latent variables for parameters representing change or growth, they used manifest variables as indicators of cognitive function and social relations. In this way, measurement error stemming from unique variance in the measurement process is not separated from occasion-specific variance (Ferrer et al., 2008).

Third, past studies have applied statistical approaches (i.e., latent change score models, latent growth curve models, cross-lagged panel model) that are not able to fully disentangle between-person variation from within-person variation in longitudinal associations (Mund & Nestler, 2019). Associations that are present on the level between individuals do not allow inferences about the actual associations in processes within individuals (Molenaar, 2004). More specifically, while modeling between-person variation provides information about whether individuals with higher cognitive functioning also tend to be those with "better" social relations stably over time, within-person variation provides insights into whether individuals' development in social relations precedes development in their cognitive functioning, or the other way around. Moreover, separating out stable between-person variation allows controlling for unobserved confounding between-person variables that cause some individuals to show stable tendencies of higher cognitive functioning and social relations than others (Hamaker et al., 2015). Therefore, modeling developmental relations in variation within individuals that is adjusted for stable between-person associations enables us to take a closer look at the actual causal developmental interplay between cognitive functioning and social relations over time.

In sum, according to the adaptive characteristic of human beings that is proposed in the life-span development theory (Baltes et al., 1999; Wahl & Gerstorf, 2018), social relations and cognitive functioning may demonstrate reciprocal associations in their dynamic development in older age. The current literature can benefit from further investigation on associations between social relations (quality and structure) and a broader conceptualization of cognitive functioning, adding a clear focus on within-person associations.

The Current Study

This study examines reciprocal within-person associations between quality of social relations, structure of social relations, and cognitive functioning in older age. Similar to the study of Zahodne and colleagues (2019), we aim to capture the unique associations between different dimensions of social relations (i.e., quality, structure) and cognitive functioning. Thus, we examine longitudinal associations between the three constructs within a single model. More specifically, in line with previous literature on effects of social relations on cognitive aging (Evans et al., 2019; Kuiper et al., 2015), we expect that higher quality and larger structure of social relations predicts better subsequent cognitive functioning. Moreover, because health is associated with network size, network diversity, and the amount of received support (Cornwell, 2009; Li & Zhang, 2015), we hypothesize that better cognitive functioning predicts higher quality and larger structure of social relations over time.

We base our conceptualization on a broader range of cognitive abilities. We include five established cognitive tests that have been used to examine individuals' capacity for social interactions and communication (Evans et al., 2019; Kelly et al., 2017; Mayes et al., 2018). We implement a second-order model for the constructs measured by multiple indicator variables, correcting the important model parameters for measurement error. Furthermore, we analyze the data using the random intercept cross-lagged panel model (RI-CLPM; Hamaker et al., 2015). This model allows examinations of the bidirectional interplay between cognitive function, quality of social relations, and structure of social network on the basis of within-person variation, adjusting for stable between-individual differences.

Method

Participants and Procedures

We examined 16-year longitudinal data from the Interdisciplinary Longitudinal Study of Adult Development and Aging (ILSE; e.g., Aschwanden et al., 2018; Siebert et al., 2016). Starting from 1994, ILSE surveyed 1,000 participants who resided in East and West Germany from two cohorts (born 1930–1932 and 1950–1952). We examined the data of 1997/1998, 2005/2006, and 2014/2016 from the older cohort (i.e., born 1930–1932) because the present study focused on older age. We did not include data of 1993/1994, because this assessment did not include

the measures of social relations. As of now, we refer to the measurement occasions as follows: 1997/1998 (i.e., the baseline of our analysis = Time 1; T1), 2005/2006 (Time 2; T2), and 2014/2016 (Time 3; T3).

At T1, the sample had 497 participants with an average age of 66.07 years (*SD* = 0.83, range = 64–68 years, 48% female). (T1 had 499 participants. We excluded two participants, because they had missing data in almost all the examined variables across all time points.) The average years of education was 12.89 (*SD* = 2.76, range = 8–18). Compared with dropouts at T3 (n = 259), those remaining in the study (n = 238) did not significantly differ with regard to gender (d = 0.02), years of education (d = 0.01), structure of social relations (d = 0.17), and cognitive abilities (ds = 0.03–0.12) at baseline. However, those who remained in the study reported significantly more emotional (d = 0.22) and instrumental support (d = 0.21), as well as higher social integration (d = 0.20).

Measures

Cognitive functioning

Cognitive functioning was assessed on a general level by a broad range of dimensions, including verbal comprehension, verbal fluency, and perceptual reasoning. Internal consistency estimates (Zinbarg et al., 2005) for cognitive functioning (Cronbach's alpha) were α = 0.74 (T1), α = 0.74 (T2), and α = 0.64 (T3). The omega hierarchical estimates were ω = 0.75 (T1), ω = 0.75 (T2), and ω = 0.67 (T3). We used the following five cognitive assessment tests.

Information.—This test is a subtest of the verbal comprehension index in the German Wechsler Adult Intelligence Scale—Revised (WAIS-R; Tewes, 1991). This test includes 24 general knowledge questions (e.g., "How many planets does the solar system have?"). The test measured an individual's ability to acquire, retain, and retrieve information. Every correct response was scored with 1 point (0–24 points).

Similarities.—This test is a subtest of the verbal comprehension index in the WAIS-R (Tewes, 1991). This test required participants to describe how pairs of words were similar (e.g., "In what way are chocolate and ice cream alike?"). The test assessed verbal reasoning and the development of concepts. It included a total of 16 questions. Each answer was scored with 0, 1, or 2 points, depending on the quality of the response, and subsequently, the points to all 16 questions were added up (0–32 points).

Letter Fluency.—This test assessed verbal fluency and vocabulary knowledge (Gordon et al., 2018). It required participants to name as many different words as possible with the initial letter of "S" and "F" within 1 min. Each correct word was scored with 1 point.

Picture Completion.—This test is a subtest of the perceptual reasoning index in the WAIS-R (Tewes, 1991). Participants were required to report a missing item in a picture (e.g., frog with only three legs). Correct answers were scored with 1 point (0–17 points).

Block Design.—This test is a subtest of the perceptual reasoning index in the WAIS-R (Tewes, 1991). It required participants to put together colored blocks in an abstract pattern as fast as possible. The item assessed the ability to understand complex visual information. The scoring was based on accuracy and time taken (0–51 points).

Quality of social relations

Quality characteristics of social relations were assessed by a German Social Support Questionnaire (*Fragebogen zur Sozialen Unterstützung*; Fydrich et al., 1999). This questionnaire includes 54 items assessing emotional support, instrumental support, social integration, and social strain on a 5-point Likert-type scale, ranging from 1 (completely disagree) to 5 (completely agree). Three subscales (i.e., a total 42 items) were used to form a latent variable of quality of social relations: inducing emotional support, instrumental support, and social integration. Social strain was not included in the latent variable of quality of social relations, because it is an independent dimension of relationship quality, different from social supports and social integration (e.g., Zahodne et al., 2019). For example, an item of emotional support is "I have friends/family who can listen well if I want to speak out." An example item of instrumental support is "If necessary, I can borrow tools or food." An example item of social integration is "Many of my friends/relatives have a similar attitude to life as me." Higher scores indicate more positive evaluation of social relations and thus higher social relations' quality. The estimates of the internal consistency of social relations' quality (Cronbach's alpha) were as follows: α = 0.81 (T1), α = 0.81 (T2), and α = 0.80 (T3). The omega hierarchical estimates were ω = 0.82 (T1), ω = 0.82 (T2), and ω = 0.81 (T3).

Structure of social relations

Structure of social relations was represented by social network diversity. Participants were asked "who do you spend your free time with?" They could choose multiple answers from 15 types of social ties, including spouse, same-sex partner, opposite-sex partner, son, daughter, father, mother, father-in-law, mother-in-law, relatives, acquaintances, colleagues, club mates, friends/clique, and befriended couples. The selected ties were added up to a score ranging from 0 to 15. Higher scores indicate more diversity in terms of variety of relationship types and were interpreted as larger social network structure.

Analytical Approach

We examined the data with RI-CLPM. This model separates within-person and between-person variance in longitudinal data analysis (Hamaker et al., 2015; Mund & Nestler, 2019). This model includes a latent intercept factor for each construct across all time points, representing stable between-person differences in the corresponding construct. Adjusting for this stable between-person variation, on the remaining within-person variation this model simultaneously estimates three different types of within-person processes of quality social relations, structure of social relations, and cognitive functioning over the three waves within 16 years. First, autoregressive relations are estimated to represent the stability of a construct within an individual over time. Second, cross-lagged relations are estimated to indicate how two constructs are related to each other over time within an individual. For example, a positive cross-lagged effect between prior structure of social relations and cognitive functioning suggests that the structure of social relations above the individuals' own average at one measurement point is associated with a subsequent above-the-average score of his or her cognitive functioning at the next time point of measurement. Third, concurrent relations are estimated to represent how within-person variation in two variables is correlated after the autoregressive and cross-lagged associations are taken into account. For example, a positive concurrent relation between structure of social relations and cognitive functioning shows to what extent deviations of structure of social relations from the person-specific average are accompanied by deviations of cognitive functioning from the person-specific average. As the effects of unobserved confounding variables that are related to stable between-person variance are controlled through the random intercept variables, we did not include further covariates in our analysis. In addition, the time intervals between T2–T3 and T3–T4 were different, which could lead to different magnitude of changes in the variables over time. Thus, we allowed the parameters to vary across waves. For identifying the latent variables' scales, we used the marker variable method, constraining each latent variable's first indicator loading to unity.

All analyses were performed with Mplus 8 (Muthén & Muthén, 1998–2017). We used robust full-information maximum likelihood estimation, which corrects chi-square and standard error estimates for multivariate kurtosis and uses all available data points for individuals that have missed individual assessments. Model fit was assessed using the χ^2 test of model fit, the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR). A model was considered well-fitting when it had a CFI values above 0.95, a RMSEA value below 0.06, and a SRMR value below 0.11 (Hu & Bentler, 1999). For tests of cross-lagged associations on the within-person level, we used one-sided hypothesis tests with alpha levels of 0.05 because our hypotheses predicted positive associations. All other model estimates are interpreted at two-sided alpha levels of 0.05.

Results

Table 1 shows the descriptive statistics of the variables of interest across three time points and Table 2 shows the correlational matrix of all the variables. Most variables of interest show a slight decline across time (Table 1; standardized mean differences). To ensure that the scales of the latent constructs of interest were comparable over time, we investigated measurement invariance in longitudinal measurement models for cognitive functioning and quality of social relations. As shown in Table 3, both constructs achieved strong invariance over time, indicating that the associations that they exhibit with each other and with

Table 1. Descriptive Statistics of Cognitive Functioning and Social Relations Across Time

	T1				T2				T3				SMD	
Variables	*n*	*M*	*SD*	Range	*n*	*M*	*SD*	Range	*n*	*M*	*SD*	Range	T1–T2	T2–T3
1 Information	496	16.24	4.57	1–24	313	16.27	4.49	2–24	105	16.21	4.14	5–23	0.01	−0.01
2 Similarities	496	24.37	6.19	2–32	313	24.50	6.03	0–32	104	24.94	4.60	6–31	0.02	0.07
3 Letter Fluency	494	30.15	9.37	6–66	312	28.80	9.26	5–58	111	28.30	10.16	0–66	−0.14	−0.05
4 Picture Completion	494	12.10	3.59	1–17	311	11.79	4.08	0–17	102	12.10	3.39	0–17	−0.09	0.08
5 Block Design	496	24.35	8.50	4–46	312	24.13	8.11	1–43	106	22.96	7.66	0–44	−0.03	−0.14
6 Network diversity	447	4.31	1.92	1–10	305	4.19	1.98	0–9	107	3.64	1.82	1–10	−0.06	−0.28
7 Emotional support	445	3.96	0.50	1.62–5	306	3.94	0.50	1.75–5	150	3.85	0.51	2.25–5	−0.04	−0.19
8 Practical support	445	3.79	0.59	1.33–5	306	3.90	0.55	1.33–5	150	3.80	0.54	2–5	0.20	−0.18
9 Social integration	445	3.93	0.50	2.54–5	306	3.92	0.49	2.46–5	150	3.81	0.52	2.62–5	−0.02	−0.23

Notes: Range refers to the observed range in the sample; SMD = standardized mean difference, i.e., differences between the average scores at two time points divided by the standard deviation of the scores at the earlier time point (single-group pretest–posttest raw score; Morris & DeShon, 2002). The SMD values indicate that most variables slightly declined over time.

Table 2. Correlations Among the Scores of Cognitive Functioning and Social Relations Across Time

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1 Information T1																										
2 Similarities T1	**0.63**																									
3 Letter Fluency T1	**0.35**	**0.47**																								
4 Picture Completion T1	**0.52**	**0.52**	**0.28**																							
5 Block Design T1	**0.42**	**0.49**	**0.26**	**0.52**																						
6 Network diversity T1	0.02	0.09	0.07	**0.12**	**0.18**																					
7 Emotional support T1	0.08	**0.12**	**0.10**	**0.12**	**0.16**	**0.26**																				
8 Practical support T1	0.01	0.06	**0.10**	0.07	0.07	**0.25**	**0.67**																			
9 Social integration T1	0.06	**0.18**	**0.18**	**0.09**	**0.16**	**0.28**	**0.59**	**0.53**																		
10 Information T2	**0.85**	**0.52**	**0.33**	**0.45**	**0.39**	0.07	0.06	0.05	0.08																	
11 Similarities T2	**0.53**	**0.65**	**0.44**	**0.44**	**0.42**	0.09	0.07	0.08	**0.10**	**0.60**																
12 Letter Fluency T2	**0.31**	**0.39**	**0.77**	**0.23**	**0.26**	0.10	**0.12**	**0.25**	**0.21**	**0.38**	**0.51**															
13 Picture Completion T2	**0.44**	**0.42**	**0.19**	**0.55**	**0.37**	0.08	**0.17**	**0.14**	**0.16**	**0.52**	**0.52**	**0.26**														
14 Block Design T2	**0.39**	**0.41**	**0.16**	**0.43**	**0.72**	**0.12**	**0.12**	0.08	0.09	**0.42**	**0.42**	**0.25**	**0.48**													
15 Network diversity T2	**0.13**	**0.25**	0.11	**0.15**	**0.24**	**0.53**	**0.28**	**0.22**	**0.21**	**0.16**	**0.21**	**0.19**	**0.15**	**0.18**												
16 Emotional support T2	0.03	0.10	0.02	**0.11**	**0.16**	**0.20**	**0.64**	**0.42**	**0.43**	0.07	0.10	0.09	**0.16**	**0.14**	**0.38**											
17 Practical support T2	0.01	0.02	0.09	0.04	0.04	**0.19**	**0.53**	**0.59**	**0.35**	0.02	0.07	**0.16**	0.10	0.06	**0.35**	**0.67**										
18 Social integration T2	0.02	**0.13**	0.09	0.09	0.11	**0.27**	**0.41**	**0.34**	**0.57**	0.07	0.10	**0.19**	**0.19**	**0.12**	**0.33**	**0.61**	**0.50**									
19 Information T3	**0.71**	**0.42**	**0.34**	**0.38**	**0.25**	−0.10	0.07	0.00	0.08	**0.81**	**0.49**	**0.29**	**0.37**	**0.24**	0.03	0.04	0.05	0.06								
20 Similarities T3	**0.48**	**0.62**	**0.41**	**0.34**	**0.24**	0.05	−0.06	−0.09	0.07	**0.45**	**0.62**	**0.43**	**0.24**	0.17	0.07	−0.05	−0.02	0.12	**0.62**							
21 Letter Fluency T3	**0.34**	**0.45**	**0.76**	**0.25**	**0.22**	−0.07	−0.03	0.02	**0.25**	**0.34**	**0.40**	**0.75**	**0.22**	0.12	0.09	−0.02	0.06	**0.19**	**0.32**	**0.41**						
22 Picture Completion T3	**0.36**	0.13	0.12	**0.49**	**0.36**	−0.02	0.15	−0.02	−0.06	**0.29**	0.14	0.15	**0.46**	**0.39**	0.13	0.18	0.01	0.02	**0.32**	**0.22**	**0.26**					
23 Block Design T3	**0.31**	**0.27**	0.08	**0.34**	**0.66**	0.18	0.17	−0.03	−0.01	**0.28**	**0.22**	0.12	**0.24**	**0.60**	**0.33**	**0.19**	0.14	0.14	**0.29**	**0.29**	0.17	**0.41**				
24 Network diversity T3	0.16	0.11	0.05	0.12	0.15	**0.34**	**0.32**	0.17	0.09	0.10	0.15	**0.21**	0.15	0.19	**0.49**	**0.29**	**0.30**	0.12	0.02	−0.03	0.11	**0.24**	**0.21**			
25 Emotional support T3	0.00	0.03	−0.02	0.16	0.03	0.14	**0.61**	**0.35**	**0.22**	−0.05	−0.03	−0.05	0.06	−0.05	**0.28**	**0.62**	**0.51**	**0.42**	−0.02	−0.11	0.04	0.16	0.14	**0.29**		
26 Practical support T3	−0.02	−0.03	0.00	0.08	0.02	0.09	**0.47**	**0.53**	**0.20**	−0.05	−0.01	−0.01	−0.02	−0.09	**0.22**	**0.41**	**0.59**	**0.31**	0.07	−0.05	0.11	0.03	0.10	**0.22**	**0.64**	
27 Social integration T3	0.03	0.13	**0.17**	0.07	0.02	0.14	**0.32**	**0.22**	**0.36**	0.02	**0.17**	0.14	0.09	−0.08	**0.20**	**0.40**	**0.34**	**0.60**	0.13	0.14	**0.21**	0.02	0.06	**0.24**	**0.62**	**0.46**

Note: Boldface correlations are statistically significant ($p < .05$).

Table 3. Longitudinal Measurement Invariance

Model	χ^2	*df*	*p* Value	CFI	RMSEA	SRMR
Cognitive functioning						
M1: Configural invariance	116.56	72	.001	0.98	0.04	0.06
M2: Weak invariance	126.47	80	.001	0.98	0.03	0.08
M3: Strong invariance	182.18	88	<.000	0.96	0.05	0.09
Social relations quality						
M1: Configural invariance	21.98	15	.108	0.99	0.03	0.04
M2: Weak invariance	24.49	19	.178	1.00	0.03	0.06
M3: Strong invariance	52.22	23	.001	0.97	0.05	0.07

Notes: CFI = comparative fit index; *df* = degrees of freedom; M, model; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

structure of social relations can be meaningfully compared across measurement points. We implemented the final RI-CLPM based on the strong measurement invariance models of cognitive functioning and quality of social relations. The model achieved a good fit: χ^2 (*df*) = 452.23 (294), *p* value < .001, CFI = 0.96, RMSEA = 0.03, SRMR = 0.07.

As expected on the within-person level, quality of social relations at T1 predicted cognitive functioning at T2 (*b* = 1.90, *p* = .050; see Table 4 and Figure 1). This effect indicated that more positive evaluation of social relations at T1 was associated with higher cognitive functioning 8 years later at T2. However, the cross-lagged effect from T2 to T3 was nonsignificant. Moreover, contrary to our expectation, prior structure of social relations did not predict subsequent cognitive functioning. In addition, prior cognitive functioning did not predict subsequent quality of social relations. As expected, prior cognitive functioning predicted subsequent structure of social relations and the cross-lagged effects were significant from T1 to T2 (*b* = 0.58, *p* = .018) and from T2 to T3 (*b* = 0.75, *p* = .026). In other words, worse prior cognitive functioning predicted smaller subsequent structure of social relations. At the between-person level, the associations between any of these three constructs were nonsignificant, which might be attributed to rather low variance estimates of the random intercepts for quality of social relations and structure of social relations.

Discussion

Using 16-year longitudinal data, we examined within-person dynamic associations between quality of social relations, structure of social relations, and cognitive functioning in older adults aged 64–68 years at T1. Results showed that worse quality of social relations at T1 predicted lower cognitive functioning over 8 years at T2, when our respondents were 72–76 years old. Moreover, worse cognitive functioning was related to a subsequent smaller structure of social relations (T1–T2 and T2–T3).

As expected, lower perceived quality of social relations within individuals was linked with worse subsequent cognitive functioning 8 years later (T1–T2). This finding adds further evidence to the literature on social relations and cognitive aging, reporting that perceived quality of relationships is a protective factor of cognitive functioning in older age (Evans et al., 2019; Kelly et al., 2017; Kuiper et al., 2015). The perceived presence of emotional and instrumental support and perceived social integration may buffer stress and loneliness of older adults and further prevent cognitive decline (Antonucci et al., 2019; Fratiglioni et al., 2004). The effect estimate was about half the size and not significant between T2 and T3. The protective effects of social factors on cognitive functioning may be weaker later in life (i.e., late 75+). This resembles the finding by Ihle and colleagues (2019) who found that young-old adults (i.e., 65–75 years) benefited more from the protective effects of leisure activity participation against cognitive decline than old-old adults (i.e., 76–90+ years).

In contrast to our expectation, we did not find evidence for a significant association between prior structure of social relations and subsequent cognitive functioning. A similar line of research suggests that social support may mediate the effects of different social network types (e.g., diverse, family-focused, friend-focused) on life satisfaction and depression (Harasemiw et al., 2019). This may be expanded to cognitive functioning, such that network diversity may influence cognitive functioning via quality of social relations. As such, the effects of structure of social relations on cognitive functioning may have been subsumed by the quality of social relations when examined simultaneously in our study. Another possible explanation for the lack of significant findings might be that the effects were too small to be reliably detected. This possibility could be explored in future studies by employing inferential techniques that can provide decisive evidence for a null hypothesis (Lakens et al., 2020).

Moreover, we expected cognitive functioning to be positively associated with subsequent quality and structure of social relations. In contrast to our expectations, cognitive functioning was not significantly associated with subsequent relationship quality. Still, the effect estimate was positive, suggesting when a person showed better cognitive

Table 4. Model Parameter Estimates

Parameter	Est.	*SE*	*p* Value	Std. Est.
Within-person				
Cross-lagged relations T1–T2				
From Quality to Cognition	1.90	1.15	.050*	0.34
From Structure to Cognition	0.03	0.08	.345	0.04
From Cognition to Quality	0.06	0.07	.170	0.29
From Cognition to Structure	0.59	0.28	.018*	0.45
From Quality to Structure	0.57	1.26	.324	0.09
From Structure to Quality	0.02	0.02	.192	0.11
Cross-lagged relations T2–T3				
From Quality to Cognition	0.89	1.15	.221	0.21
From Structure to Cognition	0.10	0.28	.367	0.13
From Cognition to Quality	0.02	0.07	.391	0.10
From Cognition to Structure	0.75	0.39	.026*	0.68
From Quality to Structure	–0.06	1.25	.324	–0.01
From Structure to Quality	0.03	0.05	.270	0.18
Autoregressive relations T1–T2				
Quality	0.35	0.36	.334	0.32
Structure	0.32	0.14	.018*	0.30
Cognition	0.66	0.24	.007**	0.58
Autoregressive relations T2–T3				
Quality	0.32	0.35	.347	0.32
Structure	0.09	0.27	.734	0.10
Cognition	0.40	0.45	.376	0.48
Concurrent relations (covariance; T1)				
Structure and Quality	0.19	0.19	.315	0.35
Cognition and Quality	0.23	0.244	.339	0.53
Cognition and Structure	0.91	1.22	.455	0.34
Concurrent relations (covariance; T2)				
Structure and Quality	0.13	0.06	.041*	0.36
Cognition and Quality	0.07	0.06	.220	0.28
Cognition and Structure	0.26	0.22	.231	0.20
Concurrent relations (covariance; T3)				
Structure and Quality	0.09	0.09	.341	0.26
Cognition and Quality	0.05	0.07	.508	0.17
Cognition and Structure	0.13	0.52	.809	0.11
Between-person				
Variances				
Quality	0.11	0.05	.746	1.00
Structure	0.38	1.17	.045	1.00
Cognition	4.37	1.69	.010**	1.00
Covariances				
Structure and Quality	0.09	0.19	.653	0.43
Cognition and Quality	–0.04	0.24	.881	–0.05
Cognition and Structure	–0.31	1.23	.804	–0.24

Notes: Cognition = cognitive functioning; Est. = estimate; Quality = quality of social relations; Std. Est. = standardized estimate; Structure = structure of social relations.

*$p \le .05$. **$p \le .01$. *p* Values for cross-lagged relations testing hypothesized predictions are one-sided, all other *p* values two-sided. Standardized variances for between-person latent variables at 1.00 indicate that these variables are exogenous (their variance is not explained by any other variables).

functioning, he or she also reported somewhat better subsequent quality of social relations. Further studies using larger samples should investigate whether this tendency holds. As an alternative explanation, the nonsignificant result may have indicated divergent within-person associations across participants. That is, participants with different levels of cognitive functioning may have received different levels of support. More specifically, when prior

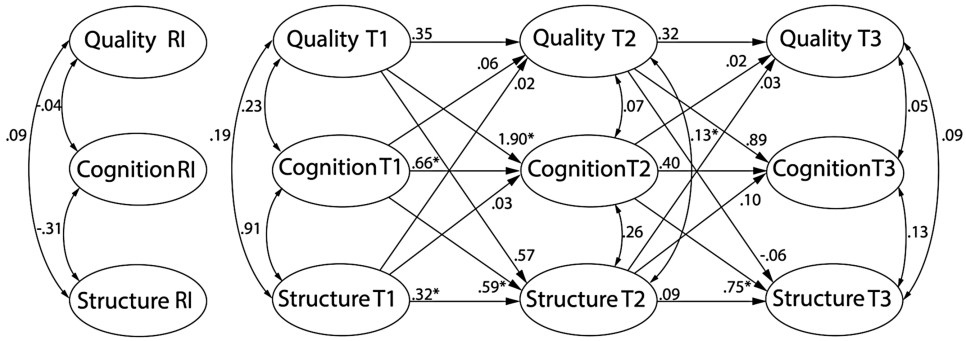

Figure 1. Parameter estimates for relations between latent variables in the random intercept cross-lagged panel model. *Notes*: Ovals represent latent variables from the model. Measurement models including indicator variables have been omitted for visual clarity. Latent variables indicated with RI represent random intercepts (stable between-person variation); all other latent variables represent within-person variation at the respective time points. Cognition = cognitive functioning; Quality = quality of social relations; RI = random intercept; Structure = structure of social relations; T1 = first measurement point; T2 = second measurement point; T3 = third measurement point.

cognitive functioning declined, some participants may have experienced decline of quality of social relations, whereas other participants may have perceived more emotional and instrumental support and higher level of social integration.

As expected, we found positive cross-lagged relations between prior cognitive functioning and subsequent structure of social relations (T1–T2, T2–T3). That is, lower cognitive functioning was related to less diverse social network 8 years later and the effects were significant over 16 years, showing this effect consistently in older age (between 64 and 84 years). This finding accords with research showing that older adults with more severe cognitive impairment also report to have less diverse social networks (Li & Zhang, 2015) and seems to be in line with studies on regulation of social relations (Lang, 2001). More specifically, there are two principles guiding how individuals adaptively regulate their social relations (Lang et al., 2009); that is, emotional closeness and perceived reciprocity regarding benefits from others. According to the socioemotional selectivity theory, older adults become increasingly selective, investing greater resources in emotionally meaningful goals and activities (Carstensen et al., 1999). Lower cognitive functioning may have strengthened older adults' perception of limited future lifetime; and the less diverse social network may have reflected older adults' changing preferences in social relationships (Lang, 2001; Lang & Carstensen, 2002). Furthermore, older adults who experienced cognitive declines may not have sufficient mental capacity to monitor the reciprocity with many different social partners (i.e., high social network diversity). Despite these different reasons, a less diverse social network might reflect how older adults adaptively modify their social relations in response to their own lower cognitive functioning. Nevertheless, a less diverse social network may reflect the fact that social ties are discontinued when individuals experience a decline in cognitive functioning. Future studies could examine potential reasons of changes in social relations to test this assumption.

Taken together, our findings suggest that quality of social relations, structure of social relations, and cognitive functioning show reciprocal associations, such that they mutually influence each other in older age within an individual (Figure 1). More specifically, lower relationship quality was associated to subsequent lower cognitive functioning, which further was related to subsequent less diverse social network. Our data seem to reflect a downward spiral with age, in which worse perception of relationship quality leads to lower cognitive functioning, subsequently leading to less diverse social network. However, alternative patterns of within-person associations may exist but were not captured by our analyses with RI-CLPM, which reflected the dominant within-person associations in our sample. This idea is, in part, supported by the findings on the null effects of prior cognitive functioning on subsequent quality of social relationships. The null findings could indicate divergent patterns across different individuals, such that for some participants, the quality of social relations did not decline due to declining cognitive functioning. This could be because of some buffering mechanism; for example, the social convoy of a particular person may offer more support once they notice some cognitive change, which results in positive quality ratings by the person receiving this support. Future studies may examine between-person determinants that mitigate or exacerbate the within-person processes of declines in resources over the aging process.

In sum, our findings are in line with the life-span developmental theory, which proposes that cognitive aging is an ongoing adaptive process of coordinating, integrating, and balancing gains and losses (Baltes et al., 1999, 2007). This viewpoint also supported the motivation of our paper: Instead of focusing on unidirectional analysis, we examined reciprocal associations between social relations and cognitive functioning, so as to better understand adaptation in cognitive aging. In fact, the codevelopment between personal characteristics and environments has also been discussed in recent personality research (Wrzus & Neyer, 2016).

This study has a number of strengths. First, we incorporated the adaptive characteristics of human beings to understand the longitudinal associations between quality of social relations, structure of social relations, and cognitive functioning in older age. We further examined a broader conception of cognition and used the RI-CLPM to disentangle within-person and between-person variance in the analysis. This model allowed us to control for unobserved confounding on the level between individuals and thus bring our findings closer to causal relations (Hamaker et al., 2015). In turn, research can provide effective evidence-based advice on maintaining cognitive health in old age (Boker & Martin, 2018). Moreover, we used a longitudinal sample with a narrow age cohort over 16 years (observing the participants from their mid-60s to their mid-80s). This enabled us to examine the within-person associations in a sample with homogeneous chronological age.

A limitation of this study is that there were three measurement points over the entire 16-year period. The rather long time intervals provide few insights into processes that happen at shorter timescales (Kuiper & Ryan, 2018). Future studies could consider using longitudinal data that have shorter intervals and more wave observations. Moreover, the information of structure of social relations relied on the self-report from the participants, which may have introduced bias from retrospective recalling and social desirability. Future studies could consider adopting ambulatory assessment methods to obtain real-time and objectively assessed information of social relations and social interaction (Luo et al., 2020; Macdonald & Hülür, 2020; Seifert, 2020). Similarly, this study assessed quality of social relations by asking participants' perception of emotional support, instrumental support, and social integration across their social ties. Evaluation of relationship quality can differ depending on types of social relations (e.g., kin vs nonkin; Lang et al., 2009; Neyer et al., 2011). Turning to statistical aspects, the RI-CLPM examined within-person associations that are dominant in a population, but there may be divergent within-person associations across different individuals. Future studies could consider combining the RI-CLPM with approaches that are able to capture between-person heterogeneity in within-person associations (Mulder & Hamaker, 2020). Finally, although we managed to keep a relatively large sample throughout the measurement points, missingness was slightly related to participants' levels of relationship quality. Therefore, we cannot rule out that the missing data caused some bias or reduced the generalizability of our findings.

Conclusion

With 16 years' evidence and a focus on within-person associations, this study was the first to examine the reciprocal associations in the dynamic development of quality of social relations, structure of social relations, and cognitive functioning with the notion of understanding adaptive process in the course of cognitive aging. Our findings showed that lower quality of social relations predicted subsequent lower cognitive functioning, suggesting quality of social relations has a protective effect on cognitive functioning. Furthermore, lower cognitive functioning predicted subsequent less diverse social network, which indicated that older adults may adaptively reduce the diversity of their network according to their (lower) cognitive functioning. In addition, the null findings of prior cognitive functioning on subsequent social relationship quality suggest there could be divergent patterns of within-person processes in face of cognitive decline. Overall, this study strengthens the idea that social relations and cognitive functioning mutually influence each other, but different aspects of social relations (i.e., quality, structure) might have different directional associations with cognitive functioning.

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Conflict of Interest

None declared.

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