KEEP OR DROP? THE ORIGIN AND EVOLUTION OF KNOWLEDGE RELATIONSHIPS IN ORGANIZATIONS

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Network research shows that strong relationships, highly embedded relationships, and brokered relationships may have different outcomes. While pros and cons are associated with each of these network structures, how this ambiguity translates into individuals’ actions of network change is unclear. Specifically, if network positions can be both beneficial and detrimental, how do individuals decide whether to maintain those positions? We develop a tie-specific model of network modification that captures the positioning in the work-related network and the level of knowledge acquired from that network for each individual in a knowledge-intensive organization. Our analysis of tie-level data identifies the level of acquired knowledge as an important disambiguating mechanism that determines how individuals manage their strong ties, embedded ties, and brokered ties over time.

Keywords: Network dynamics, network microfoundations, knowledge acquisition, social embeddedness, agency.

INTRODUCTION

The contributions that people make in knowledge and innovation contexts depend on their individual human capital, and on the interactions in which they choose to engage and exchange knowledge, information, and ideas with other organizational members (Grigoriou & Rothaermel, 2014). Social network research has argued that knowledge exchanges are dynamic systems that emerge, evolve, and terminate over time (Ahuja, Soda, & Zaheer, 2012). We take on the challenge to enhance the scholarly understanding of these dynamic processes by focusing on the microfoundations of network changes, where individuals create or break individual ties with one another (Ahuja et al., 2012; Lizardo & Pirkey, 2014; Tasselli, Kilduff, & Menges, 2015). By investigating the mechanisms that induce individuals to change or preserve the social ties through which they exchange knowledge, we respond to Lizardo and Pirkey's suggestion that "the time has to come to reopen central conceptual issues […] related to the *emergence* of network ties, their *maintenance* and *evolution* over time, and ultimately the factors that contribute to dynamic *tie persistence* and *decay*" (2014, p. 36).

Network research has been interested in the outcomes associated with the structural and relational characteristics of relationships (Borgatti & Halgin, 2011). Basically, a long and rich research tradition shows that different structural configurations of network correspond to different outcomes (Burt, 2005).

When considered from a dynamic perspective that focuses on how individuals decide which relationships to keep, drop, or create over time, our theory builds on the idea that the inherent tensions among the differential effects of network structures are even sharper. We argue that individuals are not randomly assigned to network positions, and that to better understand the value they extract for their networks we should investigate why they choose to maintain or change those positions. In particular, the fact that positions may have positive and negative effects implies that they may pull an individual towards opposite actions of change, as those relationships that should be maintained (or created) for some reasons are the same that should be terminated (or not created) for other reasons. This raises an important question: if an actor occupies a network position that may have both advantages and disadvantages, how does the actor decide which relationships to create, preserve, or drop?

Our theory and empirics focus on a knowledge-intensive organizational context in which actors mainly interact with each other to access and integrate knowledge in order to generate innovation, and answer the important question raised above by developing a fine-grained understanding of the logic underlying network transformations. In this context, knowledge exchanged by organizational members is a foundational driver of networked action. Thus, we develop a theory that identifies the knowledge that an individual is able to obtain from her network as the key disambiguating mechanism that shapes the decision to keep or drop (create or not create) strong ties, highly embedded ties, and brokered ties. In the last decade, adopting longitudinal data and design, a new stream of network research has tried to disentangle the processes through which ties and network structures emerge and change over time (CITES HERE). This prolific literature also attempted to understand the implications and consequences of these evolutions on relevant outcomes, thereby mapping and testing the entire causal chain from the origins to the outcomes of networks. Nevertheless, findings are often controversial and the question of what triggers specific patterns of network evolution is still unanswered. To enhance scholarly understanding on this key phenomenon we offer a non-deterministic theory that suggests that similar network properties *per se* may lead to different actions of network change. Specifically, we identified the inherent uncertainty associated with how actual network ties and structures shape their future evolution, and in turn suggest the knowledge that individuals are able to acquire from their networks as a key factor that reduces this uncertainty. Put differently, our key contributions is to tease out the contingent effect of knowledge acquisition as a key mechanisms, among others, that — in a knowledge-intensive context— explains when and how individuals with different relational constraints and opportunities regulate their actions of tie change. We test our theory in the organizational context of a Danish chemical firm that manufactures products for the pharmaceutical industry. Our results, including those we obtain by adopting dynamic network models that control for network-level effects, confirm the role of knowledge as a key disambiguating force that drives individuals to choose between different types of tie-specific network actions.

THEORY DEVELOPMENT

Early calls for a theory of social networks that incorporates a dynamic perspective (Emirbayer & Goodwin, 1994; Salancik, 1995) nurtured a prolific stream of research on the origins and evolutionary patterns of social structures (Ahuja et al., 2012; Baum, Shipilov, & Rowley, 2003; Cannella & McFadyen, 2016; Vissa, 2012; Zaheer & Soda, 2009). Network changes involve the formation, termination, or transformation of ties between pairs of actors. Taken together, changes in individual ties may be reflected in changes in ego-network structures that, in turn, combine with complex and interdependent patterns into macro network changes (Ahuja et al., 2012). Thus, network transformations are inherently phenomena of interdependent changes in which the most elemental factors are individual ties (Newman, Barabasi, & Watts, 2006).

Network research highlights the position that individuals occupy in the social space as a key determinant of network change (Ahuja et al., 2012). Consistent with Blau’s (1994) idea of the structural context of action, the basic intuition is that much networking behavior is conditioned by the information, trust, and access conferred through individuals’ positions in their social networks. In that sense, those positions provide individuals with opportunities for change and impose constraints on that change (Rivera, Soderstrom, & Uzzi, 2010; Stevenson & Greenberg, 2000).

Borgatti et al. (Borgatti & Halgin, 2011) argue that something like wealth may enable individuals to buy their positions, which they then use to obtain greater wealth. In knowledge contexts, particularly those in which the knowledge is mobilized for innovation purposes, the level of knowledge that organizational members obtain by virtue of their network position is a key element of this wealth. As a consequence, a key force of network change is the knowledge that actors are able to acquire from their networks (Cannella & McFadyen, 2016). Network theory and social capital theory establish causal links between structural positions and knowledge acquisition (Adler & Kwon, 2002; Borgatti & Halgin, 2011; Kwon & Adler, 2014). These links draw on different theoretical mechanisms. For example, Burt's (2004) brokerage argument suggests that a broker is more knowledgeable because she links otherwise disconnected alters that likely channel non-similar and, therefore, valuable knowledge inputs to her. Conversely, close networks may be the conduit for more meaningful and familiar knowledge that turn into advantages by virtue of depth and specialization (Ahuja, 2000). Although controversial, these arguments share the fundamental insight that being networked in a given manner may trigger important knowledge-related advantages that generally do not originate from knowledge flows within specific individual ties but rather from the fit and synergies among the multiple knowledge inputs that individuals can obtain via their individual networks (Amabile, 1996; Hennessey & Amabile, 2010).

Thus, the mechanisms through which the knowledge obtained by individuals can shape the specific forms of intra-organizational networks evolution are several. For instance, from the perspective of the brokered alters, connecting directly may avoid the inherent inefficiency of being mediated by a broker. Moreover knowledge, particularly when tacit, can be better recombined for innovation purposes by directly strengthening connections among individuals that are loosely connected (Reagans and McEvily 2003; Obstfeld, 2005). Furthermore, embedded knowledge networks may achieve a more balanced and symmetric structure for the alters, avoiding knowledge arbitrage. In sum, knowledge provides incentives to transform the prior social structure into one that may be more conducive to generating innovation.

Building on these intuitions, together with the idea that subpar performance triggers a search for solutions that stimulates the exploration of new courses of action (Baum, Rowley, Shipilov, & You-Ta, 2005; Cyert & March, 1963), we develop our theory on the idea that the amount of knowledge that individuals are able to obtain from their ego networks constitutes a key force behind network changes (Cannella & McFadyen, 2016; Zaheer & Soda, 2009).

Structural embeddedness and the creation and termination of ties

Embeddedness in a network of common alters has been argued to mitigate the pursuit of individual self-interests (Krackhardt, 1999), induce higher levels of trust and effort (Kilduff & Brass, 2010; Uzzi, 1996), and sustain longer-term cooperation and coordination (Obstfeld, 2005). These arguments seem to imply that embeddedness in a network of common alters should facilitate the formation of new transitive ties by reducing ego's search costs and uncertainty, by increasing the cost of misbehaving for alter (as well as for ego), and by facilitating the establishment of a collaborative environment between the embedded parties (Coleman, 1988; Dahlander & McFarland, 2013; Simmel, 1950). For the same reasons, actors who already are embedded in closed triads should be unwilling to disband those triads by exiting the group, and they should be likely to subordinate individual interests to collective interests (Dahlander & McFarland, 2013; Krackhardt, 1999).

At the same time, a different line of argumentation highlights that, contrary to ties that link otherwise disconnected individuals, embeddedness in a network of common alters gives the parties less autonomy and independence relative to other actors in the triad (Gargiulo & Benassi, 2000) as well as lower access to non-redundant information (Burt, 1992;

Granovetter, 1973). Ties embedded in a network of common alters are less likely to be conducive to the acquisition of valuable information (Burt, 2004) as well as less likely to provide the autonomy and independence needed to search for that information (Gargiulo & Benassi, 2000). Moreover, ties embedded in closed triads are expected to be stable because the actors are more likely to establish cooperative norms and to subordinate individual interests to collective interests (Krackhardt, 1999; Simmel, 1950). As a result, close social structures are subject to inertia and path dependence, and represent durable patterns of relationships (Coleman, 1988).

This equilibrium does not take into account any intention and motive of individuals to break off with the constraints associated with highly embedded networks. In particular, it is unclear how the logic of structural embeddedness applies to those individuals who experience an increased need to strategically change their networks.

We suggest that the perceived cost and benefit of creating and maintaining highly embedded ties is contingent on ego's knowledge acquisition (Zaheer & Soda, 2009), so that the lower the amount of knowledge that an individual perceives to obtain from her network, the less likely she will be to form and maintain highly embedded relationships. Put differently, when network structures are unable to provide the focal actor with sufficient variation and quality in ideas and content, that actor will have an incentive to opt out of those relationships (Burt & Soda, 2017). Moreover, individuals with more resources tend to contribute more to the public good in relative (Fehr & Schmidt, 1999) and absolute (Becker, 1974) terms than individuals with less resources. In line with these insights, we expect ego's willingness to subordinate individual interests to collective interests to be contingent on ego's perceived access to useful knowledge resources. Thus, the more ego perceives her network as inconducive to the acquisition of knowledge, the more she will be concerned about her individual situation, and the less likely she will be to create or maintain highly embedded relationships.

This reasoning suggests:

Hypothesis 1: The lower is the knowledge acquisition of a focal individual, the lower the probability that she will create a tie with an alter with whom she has a high number of common third parties.

Hypothesis 2: The lower is the knowledge acquisition of a focal individual, the higher the probability that she will terminate a tie with an alter with whom she has a high number of common third parties.

Relational embeddedness and tie termination

A similar logic applies to strong ties that have developed over a relatively long period of time and tend to involve high emotional closeness among the actors (Krackhardt, 1992; Marsden & Campbell, 1984). Strong ties embody a range of elements, including values, norms, and affect, which represent valuable resources (Nahapiet & Ghoshal, 1998). The accumulated social capital that two actors hold because of an existing strong tie should, in principle, decrease ego's propensity to terminate the tie (Dahlander & McFarland, 2013).

However, an alternative line of argumentation is that strong ties tend to link similar people to each other, which introduces the well-known problem of high information redundancy (Granovetter, 1973). Strong ties are unlikely to be beneficial from an information-access perspective, which should increase ego's propensity to terminate those ties over time, especially in knowledge-intensive settings.

Based on these considerations, and similar to our argument in Hypothesis 2, we propose that the lower the amount of knowledge that a person is able to obtain from her network, the more likely that person will be to terminate the strong relationships in her network. In particular, the attachment that emerges from investments in strong relationships may lead people to maintain strong ties even though they are not particularly fruitful from an information access perspective (Dahlander & McFarland, 2013). However, the willingness to adhere to the social and affective expectations that induce the individual to maintain those relationships should be contingent on the extent to which network structures are able to provide the focal actor with sufficient knowledge resources (Zaheer & Soda, 2009). In other words, the perceived costs of maintaining strong ties should be contingent on ego's knowledge acquisition. More specifically, the lower the level of knowledge that an individual is able to obtain from her network, the less the individual will be constrained by social rules and affective expectations, and the more likely she should be to terminate strong relationships.

Hypothesis 3: The lower is the knowledge acquisition of a focal individual, the higher is the probability that she will terminate a tie with an alter with whom she has a strong relationship.

Alter's brokerage with ego and tie termination

Actors are motivated to improve their positions in the network in order to access resources held by others. For this reason, individuals attempt to occupy and maintain brokering positions in order to gain access to non-redundant information (Zaheer & Soda, 2009). A much less explored but equally interesting perspective is the viewpoint of those actors who are tied to a broker (Brass, 2009; Clement, Shipilov, & Galunic, 2017; Galunic, Ertug, & Gargiulo, 2012). In particular, while we know that social actors may both benefit and suffer from being tied to a broker (Brass, 2009; Clement et al., 2017), we know little about whether these actors are willing to maintain ties with brokers who bridge them to otherwise non-accessible parts of the network.

Structural holes theory traditionally regards brokers who benefit from the disconnection of alters as actors who take advantage of information arbitrage and privileged access to others' resources (Burt, 1992). In particular, bridging structural holes is regarded as an individualistic strategic behavior that prioritizes individual rather than collective goals, focuses on the fulfilment of self-interests, and prioritizes task achievement above harmonious relationships (Xiao & Tsui, 2007). Thus, brokerage may facilitate the accumulation of power and exacerbate inequalities (Stovel & Shaw, 2012).

This well-established view on brokerage suggests that brokers exploit otherwise disconnected alters to keep the benefits private (Burt, 1992), which in turn implies that social actors should attempt to terminate their ties with brokers over time. This view on the evolution of brokerage ties seems consistent with research showing that such ties have a much faster rate of decay than other kinds of relationships (Burt, 2002).

A different perspective is offered by research on the "non-partisan broker," or *tertius jungens* (Obstfeld, 2005, which highlights that although a brokering position might lend itself to the pursuit of self-interest, this does not necessarily need to be the case (Stovel & Shaw, 2012). Specifically, brokers can have distinct strategic orientations (Soda et al, 2018). Thus, a (structural) opportunity to play people against one another for the broker's exclusive benefit does not necessarily imply that the broker will take that opportunity (Obstfeld, 2005; Stovel & Shaw, 2012). In this sense, while "the *tertius gaudens* concept has a central role in structural holes theory (e.g., Burt, 1992, 2000)" (2005, p. 102), research also acknowledges the possibility of a broker of the *jungens* type "who acts as a mediator, or 'non-partisan,' to create or preserve group unity" (Obstfeld, 2005, p. 103; Simmel, 1950). The non-partisan broker creates value for ego by either making an effort to create a direct contact between ego and the previously unconnected alter or, more simply, by functioning "as an arbiter who balances … their contradictory claims against one another and eliminates what is incompatible in them" (Simmel, 1950, p. 147). This alternative view implies that social actors may benefit from being connected to brokers, which should increase their willingness to maintain their ties with brokers over time.

Taken together, these considerations suggest that while brokers may attempt to maintain their privileged position in the structure, their alters may have more ambiguous feelings about their links with brokers. Based on this intuition, we propose that ego's propensity to terminate a tie with a broker should be contingent on ego's level of knowledge acquisition, as the level of knowledge acquired should provide ego with an indication of whether having brokers in her network is beneficial. Specifically, brokers are normally in control of significantly higher levels of valuable knowledge than non-brokers (Burt, 2004). Thus, an inability to obtain high levels of knowledge from her network while being connected to one or more brokers should suggest to ego that the brokers in her network are not sharing valuable resources with her. This should increase ego's propensity to terminate ties with alters that occupy brokering positions.

Hypothesis 4: The lower is the knowledge acquisition of a focal individual, the higher is the probability she will terminate a tie with an alter through which she is brokered to third parties.

METHODS

Data collection and research site

We obtained the empirical data to test our hypotheses from ChemDan (a fictitious name), a Danish chemical firm that manufactures products for the pharmaceutical industry. ChemDan incorporates large parts of the value chain and offers its clients customized solutions drawing on knowledge from several employees in the firm. The close proximity of activities is very important for ChemDan, which puts a strong emphasis on knowledge sharing among employees. For this reason, all of the company's activities are located at the same site.

ChemDan offers an excellent context for the analysis of social structures, as its culture emphasizes the role of informal interpersonal relationships in the workplace.

In order to study the evolution of social relationships, we collected data on network relationships and employee behavior at two points in time. The data collection was conducted in close collaboration with the firm. At the time of the initial data collection, ChemDan was preparing to relocate some employees to a new building located a few meters away from the older building. The company was therefore interested in learning more about the determinants of employees' knowledge-sharing behaviors.

The data were collected through two web-based questionnaires. The first survey was carried out six months before the relocation and the second survey was administered twelve months after the first. The two questionnaires, which were identical, were developed on the basis of a focused literature review. The network-related questions followed Burt's design (1992), and used the standard method of name-generator and name-interpreter items (Marsden, 1990) in which respondents (egos) were first asked to draw up a list of contacts (alters) with whom they had one or more criterion relationships (name generators) and then to characterize their relationship with each person listed (name interpreters). All questions were translated into Danish and back-translated into English in order to reduce the risk of comprehension problems (Brislin, 1986). The questionnaires were pretested with management scholars and managers, as well as with representatives of ChemDan.

The initial samples comprised the entire organization, and amounted to 93 people for the first survey and 98 for the second. The response rate for the first survey was 86 percent, while it was 81 percent for the second.

We tracked the evolution of each potential tie in the network over time. In other words, we compared the presence (or absence) of a tie between any given pair of actors at a point in time with the presence (or absence) of a tie between the same two actors at a second point in time (twelve months later). Because of missing values in the behavioral variables (especially for the self-reported item on knowledge acquisition), the responses of 69 of the 80 employees who responded to the first questionnaire (and provided network information) were usable. Of these 69 individuals, 6 exited the firm before the second data-collection period, which restricted our number of egos to 63. In principle, each of these 63 individuals could have relationships with 92 potential alters (i.e., 93 minus themselves) in the first data-collection instance and with 97 potential alters in the second data-collection instance. However, after the first survey, 9 individuals exited the firm and 15 new individuals were hired. In order to track the evolution of individual ties over time, we looked at all ties between the 63 egos who provided us with usable responses and each of the 83 alters that were present in ChemDan at both data-collection points (i.e., the 92 individuals who were present during the first survey minus the 9 who left the firm). After removing a few observations because of missing values, the final number of ties used in the data analysis was 5,213. Each of these potential ties were observed at both points in time.

We examined the risk of non-response bias for both datasets. First, we discussed the results and the demographic characteristics of respondents (e.g., age, education, tenure, gender) with firm representatives, who assured us that there were no visible biases differentiating the respondents from the overall demographic distribution of employees. In addition, we conducted a wave analysis to compare the demographic variables for early (first week) and late (second week) respondents (Rogelberg & Stanton, 2007). The assumption is that the group of late respondents will be more similar to non-respondents than the group of early respondents. An analysis of variance (ANOVA) of the difference in means for the two groups showed that the hypotheses of differences in the means could all be rejected (F-values < 2). These tests and the high response rate for both surveys make us confident that the data are not affected by major problems of nonresponse bias.

Measures

The dependent variables (tie termination and tie formation) are based on each ego's own assessment and listing of work-related ties at two points in time. The network variables (alter's brokerage with ego, embeddedness of existing tie, and embeddedness of non-existent tie, network size) are based on ego's and alters' information, as they are calculated based on the network matrix obtained from the first survey. The remaining variables (knowledge acquisition, tie strength, and all control variables except network size) are operationalized through the self-reported information obtained in the first survey.

Dependent variables

Tie formation. We asked each respondent to identify those colleagues with whom he or she had "communicated the most regarding work-related topics" in the last year. The item was modified from Brass (1985) and Burkhardt and Brass (1990). In each data-collection instance, we created a list of work-related ties as assessed by each employee in the organization. In order to compute tie formation, we observed all possible dyads in the network at both points in time and set tie formation equal to 1 if ego did not report a tie with the focal alter at the time of the first survey but reported a tie with that alter at the time of the second survey. Tie formation was set equal to 0 if ego did not report a tie with the focal alter in either survey.

This measure is designed to capture tie modifications as actioned (and thus perceived) by ego. For this reason, ties that were mentioned by alters but not by ego were not considered to be relevant. In other words, we computed the measure of tie formation using the original, asymmetric matrix of network relations. Of the 4,880 dyads that did not have a tie at the time of the first survey, 125 dyads had a tie at the time of the second survey.

Tie termination. We applied a similar approach to measure tie termination. More specifically, in order to compute tie termination, we observed all possible dyads in the network at two points in time. For each (ego-alter) dyad, tie termination was set equal to 1 if ego reported a tie with the focal alter at the time of the first survey and did not report a tie with that alter at the time of the second survey. Tie termination was set equal to 0 if ego reported a tie with the focal alter in both surveys. The variable was computed based only on ego's listing of work-related ties. Of the 333 dyads that had a tie at the time of the first survey, 237 dyads had terminated that tie by the time of the second survey.

Independent variables

While our dependent variables (tie formation and tie termination) are calculated by comparing the relational data obtained through the second survey with those obtained through the first survey, all of our independent variables are constructed using information obtained through the first survey. This is based on the idea that network change is triggered by a configuration of factors at an earlier point in time than the event itself. Thus, the structure of our data allows us to test the causal claims developed in our hypotheses.

All network variables are calculated based on a matrix of network relations at the time of the first survey (relation = 1, no relation = 0), symmetrized according to the rule that a pair was considered to have a tie when either member nominated the other (Blau, 1962; Brass & Burkhardt, 1993; Mehra et al., 1998; 2001; 2006). To check whether the results were affected by this definition, we also symmetrized the work-related communication matrix using the rule that a pair was considered to have a tie only if both parties nominated each other. The result patterns remained the same. Descriptive data for all variables before standardization are included in the correlation matrixes (Tables 1 and 2). In the analysis, all variables are standardized (mean = 0; standard deviation = 1), allowing us to compare the size of the coefficients across the variables and to avoid issues of multicollinearity when creating interaction effects.

Embeddedness of non-existent tie captures the extent to which two actors who do not have a tie with each other are tied to the same alters in the network. This variable was calculated using the Jaccard similarity routine in UCINET (Borgatti, Everett, & Freeman, 2002). For each dyad in the network, the Jaccard routine calculated the number of times that both actors reported a tie to the same third actors as a percentage of the total number of ties reported.

Embeddedness of existing tie captures the extent to which two actors who have a tie with each other are also connected to common third parties. This measure was calculated in UCINET (Borgatti et al., 2002) by counting the number of alters with whom both actors of an existing dyad were tied.

Tie strength is measured as the average of the frequency and emotional closeness scores (Burt, 1992; Hansen, 1999; Hansen, Mors, & Løvås, 2005). Specifically, for each tie listed, each respondent was asked to qualify the relationship in terms of its frequency and emotional closeness. The item for frequency of communication was: "How often do you communicate with this person on work-related issues?". It was measured using a nine-point scale with the endpoints of "never" (= 1) and "multiple times per day" (= 9). The emotional closeness item was: "How close is your relation with this colleague?". It was measured using a seven-point scale (1 = "very distant" and 7 = "very close"). The mean values of frequency and closeness (before standardization) were 3.9 and 6.0, respectively. Frequency and closeness were significantly correlated ($r = 0.37$, $p = 0.002$). The two items were standardized and averaged to create an index of tie strength for each employee.

Alter's brokerage with ego captures the extent to which alter is involved in brokering activities that are relevant for ego. These brokering activities are relevant for ego when alter is brokering between other actors in the network with whom ego does not have direct ties. We computed this measure in two steps. First, we calculated the brokerage score of each actor in the network. Second, for each ego-alter dyad, we weighted alter's brokerage score by the extent to which ego and alter shared the same third-party ties. The brokerage score of each actor in the network was calculated using the structural holes routine in UCINET (Borgatti et al., 2002), where we specified it as the additive inverse of Burt's (1992) constraint measure. The extent to which ego and alter shared third-party ties was computed using the Jaccard similarity routine in UCINET (Borgatti et al., 2002) described above. Jaccard similarity varies from 0 to 1. More formally, alter's brokerage with ego was computed as alter's brokerage multiplied by 1 minus the Jaccard Similarity of ego and alter.

Knowledge acquisition measures the respondent's acquisition of work-related knowledge from colleagues in the firm. We asked respondents to indicate the extent to which they had "received/used knowledge from colleagues in their own department" (two items) and "received/used knowledge from colleagues in other departments" (two items). This is an inherently relational measure of the quantity of knowledge that each respondent can obtain via her ego network. The four items, which were developed by Reinholt *et al.* (2011), were measured on a scale anchored by 1 = "no or very little extent" and 7 = "very large extent." The Cronbach's alpha for this construct was 0.88 and the composite reliability was 0.88, with an AVE value of 0.64. These measures suggest that the construct is highly reliable and characterized by convergent validity.

Ego's knowledge acquisition is operationalized as an ego-level variable rather than a dyad-level variable. We use this operationalization because creative outputs result from the acquisition and recombination of different knowledge sources (Amabile, 1996; Ford, 1996; Hennessey & Amabile, 2010). Thus, the value of each knowledge input depends on the synergies between that input and other inputs (Amabile, 1996; Hennessey & Amabile, 2010). As a consequence, while relationship-specific characteristics of knowledge mobilization, such as the ease of knowledge transfer, are better captured at the tie level (Reagans &

McEvily, 2003), an overall measure of the perceived level of knowledge acquisition that is reflective of the quality, synergies, and overall volume of all of those inputs is better captured at the ego level—that is, when the respondent is allowed to simultaneously consider the knowledge that she gets from all work collaborations in her network (Reinholt et al., 2011).

The survey also asked managers to assess those employees who reported directly to them by indicating the extent to which each employee received and used knowledge from colleagues in his or her own department or other departments. We were able to obtain these data for a subsample (66 percent) of the population. As an additional test, we conducted an inter-rater reliability analysis of the knowledge-acquisition assessment for those individuals who both reported their own knowledge acquisition and were evaluated by their managers, and then compared the means and standard deviations of the two measures. We found high and significant ICC coefficients of 0.62 and 0.66, as well as means and standard deviations that were not significantly different. These tests provide additional evidence that the knowledge-acquisition measure is not confounded by respondent-specific factors.

Control variables

Network size. Decisions to form new ties or terminate existing ones may be influenced by the size of ego's network. For example, an employee who has already established a large network of contacts could be more prone to terminate some ties than an employee with a small network. Similarly, an employee with a large network may feel less need to add new ties than an employee with a smaller network. For this reason, we control for ego's network size, calculated as the number of contacts in the network to which ego is directly connected (Freeman, 1979; Wasserman & Faust, 1994).

Number of ties created or terminated. At the aggregate level, decisions to terminate ties may also be influenced by the extent to which ego engages in tie formation and vice versa. For this reason, we control for the total number of ties created by ego in the model on tie termination, and for the total number of ties terminated in the model on tie formation.

Education and tenure. Education and experience provide people with more complete cognitive structures. Thus, employees with higher levels of education or more experience may be better able to use the knowledge they acquire and, consequently, they have less need to renew their networks. For this reason, we control for education (= 1 if ego has a university degree and 0 otherwise) and tenure (measured as the number of years that ego had been employed by ChemDan).

Leadership. Employees occupying leadership positions may feel obliged to engage in network action in certain ways. For instance, leaders tend to be the key referents for multiple work-related matters and they might find it harder to terminate ties with colleagues whose careers they are responsible for. We therefore control for an employee's leadership responsibility (dummy variable; 0 = no leadership, 1 = leadership), where leadership responsibility is defined as having formal managerial responsibilities over other employees.

Gender. We control for ego's gender as another factor that might affect the propensity to engage in network modifications.

Ego moved office and alter moved office. Network action may also occur for reasons that are exogenous to the people involved in the relationship, such as organizational and workflow design (Burt, 2001; McEvily, Soda, & Tortoriello, 2014). Therefore, we control for whether ego or alter was moved to a different office location in the time between the two surveys (two dummy variables, one for ego and one for alter; 0 = old office location, 1 = new office location). These variables control for the effect that the relocation of some employees to new offices might have on relationship creation and termination.

Tie duration controls for the possibility that ties developed over a long period of time may be characterized by more emotional involvement than recently developed ties, which could make their termination more difficult. The duration of each tie was measured by asking "How long have you known this colleague?" and was measured on a six-point scale (1 = less than six months, 6 = more than ten years). For ties reported by both ego and alter, tie duration was calculated as the average duration reported by the two actors.

Tacitness. Ties that are conducive to the mobilization of tacit knowledge might be harder to establish, but they might also be more likely to lead to the exchange of valuable information (Nonaka, 1994). For these reasons, the termination of such ties may be less likely. We thus control for the tacitness of the knowledge transferred in each tie, which we measured by asking respondents to use a seven-point scale based on Ambrosini and Bowman (2001) to answer the following question: "To what extent is the communication with this person about knowledge that is easy to communicate and codify (= 1) or knowledge that is deeply ingrained and difficult to codify (= 7)?". For ties reported by both ego and alter, the tacitness of the knowledge exchanged was calculated as the average value reported by the two actors.

Face-to-face interactions may imply higher emotional involvement than relationships that are based on indirect communication. High involvement, in turn, may make it more difficult to terminate an existing tie. Therefore, we control for the nature of communication, which we measured by asking whether "The communication with this person is predominantly face to face (= 1) or occurs through various electronic and printed media (= 7)." The values were averaged when ties were reported by both ego and alter.

Distance. Physical proximity between the two actors in a dyad may influence ego's propensity to terminate an existing relationship or create a new one. We therefore control for physical distance in our models. This item was measured by calculating the distance (in meters) between the desks' locations for each pair of actors.

Difference in knowledge acquisition. The level of knowledge that an individual is able to obtain from her ego network ideally reflects the quality, synergies, and overall volume of network-driven knowledge benefits (Reinholt et al., 2011). For this reason, it represents a key driver of network modification (Cannella & McFadyen, 2016). However, tie-specific differences in the level of knowledge may also drive decisions to (not) create or terminate a certain tie. For this reason, we control for the difference in knowledge acquisition between each ego-alter dyad. To do so, we use the measure of knowledge acquisition described above and calculate alter's knowledge acquisition minus ego's knowledge acquisition.

Same action. For each dyad, we treat ego's action as distinct from alter's action and use this distinction to infer agency. This suggests a need to control for instances in which ego's and alter's actions of creation and termination coincide. In order to do so, we include a same-action dummy, which takes the value of 1 when the two actors in each dyad engage in the same network action of termination (in the termination models) or creation (in the creation models), and 0 otherwise.

Number of ties with new entrants. The number of ties reported in the second survey with individuals that was not present in the company at the time of the first survey was added in order to control for the confounding effect of tie changes being determined by new entrants. The variable varies from 0 to 2 new entrants.

RESULTS

In order for a tie to be terminated, it must exist at a previous point in time. For this reason, the models on tie termination include all observations that are at risk of being terminated—that is, all ties that existed at the time of the first survey. Similarly, in order for a tie to be created, it must be absent at a previous point in time. Therefore, the models on tie creation include all observations that are at risk of being created—that is, all ties that did not exist at the time of the first survey.

Descriptive statistics and pairwise correlations for all variables in the two samples are shown in Table 1 (tie formation) and Table 2 (tie termination). None of the correlations suggests problems of multicollinearity.

Insert Tables 1 and 2 here.

Econometric approach

As our data include multiple observations for each ego and each alter, the observed relationships are not independent. This kind of clustering violates the independence assumption in our models and may reduce the size of the standard errors. To adjust the standard errors for clustering, we introduced a random effect for every ego and every alter in our analysis. The (two-way) random effects can also control for potential unmeasured characteristics of egos and alters that might have affected the outcome in terms of the termination or formation of ties. Tie formation and tie termination are binary dependent variables. As we are dealing with outcomes that are binary rather than normally distributed, an appropriate error distribution for our dependent variables needs to be incorporated into the model. For these reasons, we ran our models as binominal logistic regression models including two random effects controlling for the clustering of egos and alters (conducted in SAS Proc Glimmix and Proc Mixed).

Results for tie formation

The results for tie formation are shown in Table 3. Model 1 includes the random effects, while the control variables are added in Model 2. Model 3 includes the main effects, and Model 4 covers the hypothesized interaction effect. Model 4 obtains the lowest fit statistics (lowest -2 log L and AIC values) and the highest McFadden’s pseudo R-squared (0.23). Therefore, Model 4 is superior to all other models and can be used to test the hypothesized effect on tie creation. Both random effects suggest that there is some clustering on the ego level (β = 0.01, z = 0.03) and the alter level (β = 0.01, z = 0.04), which is not explained by the other variables in the model.

Insert Table 3 here.

In Model 4, the embeddedness of non-existent tie variable is positive, which suggests that embeddedness in a network of common alters facilitates the formation of new ties. However, the results on the interaction effect between embeddedness of non-existent ties and ego's (decreasing) knowledge acquisition (β = -0.01, p = 0.18) require us to reject Hypothesis 1. Taken together, these results suggest that the formation of ties embedded in a network of common alters is not sensitive to ego's level of knowledge acquisition.

We also conducted additional tests that were well suited to the structure of the data (i.e., relatively rare events), such as penalized likelihood models (Firth method) and rare-event analyses. All models offered results qualitatively identical to those discussed above.

Results for tie termination

Table 4 shows four models with tie termination as the dependent variable. Model 5 includes the random effects, while the control variables are added in Model 6. Model 7 covers the main effects, and Model 8 shows the hypothesized interaction effects. Model 8 obtains the lowest fit statistics (lowest -2 log L and AIC values) and the highest McFadden's pseudo R-squared (0.22 for Model 8; 0.19 and 0.10 for Models 7 and 6, respectively). We can conclude that Model 8 is superior to all other models and can be used to test the hypothesized effects on tie termination.

Insert Table 4 here.

The random effect for ego level (β = 0.02, z = 0.004) indicates a clustering effect of interdependence at the ego level, which is controlled by the random effect. That is not the case for the random effect on the alter level (β = 0.01, z = 0.05), which implies that there is much less interdependence on the alter level. The fact that the coefficient for the ego-level random effect drops from 0.06 in Model 5 to 0.02 in Model 8 suggests that two thirds of the variation on the ego level is explained in our final model.

The interaction of embeddedness of existing tie with (decreasing) knowledge acquisition shows a positive effect on termination (β = 0.04 p = 0.04). The interaction between tie strength and (decreasing) knowledge acquisition has a positive effect on termination (β = 0.07 p = 0.01). Similar results also apply to the interaction of alter's brokerage with ego and (decreasing) knowledge acquisition (β = 0.04 p = 0.03). In line with Hypotheses 2, 3, and 4, respectively, these interactions suggest that the lower the level of knowledge that an individual is able to obtain from her network, the higher is the probability that the individual will terminate highly embedded, strong, and brokered ties in her network.

To further interpret these results, we conducted simple slope tests for all interactions, as presented in Tables 5, 6, and 7. These tests show that the lower the level of knowledge acquisition, the more likely the termination of embedded ties, strong ties, and brokered ties becomes. In particular, decreasing the level of knowledge acquisition by one standard deviation when the level of embeddedness is one standard deviation above the mean increases the likelihood of termination by 0.13. However, an identical decrease in knowledge acquisition increases the likelihood of termination by only 0.02 when the level of embeddedness is one standard deviation below the mean. Similarly, decreasing the level of knowledge acquisition by one standard deviation when the strength of the relationship is one standard deviation above the mean increases the likelihood of termination by 0.12. A similar decrease in the level of knowledge acquisition when the strength of the relationship is one standard deviation below the mean leads to an increase in the likelihood of termination of only 0.02. Lastly, decreasing the level of knowledge acquisition by one standard deviation when ego's commitment in brokered ties is one standard deviation above the mean leads to an increase in the likelihood of termination of 0.12. However, the same shift in knowledge acquisition when ego's commitment in brokered ties is one standard deviation below the mean leads to an increase in the likelihood of termination of only 0.03. Taken together, these results confirm Hypotheses 2, 3, and 4.

Insert Tables 5, 6, and 7 here.

DISCUSSION

We developed a theory of tie formation and termination in an organizational context of knowledge sharing and exchange where actors primarily interact in order to access and integrate knowledge and, thereby, generate innovation. By studying the micro-evolution of organizational networks in an organizational context, we make important contributions to research on the microfoundations of social networks (Ahuja et al., 2012; Tasselli et al., 2015). First, we provide a fine-grained picture of the interplay between the positions that individuals occupy in their networks and the actual knowledge that they are able to obtain from those networks. Specifically, while our model builds on the fundamental intuition that individuals' positions in their networks are important for understanding their decisions about network change (Ahuja et al., 2012; Rivera et al., 2010), our results show that these decisions may change dramatically depending on the individual's need for knowledge. One new and interesting insight that can be derived from our results is that individuals seem to be willing to differentially treat embedded, strong, and brokered work relationships depending on the extent to which the knowledge they can access from their existing networks is beneficial. Based on these findings, we are tempted to propose that social actors are not necessarily "purposive under social structural constraints" (Burt, 1992 p. ix), but rather socially constrained when knowledge-access considerations allow it.

Second, our theoretical and empirical approach challenges those perspectives that link networks' structural and relational properties to unidirectional effects of change (Dahlander

& McFarland, 2013; Gargiulo & Benassi, 2000; Stovel et al., 2011). Our contribution to this discussion is an alternative, non-deterministic view that allows similar network properties to justify opposite actions of change. In so doing, we point out the inherent uncertainties regarding how network structures shape their own evolution, and we highlight the need to simultaneously consider knowledge-related contingencies to more accurately predict instances of tie-specific network evolution.

Third, research on the dynamics of social networks has largely focused on variance at the ego-structure level, studying changes in the number (Cannella & McFadyen, 2016; Vissa, 2012) and configuration (Baum et al., 2003; Zaheer & Soda, 2009) of ties, and paying considerably less attention to the micro-changes at the level of the individual tie that generate those larger structural changes (Dahlander & McFarland, 2013). Thus, while we have a good understanding of how and why social structures change over time, we are much less informed about the evolutionary pattern of the individual relationships that, in fact, generate the evolution of the larger social structure (Tasselli et al., 2015). By unfolding the forces that lead individuals to choose between different types of tie-specific network actions, our analysis answers important questions about the origin and evolution of individual ties that have been largely neglected, despite calls for more social network research on micro-level topics (Dahlander & McFarland, 2013; Lizardo & Pirkey, 2014).

Limitations and future research

While we believe that this study makes important contributions to research, those contributions are not free from limitations. First, our study is limited to the work-related network of intra-organizational ties in one organization. Thus, our empirical tests are limited to the informal work relations that emerged in that organization. Although prior research has highlighted similarities between task relationships and more personal relationships, such as friendship (Krackhardt, 1992), it is left for future research to verify the extent to which the broader mechanisms captured in our study apply to different types of ties. We are aware that knowledge access and exchange are not the only reason for individuals' networking. We propose knowledge acquisition as a contingency mechanism, among possible others, for how individuals decide on a set of structurally different ties—i.e., embedded, strong, and brokering ties, where these ties bring opportunities for, as well as constraints to change may not be necessarily knowledge related.

Second, while we attempted to capture the role of individual agency in introducing network modifications together with relational and structural variables, the role of individual personality is back-boxed in our study. Yet, we know that personality plays a fundamental role in explaining why individuals occupy specific network positions and how they benefit from those positions (Fang et al., 2015; Mehra et al., 2001). As most psychological traits are considered to be relatively stable over time, we controlled for unobserved individual heterogeneity with the application of ego- and alter-level random effects. Nevertheless, an important extension of our study could be to explicitly integrate our theorizing with specific psychological variables.

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Table 1. Descriptive statistics and pairwise correlations for the tie-formation sample

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1) Tie formation	1															
2) Embeddedness of non-existent tie	0.18	1														
3) Knowledge acquisition (R)	-0.04	-0.06	1													
4) Network size	0.04	0.17	-0.15	1												
5) Number of ties terminated	0.01	0.18	-0.06	0.37	1											
6) Education	0.04	0.12	-0.06	0.31	0.30	1										
7) Tenure	-0.02	0.02	0.34	0.07	0.08	-0.24	1									
8) Leadership	-0.02	-0.09	-0.02	-0.34	-0.23	-0.43	-0.12	1								
9) Gender	-0.01	-0.01	-0.18	-0.01	-0.04	-0.01	-0.15	-0.06	1							
10) Ego moved office	0.01	0.11	0.01	0.22	0.38	0.21	-0.18	-0.01	-0.05	1						
11) Alter moved office	0.02	0.06	-0.01	-0.01	-0.02	-0.01	0.01	0.01	-0.01	-0.03	1					
12) Physical distance	-0.06	-0.04	0.02	0.01	0.03	-0.01	0.01	0.01	-0.01	-0.01	-0.04	1				
13) Alter’s brokerage with ego	-0.02	0.02	0.01	-0.06	-0.05	-0.03	-0.01	0.03	-0.01	-0.03	0.01	0.02	1			
14) Difference in knowledge acquisition	-0.02	-0.01	0.31	-0.09	-0.04	-0.04	0.21	-0.01	-0.11	0.01	-0.01	0.02	0.20	1		
15) Same action	0.37	0.06	-0.02	0.01	0.01	0.02	-0.01	0.01	0.01	0.01	0.01	-0.02	0.01	0.01	1	
16) Ties with new entrants	0.07	-0.01	0.04	0.01	-0.13	0.13	-0.11	-0.06	0.05	-0.21	0.01	0.01	0.01	0.02	0.04	1
Mean	0.03	0.04	2.62	9.67	4.79	0.47	8.30	0.86	0.60	0.78	0.82	10.0	0.59	-0.01	0.004	0.57
Std. dev.	0.16	0.06	1.24	4.27	3.01	0.50	6.83	0.37	0.49	0.42	0.39	3.3	0.24	1.54	0.06	0.71
Min. values	0	0	1	1	0	0	0	0	0	0	0	0	-0.10	-6	0	0
Max. values	1	0.5	7	18	13	1	29	1	1	1	1	65.5	0.85	6	1	2

N = 4,880; values before standardization of the variables; coefficients above |0.03| have p-values < 0.05 and coefficients above |0.04| have p-values < 0.01.

Table 2. Descriptive statistics and pairwise correlations for the tie-termination sample

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1) Tie termination	1																			
2) Embeddedness of existing tie	-0.11	1																		
3) Tie Strength	-0.19	0.26	1																	
4) Alter's brokerage with ego	0.19	-0.21	-0.32	1																
5) Knowledge acquisition (R)	0.14	0.12	-0.12	-0.01	1															
6) Network size	-0.01	0.19	-0.09	0.09	0.10	1														
7) Number of ties created	-0.13	-0.07	-0.13	0.15	-0.04	0.24	1													
8) Education	-0.06	0.13	0.01	0.01	0.02	0.38	0.19	1												
9) Tenure	-0.04	0.09	-0.02	0.07	0.31	-0.01	0.01	-0.16	1											
10) Leadership	0.08	0.17	0.09	0.07	0.06	0.28	0.27	0.46	0.15	1										
11) Gender	-0.08	-0.15	0.03	0.06	-0.14	-0.02	0.12	-0.04	-0.11	0.01	1									
12) Ego moved office	0.17	0.11	0.01	-0.01	0.03	0.22	0.06	0.12	-0.25	-0.06	0.03	1								
13) Alter moved office	-0.01	-0.01	-0.04	0.11	-0.05	0.15	0.14	0.11	-0.01	-0.05	0.01	0.17	1							
14) Tie duration	-0.03	0.13	0.04	0.04	0.29	0.17	0.04	-0.09	0.36	0.15	0.05	-0.01	-0.04	1						
15) Tacitness	0.02	-0.06	0.25	0.10	-0.03	0.04	-0.05	0.14	-0.04	-0.02	0.13	-0.07	0.02	0.09	1					
16) Face-to-face	0.06	-0.11	-0.13	0.14	-0.01	0.03	0.09	-0.10	0.01	-0.04	0.08	-0.02	0.07	0.15	0.24	1				
17) Physical distance	0.14	-0.21	-0.29	0.19	-0.06	0.04	0.12	0.12	-0.10	-0.01	0.13	-0.06	0.03	0.01	0.11	0.15	1			
18) Difference in knowledge acquisition	0.05	0.03	0.02	-0.01	0.37	0.07	-0.07	0.07	0.22	0.02	-0.24	0.05	0.05	0.04	0.04	0.01	-0.07	1		
19) Same action	0.21	0.15	0.10	0.02	0.02	0.03	-0.01	0.05	-0.02	-0.13	0.08	0.10	0.04	0.01	0.06	0.01	-0.03	-0.06	1	
20) Ties with new entrants	-0.16	-0.09	-0.14	-0.03	-0.06	0.02	0.24	0.17	0.09	-0.06	0.10	-0.39	-0.05	0.05	-0.06	-0.01	0.08	-0.01	-0.03	1
Mean	0.71	2.62	0	0.58	2.60	11.7	2.82	0.52	8.69	0.81	0.63	0.82	0.90	4.19	4.83	3.40	11.1	0.23	0.10	0.56
Std. dev.	0.45	1.55	0.85	0.17	1.07	3.1	2.13	0.50	6.46	0.39	0.48	0.38	0.30	1.36	1.50	1.00	18.4	1.22	0.30	0.64
Min. values	0	0	-1.3	-0.1	1	3	0	0	0.3	0	0	0	0	0	0	0	0	-4.5	0	0
Max. values	1	6	1.61	0.85	6	18	8	1	29	1	1	1	1	6	7	6	65.5	3.5	1	2

N = 333; values before standardization of the variables; coefficients above |0.10| have p-values < 0.05 and coefficients above |0.14| have p-values < 0.01.

Table 3. Logistic regression analysis for tie formation

	Random effects Model 1		Base model Model 2		Main effects Model 3		Interaction effects Model 4	
Embeddedness of non-existent tie					0.02	(0.001)	0.02	(0.001)
Knowledge acquisition (R)					-0.01	(0.12)	-0.01	(0.09)
Embeddedness of non-existent tie * knowledge acquisition							-0.01	(0.18)
Network size			0.01	(0.02)	0.01	(0.03)	0.01	(0.04)
Number of ties terminated			-0.01	(0.04)	-0.01	(0.02)	-0.01	(0.02)
Education			0.01	(0.79)	0.01	(0.93)	0.01	(0.87)
Tenure			-0.01	(0.49)	-0.01	(0.59)	-0.01	(0.59)
Leadership			-0.01	(0.58)	-0.01	(0.60)	-0.01	(0.57)
Gender			-0.01	(0.26)	-0.01	(0.14)	-0.01	(0.14)
Ego moved office			-0.01	(0.72)	-0.01	(0.98)	-0.01	(0.99)
Alter moved office			0.01	(0.20)	0.01	(0.49)	0.01	(0.48)
Physical distance			-0.01	(0.001)	-0.01	(0.001)	-0.01	(0.001)
Alter’s brokerage with ego			-0.01	(0.07)	-0.01	(0.12)	-0.01	(0.12)
Ego-alter difference in knowledge acquisition			0.01	(0.95)	0.01	(0.51)	0.01	(0.49)
Same action			0.96	(0.001)	0.95	(0.001)	0.95	(0.001)
Number of ties with new entrants			0.01	(0.008)	0.01	(0.002)	0.01	(0.003)
Intercept	0.03	(0.002)	0.02	(0.004)	0.02	(0.001)	0.02	(0.001)
Random effect – ego level	0.01	z=0.001	0.01	z=0.001	0.01	z=0.03	0.01	z=0.03
Random effect – alter level	0.01	z=0.01	0.01	z=0.01	0.01	z=0.03	0.01	z=0.04
-2 log Likelihood	-4177.6		-4840.3		-5090.4		-5107.0	
AIC	-4169.6		-4805.6		-5061.5		-5067.0	
McFadden’s R-squared	n.a.		0.16		0.22		0.23	

N = 4880; *p*-values in parentheses; values after standardization of the variables.

Table 4. Logistic regression analysis for tie termination

	Random effects Model 5		Base model Model 6		Main effects Model 7		Interaction effects Model 8	
Embeddedness of existing tie					-0.04	(0.11)	-0.05	(0.06)
Tie strength					-0.11	(0.001)	-0.10	(0.003)
Alter's brokerage with ego					0.04	(0.12)	0.03	(0.19)
Knowledge acquisition (R)					0.06	(0.13)	0.06	(0.15)
Embeddedness of existing tie * knowledge acquisition							0.04	(0.04)
Tie strength * knowledge acquisition							0.07	(0.01)
Alter's brokerage with ego * knowledge acquisition							0.04	(0.03)
Network size			0.01	(0.92)	-0.01	(0.97)	0.01	(0.97)
Number of ties created			-0.09	(0.01)	-0.11	(0.002)	-0.11	(0.002)
Education			-0.09	(0.03)	-0.10	(0.02)	-0.09	(0.03)
Tenure			-0.02	(0.68)	-0.05	(0.18)	-0.04	(0.34)
Leadership			-0.11	(0.009)	-0.12	(0.001)	-0.12	(0.001)
Gender			-0.06	(0.09)	-0.05	(0.12)	-0.05	(0.12)
Ego moved office			0.10	(0.01)	0.10	(0.008)	0.10	(0.006)
Alter moved office			0.01	(0.97)	-0.01	(0.80)	-0.01	(0.74)
Tie duration			-0.01	(0.78)	0.01	(0.93)	-0.01	(0.77)
Tacitness			0.01	(0.97)	0.03	(0.21)	0.03	(0.18)
Face-to-face			0.02	(0.44)	-0.01	(0.80)	0.01	(0.82)
Physical distance			0.09	(0.006)	0.04	(0.11)	0.04	(0.14)
Difference in knowledge acquisition			-0.01	(0.97)	-0.01	(0.71)	-0.01	(0.72)
Same action			0.27	(0.003)	0.30	(0.001)	0.28	(0.001)
Number of ties with new entrants			-0.01	(0.89)	-0.01	(0.82)	-0.01	(0.80)
Intercept	0.72	(0.001)	0.68	(0.001)	0.68	(0.001)	0.69	(0.001)
Random effect – ego level	0.06	z=0.002	0.03	z=0.002	0.02	z=0.004	0.02	z=0.004
Random effect – alter level	0.01	z=0.03	0.01	z=0.04	0.01	z=0.04	0.01	z=0.05
-2 log Likelihood	373.6		330.0		300.8		290.5	
AIC	381.6		368.0		346.8		342.5	
McFadden's R-squared	n.a.		0.10		0.19		0.22	

N = 333; *p*-values in parentheses; values after standardization of the variables.

Table 5. Simple slopes test for Hypothesis 2

Gradient	0.04	-0.02	-0.07	-0.12	-0.16
T-value	0.327	-0.244	-2.844	-3.183	-2.834
P-value	0.781	0.631	0.005	0.002	0.007
Knowledge acquisition	-2 SD	-1 SD	Mean	+1 SD	+2 SD

Table 6. Simple slopes test for Hypothesis 3

Gradient	0.04	-0.02	-0.08	-0.14	-0.20
T-value	0.368	-0.293	-2.419	-4.193	-2.029
P-value	0.713	0.77	0.016	0.001	0.027
Knowledge acquisition	-2 SD	-1 SD	Mean	+1 SD	+2 SD

Table 7. Simple slopes test for Hypothesis 4

Gradient	0.13	0.09	0.05	0.01	-0.03
T-value	2.293	2.207	2.006	0.281	-0.404
P-value	0.037	0.033	0.046	0.779	0.686
Knowledge acquisition	-2 SD	-1 SD	Mean	+1 SD	+2 SD