Social network characteristics and their associations with stress in older adults: Closure and balance in a population-based sample

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Abstract

Objectives: Integration into social networks reduces stress during adverse life-events and improves coping with disability in late life. The aim is to investigate whether social network closure (frequent contact among ties) and balance (positive contact among ties) are associated with perceived stress. We expect lowest stress for older adults with highly closed and balanced networks.

Method: Panel data on self-reported egocentric networks stem from the population-based Chicago Health Aging and Social Relations Study (CHASRS). Five waves were collected between 2002 and 2006, with 708 observations from 160 participants aged 50-68 years at baseline. Data include information on the participants' social relationships, i.e., interaction frequency and relationship quality, for ego-alter ties and alter-alter ties, and participants' perceived stress. The analytical strategy employed fixed- and random-effects models.

Results: Participants reporting the highest number of balanced relationships (positive ties among alters) experience least stress. This effect holds independently of socio-demographic confounders, loneliness and network size.

Discussion: The absence of a stress-reducing effect from network closure suggests that balance matters more. Future research would benefit from considering balance when examining the characteristics of social networks that impinge on mental health outcomes in older adults.

Keywords: Wellbeing, personal networks, social support, triad, follow-up study

Introduction

Integration into socially supportive relationships is commonly believed to benefit older adults' wellbeing, since it reduces stress during adverse life-events and improves coping with illness and disability in late life (Cohen, 2004; Thoits, 2010). Two socio-epidemiological explanations for this association have received much attention. First, the *Main Model* states an overall beneficial effect of rich social network structures on wellbeing (Berkman, Glass, Brissette, & Seeman, 2000; Cohen & Wills, 1985; Thoits, 2011). Positive associations have indeed been found for network size and relationship diversity with physical, cognitive and mental health (Barefoot et al., 2005; Cohen, Doyle, Skoner, Rabin, & Gwaltney, 1997; Cornwell & Laumann, 2015; Ellwardt, Van Tilburg, & Aartsen, 2014; Yang, Boen, & Mullan Harris, 2015). Mechanisms include attachment processes, the development and maintenance of meaningful social roles, stimulation of intellectual activity, and social control of health behaviors, each of which has known associations with health (Berkman et al., 2000). Moreover, observational research has suggested improvements in stress-related biomarkers, cardiovascular reactivity, the neuroendocrine and immune system (Uchino, 2006), while lack of social relationships constitutes a stressor on its own (Hawkley & Cacioppo, 2010).

Second, the *Buffer Model* stresses the function of social networks and proposes a moderating process: Social networks protect people from potentially detrimental effects of stressors (Cohen & Wills, 1985; Thoits, 2011). Interpersonal relationships provide resources that are responsive to the needs caused by stressful events. Important resources are the perceived availability of emotional and instrumental support, appraisal and information from others (House & Kahn, 1985).

Besides the recent "explosion of network-focused gerontological research" (Cornwell & Schafer, 2016, p. 182), few studies on older adults' stress have explored the structural features of social networks. Social networks refer to a defined set of actors—which may, for instance, include an older adult's relatives, friends and neighbors—and the social relationships that connect them in a larger structure (Wasserman & Faust, 1994, p. 8). Importantly, social networks do not automatically deliver support but rather provide conditions that hamper or enhance its delivery. Here, structure is key.

Two important aspects of network structure have remained underexplored: closure and balance. We refer to *closure* when an older adult is *strongly* connected to two (or more) people who also have a *strong* connection among each other (i.e., interact frequently). Confidant networks with many connections between network members ease the flow of resources, because members are effective in coordinating help (Ashida & Heaney, 2008). In contrast, weakly connected networks can impede access to support, even if it is readily available. Balance assumes closure (interconnected triads), but adds an affective component. Specifically, we refer to *balance* when an older adult is *positively* connected to two (or more) people who also have a *positive* connection with each other. Confidant networks with many positive connections yield a wide range of beneficial resources (Ashida & Heaney, 2008). In contrast, ambivalent or dysfunctional connections induce rather than reduce stress (Gurung, Taylor, & Seeman, 2003; Rook, 2015; Uchino, Kent de Grey, & Cronan, 2016).

Previous stress research has often investigated the individual's direct social connections to others, but paid less attention to interconnections among others in their network. More crucially, traditional measures such as network size—which assess only positive direct relationships—are unable to detect the aforementioned counterproductive effects of network structure on stress. Older adults in particular may be affected by weak or ambivalent

relationships between others in their network (e.g., when two family members fight, Widmer, Girardin, & Ludwig, 2018): If a focal person (*ego*) who has positive relationships to two others (*alters*) perceives their relationship to be negative, the focal person runs the risk of suffering psychosocial imbalance (Rawlings & Friedkin, 2017). Neither the main nor the buffer argument would irrevocably hold in contexts of low closure and low balance. We argue that a focus on structural features in networks, and related sociometric data can close this research gap.

The aim of this study is to investigate which kinds of personal social networks reduce stress, using a social network perspective. We employ a novel research design that considers (a) the quality of the older adults' direct relationships (ego-alter ties), and (b) the perceived quality of the older adults' interconnections *between* their contacts (alter-alter ties, as experienced by ego). We expect that perceived stress is lowest for older adults embedded in highly closed and balanced network structures. We test our expectations with panel data from the Chicago Health, Aging, and Social Relations Study (CHASRS).

Background

Social relationships as buffers of stress

Roughly half a century of stress research has offered a number of major findings (Thoits, 2010). The damaging impact of stressors, defined as negative events, chronic strains and traumas, is substantial for physical and mental health. Stressors contribute to cumulative disadvantages over the life course, thereby widening the health gap in old adulthood. The impact of stressors on health and wellbeing is reduced among individuals with social support, described as receiving or perceiving emotional, informational and practical assistance from significant others (Thoits, 2010). Because of this, embeddedness into socially supportive networks has been considered part

of older adults' resilience, that is the capacity to cope with and adapt well in the face of adversity, trauma, tragedy, threats, and other significant sources of stress (MacLeod, Musich, Hawkins, Alsgaard, & Wicker, 2016).

Explanations for the health benefits of social relationships are manifold. They include direct pathways based on normative processes and behavioral guidance through social control by others, attachment and purpose in life through role obligations, and the nurturing of self-worth and mastery (Berkman et al., 2000; Thoits, 2011). Moderating mechanisms primarily rest on the stress-buffering process (Thoits, 2011). The occurrence of an acute stressor displaces the individual into an extraordinary situation that exceeds the usual everyday demands. In this situation, significant others in the individual's network can deliberately enact coping assistance and temporarily tolerate violations of reciprocity in social exchanges in their attempt to support the strained individual. This assistance can comprise emotional sustenance, such as signaling understanding and expressing concern, and instrumental aid, such as providing material resources and supplying constructive solutions.

Yet, not all kinds of social exchanges yield the full potential to bolster distressed individuals. Support is assumed to be most effective when the aid provider optimally matches the recipient's demands (Cohen & Wills, 1985), and the recipient perceives the support as helpful (Uchino, Carlisle, Birmingham, & Vaughn, 2011). In contrast, unmet expectations regarding informal care (e.g., from close family members), increase depressive symptoms and distress (Ashida, Marcum, & Koehly, 2018). Similarly, support is presumably more effective when the aid provider is a close instead of a distant significant other due to better knowledge of the recipient's needs (Thoits, 2011). And crucially, the recipient's relationship with the aid provider should be positive, as exposure to ambivalent and negative relationships gives rise to additional strain (Holt-Lunstad, Uchino, Smith, & Hicks, 2007; Rook, 2015). While the stress literature

offers many more interesting insights, we restrict the following discussion to the latter two arguments on network structure: the degree to which relationships are closed and positively balanced.

Closure in social networks

The structure of the interpersonal environment channels social support resources to and from individuals. Structures that ease the flow of resources are closure and density. Closure refers to completeness of social relationship triads, meaning that all three individuals are connected (Wasserman & Faust, 1994, p. 116). Networks with many closed triads are typically denser than networks with many open triads. High local network density, also defined as the degree to which an individual's contacts in a network are interconnected, has been shown to reduce stress exposure (Haines & Hurlbert, 1992). This is because dense networks often include stronger ties than sparse networks. Compared to weak ties, strong ties are more intense in terms of time, intimacy, reciprocity, and emotional investments. This greater intensity of strong ties is believed to be key for the effective protection from mental illness in general and stress in particular (Ferlander, 2007).

Yet, these potential benefits come at a price. Individuals are obliged to return investments and favors. These obligations are stronger in strong than in weak ties. According to *Social Exchange Theory* (Blau, 1964; Gouldner, 1960) people who give a lot expect some kind of reciprocity. Reciprocity can be direct, consisting either of the same resource type or a different benefit, or indirect (i.e., the favor is returned through an intermediate person); and/or immediate or delayed (i.e., provided at a later time point in life). The case of indirect reciprocity is central to our argument that next to strong relationships with direct contacts, strong interconnections between ones contacts may yield additional reductions in stress.

Evolutionary theory (Nowak, 2006) proposes too that, in close communities, social exchange does not necessarily need returning in the same proportion and from the same person. The strong ties in close communities often come with a set of normative expectations related to solidarity. Exchange partners are obliged to give something back – however, there is no strict mental accounting, but instead forgiveness regarding a lack of direct reciprocity. Network members are therefore more inclined to seek and accept support, knowing that incidental violations of the reciprocity norm are permitted, and that they can return the favor elsewhere within the community later. The other network members trust they, too, can rely on someone else's help in times of crisis. Not helping, in contrast, may lead to exclusion from future generalized exchanges by the community (Bowles & Gintis, 2004). As a result, generalized exchange systems facilitating indirect reciprocity are associated with greater degrees of solidarity (Uehara, 1990). Similarly, network theories about closure (Burt, 2005; Coleman, 1988) hold that a relationship is more likely to endure if it is embedded in a cluster of two or more mutual ties; this structure results in a more reliable source of help than structurally isolated relationships.

In sum, we argue that stress-reducing conditions, including actual access to and overcoming the threshold of asking for support, become more favorable when someone to whom one has a strong tie is also well-connected through shared contacts. Note that an individual's perceived network may not be perfectly aligned with the actual network. A perceived sense of community, however, will still promote the individual's inclination to demand and provide support, and thereby increase the odds of receiving support.

Essentially, an older adult's egocentric network can be conceived as the accumulation of multiple triads, where the older adult is connected to two or more contacts who may or may not have a third connection between them. A network high in closure consists of many triads with three strong ties. We expect:

Hypothesis 1. The higher the number of closed triads in a focal individual's personal network, the lower the level of perceived stress of this individual.

Balance in social networks

Besides reciprocity norms, individuals in social networks face emotional interdependencies. They have feelings toward others and anticipate the feelings of these others during interactions. Early *Balance Theory* posited that individuals prefer situations ("states") that minimize cognitive dissonance (Cartwright & Harary, 1956; Heider, 1946). States that minimize dissonance rely on a perceived balance among relationships. A balanced state exists if, in a triad, all three relationships are perceived as positive, or if two are negative and one is positive. An example for the first configuration is a triad where ego likes both alters, and both like each other (i.e., "the friend of my friend is my friend"). An example for the second configuration is a coalition where ego likes one alter but dislikes the other, and the alters dislike each other (i.e., "the enemy of my friend is my enemy"). Other states represent a case of imbalance, e.g., "the enemy of my friend is my friend". Retaining relationships to two friends who dislike one another (imbalance) produces cognitive dissonance. The focal person is assumed to strive for balance by changing her attitude to an alter.

This theory was later generalized to structural balance, which suggests that the formerly proposed micro-level processes play out at the macro level (Hummon & Doreian, 2003; see Rawlings & Friedkin, 2017, for a recent application). Specifically, the individuals' preference for cognitively balanced states drives behaviors in social interactions, such as changing or dropping a tie, towards the reduction of relational tensions. As a result, imbalanced structures are less stable than balanced ones. On a collective level, these choices shape group structure over time in

a way that whole networks are partitioned into locally stable, balanced—but not necessarily conflict free—subsets.

People are not always able to resolve imbalance, that is change or drop a tie. Creating balance (e.g. through building a coalition) by jeopardizing one's own relationships is an unattractive alternative, because direct involvement in strained relationships constitutes an even greater chronic stressor (Holt-Lunstad et al., 2007; Newsom, Mahan, Rook, & Krause, 2008). Avoiding others is difficult in dense or long-standing social groups, for example within family networks. Persistent states of imbalance produce tension and unpleasantness (Cartwright & Harary, 1956). This way, for example, an older adult who is stuck between two fighting family members finds herself in an uncomfortable position, regardless of the fact that she herself has only positive relationships with them. Recent empirical research on older adults' family networks demonstrated that dyadic conflict often involves third parties, so that in many cases conflict in families acquires a collective dimension (Widmer et al., 2018). Being an intermediary in conflict-ridden family contexts was found to be related to more psychological health problems, including increased perceived stress and depressive symptoms.

In sum, an older adult in an imbalanced network may still benefit from support of her direct contacts, but some of the stress-reducing effects may be neutralized by the stress-inducing tensions between these contacts. We therefore hypothesize that triads with three positive relationships yield the highest potential to reduce stress:

Hypothesis 2. The higher the number of balanced triads in a focal individual's personal network, the lower the level of perceived stress of this individual.

To the best of our knowledge, this study is the first to leverage the full range of closed (versus open) and balanced (versus imbalanced) triads and their impact on perceived stress. Furthermore, we include both kin and non-kin in the analysis of older adults' personal networks.

Method

Study population

Data stem from the longitudinal population-based Chicago Health, Aging, and Social Relations Study (CHASRS). Study participants were of non-Hispanic White, African American, and non-Black Latino American origin, born between 1935 and 1952, and living in Cook County Illinois. They were selected with a multistage probability design, which (1) identified households that likely included an adult aged 50-65 years, stratified by ethnic origin, (2) screened for eligible individuals within households, and (3) applied a quota at the household and individual level for achieving approximately equal distributions across all possible combinations of ethnic origin and gender. Participants were paid $126 for completing a day-long laboratory protocol at the University of Chicago. The response rate at baseline was 45% (229 participants), and the sample's characteristics resembled closely those from the Health and Retirement Study (HRS; Hawkley et al., 2008). Extensive information about the study, including attrition, is published in Cacioppo & Cacioppo (2018).

CHASRS comprises ten waves, which were collected annually from 2002-2013, with an exception for year six due to a break in funding. We used the first five waves (2002-2006) before the break, as each wave included information about participants' networks with a comprehensive social network interview. To be included in our longitudinal analysis, participants had to partake in the study until the fifth wave. Furthermore, in each wave, cases were excluded if they had missing data on any of the variables used in analyses (i.e., listwise deletion). We excluded one outlier: There was one participant who became widowed, which occurred between the first and second wave. Model parameters regarding the change to widowhood were heavily biased, so that

we dropped the first observation of this participant. Based on our inclusionary criteria, we retrieved a final analytical sample of 708 observations from 160 participants, with an average of 4.4 complete waves. Mean age at baseline was 57.3 years (*SD*=4.2) and 55% were female. More descriptive information on the pooled sample is included in *Table 2*.

Dependent variable

Self-reported perceptions of stress were assessed with the validated 10-item Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983). Participants indicated on a 4-point scale from "never" to "very often" if they had felt or thought in a certain way in the last months, e.g., nervous and stressed, unable to control important things, and that they could not cope with all the things they had to. Cronbach's alpha of the scale was .84 (Hawkley, Masi, Berry, & Cacioppo, 2006). The sum score could range from zero to 40, with higher values indicating greater stress. Because the scale's distribution was positively skewed in our final sample, we recoded any values above 30 into 30.

Independent variables

Closure and balance in networks based on information about two types of relationships. Information on *ego-alter* relationships regarded the interaction frequency and relationship valence of the focal study participant ("ego") with each of her contacts ("alters"). Information on *alter-alter* relationships regarded the interaction frequency and relationship valence for every possible relationship among ego's contacts ("alters"). For example, a personal network of five alters contains five possible ego-alter relationships and ten (=5×4/2) possible alter-alter relationships.

Study participants identified, in three separate name generators, specific alters "with whom you most often discussed matters important to you" (limit of eight alters), "who have been very demanding of you during the past year, or who have caused you a lot of stress or anxiety" (limit of three alters), and "who have been very supportive of you during the past year." (limit of three alters). Because these name generators were presented at every wave, names and numbers of alters varied over time. Several questions followed for every of the listed alters, including interaction frequency and relationship valence. Similar assessments have been used in large-scale aging surveys, such as the National Social Life, Health, and Aging Project (NSHAP, Cornwell, Schumm, Laumann, Kim, & Kim, 2014).

Interaction frequency between ego and alter was measured with the question "How often do you talk to this person?". Eight answers ranged from "every day" to "less than once a year". We dichotomized interaction frequency into weak (0=once a week or less frequent) versus strong (1=every day or several times a week) for the computation of closure in triads. This cut-off seemed theoretically meaningful and was empirically close to the sample's mean.

Relationship valence between ego and alter was operationalized with the question "How would you describe your relationship with this person?". Possible responses ranged from "don't like" (-3) to "like" (+3). We recoded answers into negative (-3 to -1), neutral (0) and positive (+1 to +3) for the computation of balance in triads.

Next, participants rated the interaction frequency and relationship valence between their previously generated alters within a wave. This submodule was constrained to the first ten listed alters to reduce participants' burden. *Table 1* illustrates an adjacency matrix similar to the one used by the interviewers. Interviewers only needed to complete half of the matrix, because relationships between alters were assumed to be reciprocal. The same prompts as above were used for each pair of alters, with the exception that for interaction frequency participants could

additionally select "have never spoken". Again, we dichotomized responses into weak (0=once a month or less often, including never) versus strong (1=once every two weeks or more often), but this time using a higher cut-off, because interaction frequency was much lower on average than in ego-alter ties. Relationship valence was recoded into negative, neutral and positive in the same manner as for ego-alter relationships.

Recall that these ratings are based on the participants' perceptions (i.e., ego served as an informant in the assessment of alter-alter ties). Participants not knowing or refusing to answer could skip a rating. Missing information was low: in 98.7% of the cases participants rated the relationship between two alters after participants had first rated their own relationships with them.

---Table-1-about-here---

Closure. Our hypothesis regarded the three relationships between ego *h* and two alters *i* and *j* in a triad. We computed and counted all possible types of triads for those triads with complete information on interaction frequency. *Figure 1a* presents the different types based on weak versus strong ties.

---Figure-1-about-here---

For instance, a value of 15 for Closure Type 1 means that in one observation (i.e., an individual in a wave) there are 15 triads where ego *h* has strong ties with both alters *i* and *j*, and both alters have a strong ties between them. In this specific example, ego's network could contain between six and ten strongly tied alters: The maximum of n=10 alters was predetermined by the censored questionnaire. However, retrieving the value of 15 was also possible with fewer alters, because an alter *i* may have belonged to multiple triads with varying others $j_1, j_2, \ldots, j_9$. A value of 15 requires a minimum of $n(n\text{-}1)/2$ alters, thus n=6 alters who are all strongly tied to one another.

We considered a triad as strongly closed when there were at least two strong ties between any of the three actors *h*, *i* and *j*. This included Closure Type 1 (sss) with the fully closed triad of strong ties only, Closure Type 2 (ssw) with ego having strong ties to two weakly tied alters (ego is a broker), and Closure Type 3 (sws/wss) with one strong tie between ego and one alter plus a strong tie between the two alters (an alter is a broker). The latter type comprised two possible scenarios—ego *h* has a strong tie with either alter *i* or alter *j*—which are considered identical from ego's perspective and thus are treated the same. The remaining types of triads were regarded as open, and are labelled Openness Type 4 (wws), 5 (wsw/sww) and 6 (www).

Balance. We computed and counted all possible types for triads with complete information on relationship valence, based on positive versus negative ties (excluding neutral ties), as shown in *Figure 1b*. Valence-based types were only created when alters knew each other. Based on Balance Theory, there is balance when the product of all three ties equals a positive value: either one or three ties are positive. Balance Type 1 (ppp) resembles the case of positive ties only (the friend of my friend is my friend). Balance Type 2 (npn/pnn) includes scenarios of coalitions where ego has a positive tie with one alter, and both mutually share a negative tie to the second alter (the enemy of my friend is my enemy). Balance Type 3 (nnp) includes the coalition of both alters against ego: they have a positive tie among themselves but mutually share a negative tie with ego (the friend of my enemy is my enemy). Imbalance exists when the product of all ties is negative: either one or three ties are negative. Imbalance Type 4 (ppn) includes positive ties of ego *h* with both alters *i* and *j*, but these alters have a negative tie among themselves (the enemy of my friend is my friend). Imbalance Type 5 (pnp/npp) contains scenarios where ego has a negative tie to one alter (the friend of my friend is my enemy), and Imbalance Type 6 (nnn) includes negative ties only.

Some types were theoretically and empirically less probable than others. Due to their low prevalence, we dummy-recoded the following types into present (1) versus absent (0): Balance Type 2 and 3, Imbalance Type 4, 5 and 6, and Openness Type 4 and 6. Positively skewed distributions made recoding necessary for Closure Type 1 (maximum set to 15), Closure Type 2 (maximum set to 15), and Closure Type 3 (maximum set to 10).

Confounding variables

Socio-demographic confounders. The analysis included age in years, dummy variables for gender (1=female), ethnicity (Black, Hispanic, non-Hispanic White), education (less than high school, high school/GED, some college, BA/BS, graduate school), marital status (married, living with partner, separated, divorced, widowed, never married), and eight categories for household income ($10,000 and less, $10,001—$20,000, $20,001—$30,000, $30,001—$40,000, $40,001—$50,000, $50,001—$75,000, $75,001—$100,000, $100,001 and more). We also controlled for measures of subjective and objective isolation, specifically loneliness and network size. This was to rule out spurious associations of closure and balance with perceived stress since loneliness and network size are both associated with stress.

Loneliness. The validated UCLA Loneliness Scale-Revised (UCLA-R) captured participants' general loneliness, operationalized as satisfaction with one's social network (Russell, Peplau, & Cutrona, 1980). The scale covers the three dimensions of inadequate intimate, relational and collective attachments, including statements such as "I lack companionship" and "There are people I can talk to". Each of the 20 items were rated from "never" (1) to "often" (4). Sum scores could range from 20 to 80, with higher scores indicating greater loneliness.

Network size. Network size was operationalized as the number of all alters identified in the name generator, regardless of their tie quality with ego.

Analytical strategy

We tested our hypotheses with a within-subject design. Fixed-effects models showed whether a change in an individual's network closure and balance was associated with a change in the same individual's perceived stress. A major advantage of this design is that it rules out unobserved heterogeneity of time-constant variables between individuals. Because individuals are compared among themselves over time, personal traits are automatically fixed. This regards both measured and unmeasured characteristics, as long as they can be assumed constant. Hence, our fixed-effects models included only the time-varying socio-demographic confounders marital status and household income. However, because the data included cases with five or fewer observations per individual, using fixed-effects models yielded the risk of overfitting and thus generating large standard errors of the parameters (Snijders & Bosker, 2012, p. 47). We therefore re-ran our fully adjusted model with random-effects, which avoided overfitting. This additionally included the remaining socio-demographic confounders and allowed comparing effects between individuals. A Hausman-test assessed whether coefficients differed significantly between the fixed-effects and random-effects model.

In a first step, we estimated the unadjusted effects of all twelve triad types separately on perceived stress. In a second step, we estimated the joint effect of the four theoretically most relevant types, but left out the remaining types to avoid multicollinearity: Closure Type 1 (sss) and Closure Type 2 (ssw), where ego had a strong tie to both alters, as well as Balance Type 1 (ppp) and Imbalance Type 4 (ppn), where ego had a positive tie to both alters. This analysis comprised a set of four models: stress adjusted for socio-demographic and social confounders,

stress adjusted for confounders and closure, stress adjusted for confounders and balance, stress fully adjusted for confounders, closure and balance. A fifth model contained the fully adjusted random-effects model. In a final step, we carried out multiple sensitivity checks.

Results

Closure and balance in personal networks

Table 2 presents the descriptive statistics of all variables used in the analysis. Pearson's correlations between the variables were mostly weak to moderate, with a maximum of r=.70 between network size and Balance Type 1 (ppp), that is, number of triads with positive ties only. Study participants on average had 16 triads with positive ties only, i.e., Balance Type 1 (ppp), and four triads with strong ties only, i.e., Closure Type 1 (sss). The distribution of the different triad types changed somewhat over the waves, however, not drastically, as shown in *Figure S1* in the Supplemental Material.

---Table-2-about-here---

Associations with perceived stress

We first ran unadjusted fixed-effects models for all triad types separately. This resulted in a negative and significant parameter for triads with three positive ties, i.e., Balance Type 1 (ppp). None of the remaining types was associated with perceived stress. These unadjusted models are presented in the Supplemental Material, *Tables S1-12* and *Figure S2*. Next, we ran the fixed-effects models adjusted for time-varying confounders, proceeding with those triad types in which ego had either two positive or two strong ties with both alters. See *Table 3*, Models 1-4. There was a negative and significant association of Balance Type 1 (ppp) with perceived stress, but

again no association of the remaining types. The fully adjusted Model 4 in *Table 3* shows that a higher number of triads of Balance Type 1 (ppp) reduced stress net of socio-demographic confounders, loneliness and network size, and the other triad types. The random-effects model in Model 5 furthermore included time-invariant confounders. Standard errors were smaller, but a Hausman-test suggested that estimates did not systematically differ from the fixed-effects model. Because the random-effects model comprised a similar pattern to the fixed-effects model with no new significant parameter estimates, overfitting did not affect our overall result: a higher number of triads of Balance Type 1 (ppp), i.e., where all three ties were positive, was associated with reduced stress within and between study participants.

Figure 2 presents the predictive margins of perceived stress by the number of these positively balanced triads, Balance Type 1 (ppp), for the fully adjusted fixed-effects Model 4. Confidence intervals for stress did not overlap for values below versus above 16 triads. This threshold resembled the sample's pooled mean. Mathematically, to cross this threshold, ego needs to have a positive tie to at least seven alters who have mostly positive ties among themselves (versus the case of six fully interconnected alters: 6×5/2=15 triads). Participants with triad counts one standard deviation above the mean reported approximately one score point less on the stress scale (this resembles 15.43% of the standard deviation of stress) than the average participant. This effect size was moderate, as margins for stress ranged from 9.64 to 13.51.

---Table-3-and-Figure-2-about-here---

These results were partly in line with our theoretical expectations. There was no support for Hypothesis 1, which stated low stress in older adults with high closure. In Hypothesis 2, we expected low stress in older adults with high balance. The results are in line with this hypothesis, and hold independently of an individual's degree of closure. However, a high number of imbalanced triads in an individual's personal network (i.e., the focal individual has positive ties

to both alters who have a negative tie among themselves; Imbalance Type 4 (ppn)), was not associated with ego's perceived stress.

Sensitivity analysis

We checked the validity of our findings with several robustness tests. The models were not subject to bias from multicollinearity, as the variance inflation factors appeared to be acceptable (mean VIF = 1.87). Neither did confounding network variables distort the results: The fully adjusted fixed models yielded similar estimates when they additionally controlled for (1) all triad types as shown in *Figure 1* simultaneously, see also *Table S13* in the Supplemental Material, or (2) number/presence of negative ego-alter ties, or (3) number of positive ego-alter ties, or (4) number of triads in which one or more neutral tie occurred. Nor did balance in networks (Balance Type 1 (ppp) with three positive ties) mediate the relationship between perceived stress and network size or number of positive ego-alter ties—balance thus represented a main effect on its own.

Furthermore, we used alternative cut-offs for tie strength and valence to test the sensitivity of our operationalizations of the triad types. Using an identical handling of ego-alter and alter-alter ties for strong versus weak ties (strong ties being defined as "biweekly contact or more often"), and applying a stricter coding for positive (only +2 and +3) versus negative (only -2 and -3) ties did not reveal different insights. There were no interaction effects of balance in networks (Balance Type 1 (ppp) with three positive ties) with age, gender and follow-up period, suggesting that effects were not specific to certain subpopulations or timing. Dropout in subsequent waves was unrelated to stress and, when controlled for, did not alter the fixed-effects results meaningfully.

Finally, fixed-effects models cannot fully rule out the possibility of reverse causation. Our sample was too small to permit rigorous testing within a structural equation modeling (SEM) framework. A cross-lagged panel model did not fit the data satisfactorily. A cross-lagged latent growth model (LGM) demonstrated a good fit. It showed a negative and significant path from the intercept of network balance (number of triads of Balance Type 1 (ppp) with three positive ties) on the slope of perceived stress, but no reverse effect from the intercept of perceived stress on the slope of network balance. Also theoretically, a reverse path appears hardly plausible. While ego's reactions to stress may directly affect her relationships with others, it seems unlikely that the relationships between the others are affected. This latter result underscores our previous finding that higher levels of balance may prevent stress levels to increase, but that this does not hold for stress levels affecting balance.

Discussion

Social support has been suggested to play a pivotal role in buffering the impact of emerging stressors on health outcomes (Thoits, 2010); yet previous research has focused predominantly on older adults' direct relationships with significant others. The present study examined which kinds of social network structures reduce perceived stress, by including the interconnections between significant others in a network. Using self-reported network panel data, we found that older adults reported least stress when their social networks were characterized by perceived presence of many positive relationships between significant others, i.e., balanced triads with three positive ties (Hypothesis 2). This association was observed regardless of the total number of direct positive relationships and relationship strength with and between others.

Theoretical and methodological implications

Our results yielded no evidence for a preventive effect of highly closed networks with many strong interconnections between significant others, i.e., triads with three strong ties (Hypothesis 1). There may be several potential reasons for this. First, indirect reciprocity—a concept that applies well to contexts of material support and cooperation, such as work teams—might simply not be the driving force of exchanging informal support in older adults' networks. Specifically, shared experiences, relationship history and emotional closeness might matter more for stress reduction than interaction frequency (Thoits, 2011). Second, also weak ties may offer health benefits. Presence of weak ties corresponds with a more diverse set of contacts, which in turn increases the likelihood of receiving non-redundant input. Third, our hypothesis builds on the assumption that a subset of exchanges in a respondent's network are guided by norms of generalized reciprocity. The population-based survey on which this study is based did not directly measure the existence or salience of this type of norm, nor does our measure of interaction frequency between significant others assess actual exchanges. Study participants, who served as proxies, cannot accurately overview all the interactions between other people in their network (Marsden, 1990). In contrast, it is often easier to grasp and recall the emotional tone of relationships between others. Particularly negative relationships are noticeable because they can have implications for the focal person too.

Interestingly and contrary to *Balance Theory* (Heider, 1946), presence of negative interconnections—e.g., in the case of imbalanced triads—did not increase stress. One reason may be that, in an imbalanced triad (Imbalance Type 4 (ppn)), the benefits of the two positive ego-alter relationships cancel out the potentially stressful effects of the one negative alter-alter relationship. According to the idea of *tertius gaudens* (Simmel, 1950, p. 154), individuals may even exploit tenuous relationships between two others for their own betterment. A

methodological reason for the non-significant effect of negative alter-alter ties may have been the study's limited statistical power combined with the low prevalence of negative alter-alter ties (the parameter estimate was positive yet insignificant, and there was sufficient change over time).

Limitations and suggestions for future research

The small sample constrained our analysis to testing a limited set of expectations. Because of this, our null results may not be interpreted as evidence against the theory, but require replication. The sample did not permit breaking down the models into subpopulations, which would be necessary to assess the impact of moderators that are known to be predictors of stress, like socio-economic status (Elo, 2009). Furthermore, the results may not be generalized beyond the population of younger older adults in an urban area. Future research will have to show whether our findings can be reproduced in different contexts, by covering larger samples with higher response rates, greater age spans and populations from other cultural backgrounds and countries. Another limitation constituted the lack of data on the significant others' (alters') perceived stress. Such information is ideally collected through interviewing the respective others, either via a snowball sample or a survey of a complete sociometric network. We thus cannot rule out that study participants were influenced by the mental states of their contacts. Previous research on social contagion has suggested that feelings and emotions spread through networks (Cacioppo, Fowler, & Christakis, 2009; Rosenquist, Fowler, & Christakis, 2011), thereby contributing to the clustering of people who have similar mental health. Future research designs could test this and other mechanisms that are driven by social network structures. Finally, though powerful, stress is only one mental health outcome. It would be interesting to study whether balance and closure are associated with related outcomes, including depression and loneliness. Because loneliness is more closely related to relationship quality than quantitative measures of

network size and interaction frequency, network imbalance seems a good candidate in triggering and exacerbating feelings of loneliness.

We encourage researchers to push theories and empirical designs towards the direction of social network gerontology. Our network study revealed mechanisms that would have remained hidden otherwise: Stress was only associated with a complex measure that included the interconnections between significant others (i.e., balance in triads), but not with a simple measure excluding these interconnections (i.e., network size). Future research would benefit from considering balance when examining the characteristics of social networks that impinge on mental health outcomes in older adults.

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Table 1.

Adjacency matrix for the assessment of frequency (F) and valence (V) of the social relationships between up to ten alters in ego's personal network.

ego01	F	V	F	V	F	V	F	V	F	V	F	V	F	V	F	V	F	V
	alter01		alter02		alter03		alter04		alter05		alter06		alter07		alter08		alter09	
alter02																		
alter03																		
alter04																		
alter05																		
alter06																		
alter07																		
alter08																		
alter09																		
alter10																		

Note.
Respondents only needed to complete half of the matrix, as frequency and valence were assessed in a non-directional way. Ego could rate relationships between up to ten alters in every follow-up. The network module also assessed relationship frequency and valence of ego with every alter (not shown).

Table 2.

Descriptive statistics including mean, standard deviation and range of all variables, pooled sample (N_{obs}=708).

Variables	M, %	SD	Min	Max
Confounders				
Age	57.30	4.31	50	68
Female	55.51 %	n/a	0	1
Ethnicity				
White	39.83 %	n/a	0	1
Black	34.75 %	n/a	0	1
Hispanic	25.42 %	n/a	0	1
Education				
Less than high school	8.33 %	n/a	0	1
High school/GED	29.80 %	n/a	0	1
Some college	26.27 %	n/a	0	1
BA/BS	14.83 %	n/a	0	1
Graduate school	20.76 %	n/a	0	1
Marital status				
Married	55.37 %	n/a	0	1
Living with partner	5.08 %	n/a	0	1
Separated	3.25 %	n/a	0	1
Divorced	21.33 %	n/a	0	1
Widowed	9.75 %	n/a	0	1
Never married	5.23 %	n/a	0	1
Household income	5.33	2.07	1	8
Loneliness	35.70	9.02	20	76
Network size	8.53	3.06	2	15
Network embeddedness [a]				
Closure Type 1 (sss) [c]	4.11	4.12	0	15
Closure Type 2 (ssw) [c]	4.50	4.62	0	15
Closure Type 3 (sws/wss) [c]	2.39	2.47	0	10
Openness Type 4 (wws) [b]	45.48 %	n/a	0	1
Openness Type 5 (wsw/sww)	10.20	7.06	0	25
Openness Type 6 (www) [b]	75.00 %	n/a	0	1
Balance Type 1 (ppp)	16.18	10.76	0	45
Balance Type 2 (npn/pnn) [b]	12.71 %	n/a	0	1
Balance Type 3 (nnp) [b]	4.24 %	n/a	0	1
Imbalance Type 4 (ppn) [b]	20.76 %	n/a	0	1
Imbalance Type 5 (pnp/npp) [b]	9.89 %	n/a	0	1
Imbalance Type 6 (nnn) [b]	3.81 %	n/a	0	1
Outcome				
Perceived stress [b]	12.12	6.14	0	30

Notes. [a] Letters in parentheses refer to tie characteristics (s=strong, w=weak, p=positive, n=negative), with the last letter denoting the alter-alter tie. For example, a triad of Imbalance Type 4 (ppn) contained two positive ego-alter

ties and one negative alter-alter tie. [b] Variable was dichotomized into presence (1) versus absence (0) of triad type. Instead of mean (M) the share (%) of presence is shown. [c] Maximum value was truncated to reduce skewness.

Table 3.
Fixed-effects and random-effects models on perceived stress.

	Model 1: Confounding variables		**Model 2: Closure variables**		**Model 3: Balance variables**		**Model 4: All variables**		**Model 5: All variables**	
	fixed		fixed		fixed		fixed		random	
Variables	B	(SE)	B	(SE)	B	(SE)	B	(SE)	B	(SE)
Confounders										
Age									-0.167*	(0.081)
Female									1.715*	(0.694)
Ethnicity (*ref.*=White)										
Black									0.802	(0.779)
Hispanic									0.153	(0.906)
Education (*ref.*=less than high school)										
High school/GED									0.242	(1.233)
Some college									-0.837	(1.273)
BA/BS									-1.301	(1.428)
Graduate school									-1.788	(1.421)
Marital status (*ref.*=married)										
Living with partner	-2.082	(1.535)	-2.093	(1.539)	-1.865	(1.530)	-1.836	(1.532)	-0.895	(1.002)
Separated	1.608	(1.883)	1.506	(1.895)	1.605	(1.872)	1.416	(1.882)	2.163	(1.316)
Divorced	-1.955	(1.564)	-2.028	(1.572)	-1.747	(1.558)	-1.880	(1.562)	-0.637	(0.804)
Widowed									-0.633	(1.231)
Never married	-2.413	(2.522)	-2.440	(2.530)	-2.229	(2.508)	-2.218	(2.513)	-2.164	(1.280)
Household income	0.219	(0.214)	0.210	(0.215)	0.199	(0.213)	0.173	(0.214)	-0.100	(0.150)
Loneliness	0.199***	(0.038)	0.201***	(0.039)	0.201***	(0.038)	0.206***	(0.038)	0.273***	(0.028)
Network size	-0.017	(0.089)	-0.029	(0.095)	0.138	(0.106)	0.120	(0.108)	0.121	(0.096)
Network embeddedness [a]										
Closure Type 1 (sss)			0.043	(0.074)			0.092	(0.075)	0.121	(0.066)
Closure Type 2 (ssw)			-0.015	(0.060)			-0.011	(0.060)	-0.037	(0.054)
Balance Type 1 (ppp)					-0.077**	(0.028)	-0.086**	(0.029)	-0.080**	(0.027)
Imbalance Type 4 (ppn)					0.439	(0.488)	0.427	(0.489)	0.313	(0.456)
Intercept	4.581*	(1.987)	4.578*	(1.991)	4.393*	(1.978)	4.364*	(1.979)	12.175*	(5.350)

N(individuals)	160	160	160	160	160
N(observations)	708	708	708	708	708

Note. Models 1-4 use fixed effects, Model 5 uses random effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. [a] Letters in parentheses refer to tie characteristics (s=strong, w=weak, p=positive, n=negative), with the last letter denoting the alter-alter tie. For example, a triad of Imbalance Type 4 (ppn) contained two positive ego-alter ties and one negative alter-alter tie.

Figure 1.

Types of closure versus openness and balance versus imbalance in triads with ties between one ego *h* and two alters *i* and *j*.

Note.
(a) Closure exists when two or three ties are strong in terms of frequent contact; openness exists when two or three ties are weak. (b) Balance exists when the product of all ties is positive in terms of liking; imbalance exists when the product of all ties is negative. Some types constitute identical scenarios from ego's perspective, which are grouped into the same type: Balance Type 2, Imbalance Type 5, Closure Type 3 and Openness Type 5. Numbers inside triangles correspond with the label of the triad type.

Figure 2.

Predictive margins of perceived stress by number of positively balanced triads (Balance Type 1: ppp).

Note.
Triads of Balance Type 1 (ppp) include three positive ties. Confidence intervals for coefficients of perceived stress do not overlap for values below versus above 16 balanced triads. Mathematically, to cross this threshold, ego needs to have a positive tie to at least seven alters who have mostly positive ties among themselves (versus the case of six fully interconnected alters: 6×5/2=15 triads).

Figure 1

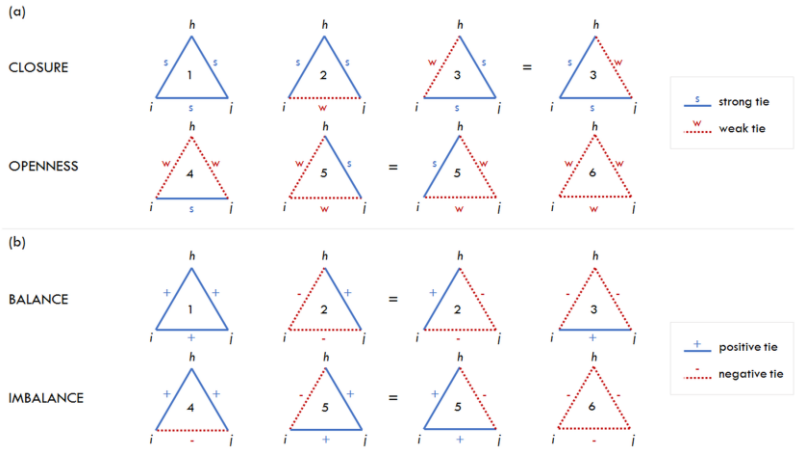

Figure 2