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Distances in Organizations: Innovation in an R&D Lab

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Abstract: *Distance between actors in an organization affects how they interact with each other, and particularly if they will exchange (innovative) knowledge with each other. Actors in each other's proximity have fewer conflicts, more trust towards each other, for example, and are thus more involved in knowledge transfer. Actors close to others thus are believed to perform better, for instance by being more innovative. This theory of propinquity's claim resonates widely in the literature and has intuitive appeal: "people are most likely to be attracted towards those in closest contact with them" (Newcomb 1956, p.575). Knowledge a focal actor receives from alters who are close is more readily accessed, better understood and more readily useable. At the same time, however, and in contrast to the what the theory of propinquity suggests, knowledge a focal actor receives from alters who are at a larger distance may be more diverse, offer unexpected and valuable insights, and therefore give rise to innovation. In order to understand these opposing expectations, scholars have indicated that distance must be conceived of as multifaceted – individuals can be close to each other in one way, while at the same time distant in another. No prior paper has extensively studied the effects of distance as a multifaceted concept, however. This study offers two distinct contributions. It argues, first, why some instances of distance affect the opportunity to interact with alters, potentially lowering an actor's performance, while other instances of distance affect the expected benefits from interaction. The latter would increase an actor's performance. This paper, secondly, is the first study to empirically test the expectations about how seven different measures for distance impact an actor's innovative performance. Innovative performance is measured as both creative contribution, as well as contribution to knowledge that has immediate commercial use (patents). In the setting of a large research lab, we find, contrary to expectations, that distance does not hurt individual innovative performance and sometimes helps it in unexpected ways.*

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Distance between actors in an organization is believed to affect if they will interact with each other to exchange knowledge (Akerlof 1997). Interaction and knowledge exchange are firmly expected in the literature to stimulate individual performance and innovativeness. The theory of propinquity, as suggested by Newcomb (1956, p.575), states clearly that "people are most likely to be attracted towards those in closest contact with them." In particular the extent to which actors are likely to exchange and build relations decreases as distance between them increases (Akerlof 1997). If knowledge is received from 'distant' others it is not likely to be readily accessed, understood and used (Dolfsma et al. 2011). Because of distance between individuals, there may not be interaction or exchange of knowledge and what knowledge is exchanged can be more easily misunderstood. Since innovation comes from combination of different pieces of knowledge, individuals are thus less likely to be innovative if the distance between them and others increases. Beyond the effect of distance between individuals on their innovativeness, Monge et al. (1985) stress that "a variety of organizational outcomes" are affected by distance between individuals.

This premise is a key one in particular in a line of research that focuses on the functioning of global or virtual teams, a key topic in today's globalizing and competitive business environment (Cummings 2004; Hinds & Mortensen 2005; Martins et al. 2004; Maznevski & Chudoba 2000; O'Leary & Cummings 2007; Olson & Olson 2000). The idea in this line of research is that 'out of sight, means out of sync' (Hinds & Bailey 2003).

Distance, however, is not a singular term, but can have multiple dimensions, instantiations, or facets. Most ways in which distance has been conceived and its consequences theorized, however, assume that distance hampers knowledge exchange and so negatively impacts individual innovativeness and performance. Knowledge received from alters in one's proximity might be too similar to what knowledge one has already, while knowledge received from alters who are more distant is more different and might lead to more actually new knowledge arising. Some suggest that the effect of distance on knowledge transfer and innovativeness can be beneficial (Gilsing et al. 2008; Wuyts et al. 2005). When and why this would be so remains unclear, however.

We make two key contributions in this paper. The first is conceptual. In addition to categorizing different instantiations of distance, we argue why some instances of distance affect the opportunity to interact with alters, potentially lowering an actor's performance, while other instances of distance affect the expected benefits of interaction. The latter would increase an actor's performance. Increased expected benefits from an individual exchanging knowledge with alters at a distance would materialize as increases in individual innovativeness, while increasing distance between an individual and their alters decreases the opportunities to interact and decrease innovativeness. Personal affiliation distance among individuals may be close, indicating that the opportunity for knowledge exchange is high. Spatial distance between individuals may be large, lowering the opportunity for exchange (Alba & Kadushin 1976). Individuals exchanging over larger distances may be able to access knowledge unavailable in their immediate environment, thus possibly providing insights that help their innovative performance. This paper, secondly, is the first study to empirically test the expectations about how seven different instantiations of distance impact an actor's innovative performance. We find, contrary to expectations, that distance does not hurt individual innovative performance and sometimes helps it in unexpected ways as in the case of hierarchical distance. Deconstructing the notion of 'distance', and recognizing that some kinds of distance mostly affect the opportunity for exchange, while others mostly affect the expected benefits of exchange, allows us to show that (1) some forms of distance stimulate innovation in an organization and other measures do not, (2) some measures of distance contribute to one kind of proxy for innovation and not to another, and thus (3) how distance is conceptualized and measured is not a mere methodological concern. We investigate these contentions for knowledge transfer between laboratory scientists, using their innovative performance measure comprehensively as both creative contribution performance, as well as contribution to knowledge that has immediate commercial use (patents).

1. Theory: Distances in Organizations

Despite being little conceptualized (cf. Wilson et al. 2008; Lechner 1991), distance between individual has been acknowledged to have "considerable influence on a variety of organizational outcomes" (Monge et al. 1985). The impact is mostly believed to be negative: distance decreases trust between inviduals, increases the likelihood and effects of conflicts, and will make people in an organization interact less frequently (Hinds & Bailey 2003; Hinds & Kiesler 1995; Monge & Kirsten 1980; Monge et al. 1985). The performance of individuals distanced to other individuals and of an organization where individual employees are at a distance to othes suffers. In more

recent years the focus for this line of research has moved to the study of global, or virtual teams, but the suggested effects remain (Maznevski 2000; O'Leary & Cummings 2007; Cummings 2004; Martins et al. 2004). In these studies, we submit, different instantiations or dimensions of ' distance' are conflated, giving rise to results that are not readily interpretable from an academic nor from a managerial point of view. Although there is some acknowledgement that different dimensions to distance may need to be recognized, each of which will impact communication in general, and knowledge transfer in particular (Boschma 2005; Danson 2000; Napier & Ferris 1993), affecting a large number of organizational performance outcomes (Monge et al. 1985), in empirical studies 'distance' has mostly been analyzed for one dimension only: spatial distance (Monge *et al*. 1985; Singh 2005; Saxenian 1994; Rogers & Larson 1984).

Some studies focus on cognitive distance (Gilsing *et al*. 2008; Nooteboom 1992, 2000), as it is clear that even those who are co-located may not readily understand each other if individuals for instance have different cognitive backgrounds. Studies focusing on cognitive distance suggest that cognitive distance can be beneficial: if two parties have too much knowledge in common, they cannot learn from each other. Some others have focused on social distance (Agrawal *et al*. 2008), as communication using electronic means have grown more common and spatial distance can be overcome using different technical means. In line with this, even being in one and the same team or social community may not mean that individuals actually interact and exchange knowledge. Some thus focused on network distance between individuals (Alba & Kadushin 1976; Reagans & McEvily 2003). In part, an absence of exchange between any two individuals may be due to a hierarchical distance between them as well, as individuals may not exchange with others beyond a faultline provided by differences in hierarchy, for instance (Bezrukova et al. 2009). Exchange of knowledge may be reduced if potential exchange partners are in a supervisor-subordinate relation (cf. Aalbers et al. 2015).

Each of these instantiations of distance is more or less established in the relevant literatures, even though the literatures are somewhat disconnected so far. Few empirical studies, however, have included multiple measures for distance, with the exception of macro or inter-firm studies in the domain of economic geography (Agrawal *et al*. 2008; Breschi and Lissoni 2009). Few studies have conceptualized why some forms of distance might be beneficial, and others might be detrimental to knowledge exchange.

We submit that distance between exchanging parties can impact the opportunity for knowledge exchange between distanced individuals on the one hand, and the expected benefit from

knowledge exchange between distanced individuals on the other hand. If there is no opportunity for knowledge exchange none may occur, if there is no expected benefit of knowledge exchange none will be initiated. Acknowledging that distance might have multiple instantiations suggests that, while cognitive distant can offer larger expected benefits, in other respect the distance between cognitively distant individuals might be large as well. A study that does not conceptually acknowledge and methodologically include this possibility might attribute findings for the one distance measure included that are in actual fact caused by other distance measures. Reduced opportunities for exchange might be compensated for by increased expected benefits of knowledge exchange over a distance. Not recognizing the different instantiations of the concept of distance might leave these dynamics unnoticed.

A. Opportunity for Knowledge Exchange

Distance can, first of all, fail to provide an opportunity for exchange.

Actors may be separated by ***spatial distance***, and classically this is shown to prevent them from interacting and exchanging (Boschma 2005; Danson 2000). In a classical study of communication and transfer of knowledge in a laboratory, Allen (1977) found that even relatively limited geographical distance between actors can hamper exchange. Individuals simply may not meet to learn about each other's projects and knowledge needs.

Distance may have a relational dimension (Amin & Cohendet 2004; Danson 2000; Boschma 2005), and be felt by the focal actor or attributed to the relation of the focal actor with an alter (Wilson *et al*. 2008). Kogut and Zander (1992) pointed out that, with regard to the innovation development process and since the formation of new cooperative relationships is a laborious process, existing social relationships are usually employed in the innovation development process. Knowledge exchange is facilitated by a personal relationship between people, as exchange of especially tacit knowledge is believed to benefit from intrinsic motivation, trust and relationship specific learning effects (Ingram & Robert, 2000; Moran & Ghosal, 1996; Nahapiet & Ghosal, 1998; Tsai & Ghosal, 1998; Osterloh & Frey, 2000; Powell et al., 1996, Starpoli, 1998). Alternatively, then, a personal distance felt between individuals in an organization can prevent knowledge transfer from occurring. Person-related distance can give rise to faultlines in an organization (Bezrukova *et al*. 2009). A number of individual factors relating to someone's personality traits and personal history have been suggested to affect what may be called the ***personal distance*** experienced between actors communicating (Monge *et al*. 1985; Wilson *et al*. 2008). Age and gender are among these (Bezrukova et al. 2009). Value orientations have been mentioned as a factor to determine personal distance between individuals as well.

Larger personal distance between the focal actor and her alters will, ceteris paribus, negatively impact their exchange of knowledge and thus their innovative performance.

What Danson (2000) calls organizational distance can also prevent exchange. Organizational distance can have two dimensions: distance created by (1) unit boundaries, and distances due to (2) hierarchy. Units boundaries in an organization can create hurdles for knowledge exchange, even when individuals are co-located (Gulati & Puranam 2009). By creating ***organizational unit boundaries*** (distance), communication within the unit is enhanced but communication between units, crossing unit boundaries, is made more difficult. Knowledge transfer and communication across boundaries "can be characterized by false starts, different interpretations and disruptions" (Reagans & McEvily 2003, p.247) as organizational boundaries can be actively maintained or even policed (Llewellyn 1994; Zuckerman 1999), just like boundaries for sciences (Gieryn 1999), genres in art (DiMaggio 1987, 1997; Hsu 2005), markets (Ruef & Patterson 2009), and ethnic groups (Barth 1969). Identities, status, and what knowledge is taken for granted depend on boundaries (DiMaggio 1997; Douglas 1966; Hsu & Hannan 2005; White 1992; Zuckerman 1999). The division of labor that results from establishing unit boundaries allows for specialization, largely attributable to the enhanced exchange of knowledge *within* each unit (Hansen 1999; Uzzi 1997). Ties that cross unit boundaries are more difficult to establish or maintain (Aalbers *et al*. 2015; Macdonalds & Williams, 1993a,b). Knowledge that crosses unit boundaries, and the messenger that has brought it, may actually be regarded with suspicion (Dolfsma et al. 2011; Hsu 2006). An individual who acts as a boundary spanner or gatekeeper, as a conduit for knowledge to transfer into an organizational unit, may thus help the organization yet be in a precarious position at the same time.

Another measure for organizational distance would be the distance between individuals, possibly within the same unit, who differ in hierarchical rank: ***organizational hierarchical distance*** (Napier & Ferris 1993). Faultline theory (Bezrukova et al. 2009) suggest that interactions and exchange between individuals might be affected by the hierarchical distance, often perceived as a faultline, between them. Levels of trust are lower between individuals from across faultlines creating this organizational distance (Li & Hambrick 2005; Postuma & Campion 2009). Individuals are said to be more likely to communicate, exchange knowledge and ultimately perform well in their organization if no or little hierarchical distance that constitute a faultline exists between them (Borgatti & Cross 2003; Jung et al. 2003; Napier & Ferris 1993; Wilson *et al*. 2008). Even when knowledge crosses a faultline, arguments or facts are weighed differently if received from across a faultline (van Knippenberg & Schippers 2007), and the amount of knowledge moving between individuals decreases (Stevenson *et al.* 1985).

People may not be co-located, may not be formally working in the same unit, or may not be of the same rank in the organization, and yet communicate with each other as they have established network contacts with each other (Aalbers et al. 2014; Amin & Cohendet 2004), reaching beyond what Reagans & McEvily (2003, p.247) call "institutional, organizational or social boundaries". Thus reducing one's distance to others one may usefully communicate and exchange knowledge with, which is likely to result in interaction with a 'different body of knowledge' (Reagans & McEvily 2003, p. 247). In such communications, people can perceive proximity yet be at a large distance in other respects, providing opportunities for knowledge transfer. Wilson *et al*. (2008) refer to the possibility of two individuals being located far from each other yet feeling close as the paradox of 'far-but-close'. This can lead to the exchange of knowledge relevant for innovation (Wilson *et al*. 2008). With some, even if distant in other respects, a focal actor may be in direct contact and can exchange knowledge with directly: direct ***network distance*** is low when a focal actor is in immediate close contact, with a diversity of others in an organization, quick to access relevant knowledge from different sources. The knowledge acquired when this direct network distance is low will help the focal actor to be more innovative (Aalbers et al. 2013, 2014; Breschi & Lissoni 2009; Burt, 2004; Hansen 1999; Sparrowe et al. 2001). A focal actor that is thus closely connected to many others thus has better opportunities to exchange, and will see her innovative performance enhanced (Borgatti & Cross 2003; Oh *et al*. 2006; Reagans & Zuckerman 2001, 2003). Along similar lines of argumentation, a focal actor may be able to tap into knowledge in an organization, accessing what is relevant for her innovative efforts, indirectly. By leveraging her direct contacts, a focal actor can access knowledge possessed by third parties, at a somewhat larger network distance, which was argued and found to benefit her innovative performance (Aalbers et al. 2015; Burt 1992; Ingram & Roberts 2000). An even more diverse knowledge base can then be drawn on, from a larger subset of an organization's members, and one is thus able to have a better sense of what existing knowledge finds support within the organization, or what new knowledge a focal actor might offer would find such support. Also, a focal actor can cast a wider net seeking to obtain knowledge to complement her own if she can access a larger number of alters indirectly, being closer to them. Even though an actor is dependent on her direct contacts to provide her with indirect knowledge that these may access, the focal actor can try to actively obtain such knowledge.[3]

[3] Burt (1992, 2004) focuses on the network as a whole, pointing to the favorable position of bridges connected separated groups. While these bridges can benefit from their position, or even exploit it for their own benefit, in the argument Burt presents, such positions are given rather than actively created by a focal actor.

Distance affects the opportunities that exist for an individual to exchange knowledge with others in the organization. We have distinguished six (6) different instantiations of distance that affect opportunities for knowledge transfer:

a. Spatial distance;
b. Personal distance;
c. Organizational unit boundary distance;
d. Hierarchical distance;
e. Network distance, direct;
f. Network distance, indirect.

In the above we have argued that as distance between a focal actor and alters increases in such a way that the opportunities for knowledge exchange are reduced in any of these six different ways, the focal actor's innovative performance is likely to decrease. We thus propose:

Proposition 1: Increased distance from a focal actor to others that reduces the opportunities for knowledge exchange decreases the actor's innovative performance.

B. Expected Benefit from Knowledge Exchange

Some have not just claimed that distance between individuals hampers exchange, but have actually defined distance as that which hampers exchange between agents (Danson 2000, p.174). Accordingly, communication between actors in an organizational setting may be impeded due to differences in the education enjoyed, and the skills or experience accumulated (Borgatti & Cross 2003; Dougherty 1992; Reagans & McEvily 2003). What is tacit knowledge for some, taken for granted background knowledge that facilitates the exchange of innovative knowledge, may not be equally tacit for others, perhaps making exchange of knowledge more difficult (Cramton & Hinds, 2005).

Others, however, expect and have found favorable performance outcomes when collaborating individuals cognitively are *not* in close proximity. ***Cognitive distance*** between a focal actor and her alters can, indeed, make sure that what is exchanged actually is more likely to be a valuable contribution to the knowledge that a focal actor already possesses, increasing the likelihood that the focal actor is innovative. A wider variety of knowledge sources is drawn on (Aalbers et al. 2015; Burt 1992**;** Ingram & Roberts 2000; Reagans and McEvily 2003; Woodman

et al. 1993), leading to a more judicial weighing of what knowledge is used even when the distant knowledge one has acquired is not actually used (Cramton & Hinds 2005; Williams & O'Reilly 1998), enhancing individual performance (Allen 1977). Exchanging knowledge with such alters will help a focal actor to understand and develop her own knowledge is such a way that it aligns better with knowledge developed by others in the organization. Focal actors who exchange with others at a larger cognitive distance to them see the use of the knowledge they themselves develop in a larger context. Exchange with an alter at a cognitive distance, in other words, helps to become more innovative (Burt 2004; Reagans & Zuckerman 2001; Rodan & Galunic 2004; Sparrowe et al. 2001). Knowledge exchanged with an alter who is closer is more likely to be similar to that of the focal actor, adding less to what the focal actor already knows (Gilsing et al. 2008; Wuyts et al. 2005).

Proposition 2: Increased distance from a focal actor to others that reduces the expected benefits of knowledge exchange increase the actor's innovative performance.

2. Data and Method

Research Site. The data was collected at a Research and Development (R&D) lab of a Dutch multinational chemical company with offices and production facilities in 49 countries around the world (cf. Siggelkow 2007). This study thus is a case study, with known advantages and disadvantages associated to this kind of research. Given the exploratory nature of studying the effects of multiple instantiations of organizational distance, this seem warranted. A number of distance variables for individual employees from different organizations, even if they can be determined, do not make sense. Social network data for different organizations cannot meaningfully be aggregated. While a cross-sectional empirical research design would in other circumstances increase representativeness, focusing here on a single organization is unavoidable. Representativeness must be established by repeating the study for other, preferably dissimilar organizations to determine what effect organization or organizational field specific circumstances have.

The company, which has annual sales of over €8 billion, operates across a broad spectrum of business activities including nutritional and pharmaceutical ingredients, performance materials and industrial chemicals. The company is structured into a number of clusters which are further subdivided into fairly autonomous operating business groups responsible for product development, manufacturing and sales. In the recent past, the company shifted away from

offering bulk products towards offering specialty and higher value added products. This shift resulted in an even stronger focus on technology and innovation making research an integral part of the company's strategy. The company commits a substantial percentage of its resources to R&D and undertakes numerous initiatives to stimulate and improve innovativeness.

Management agreed to the use of a network questionnaire, tailored for the specific setting, and administer it to a total of 195 lab researchers and lab managers. The target population represented all researchers (lab assistants e.g. were excluded) and project managers employed by the two participating R&D labs. The decision to include all research and project managers in the study meant that our survey would achieve a complete view of the network of individuals involved in knowledge development and diffusion. An electronic survey was distributed to this population of R&D lab researchers or engineers. Within network analysis, one-site, socio-centric research approaches are the standard, since this type of research design allows for the identification of a clear network boundary (e.g. Krackhardt 1990).

The survey was distributed to the target population through intra-company mail from the office of the R&D managers. The decision to send the survey via internal organization mail rather than from a university address served a two purposes: signaling the company's support and avoiding possible technical problems. After three weeks, approximately fifty-five percent of the R&D network surveys were returned. We then sent out a personalized reminder in case of non-response and subsequently personally approached remaining non-respondents. Our study thus achieved a 97 percent survey response rate for the target population in three rounds and one month of surveying - a high response rate that social network analysis requires (Scott 1991; Wasserman & Faust 1994).

Measures. Data was gathered using a standard survey method incorporating a name generator question (dyadic level data), and questions to characterize both a relationship and an individual (e.g. Marsden 1990, 2004). In answering the name generator question ('Over the past 6 months are there any work related contacts from whom you regularly sought (research related) information and advice to enhance your effectiveness as a researcher?' [Your most valued work contacts]), each respondent was asked to list his or her key contacts, offering 14 spaces, with the possibility for respondents to add more contacts. We did not require that a contact corroborate a tie. Rather than use self-reported contact, to calculate the network variables (below) and draw the network figure, we use an in-degree approach. Using in-degree measures of how often a focal actor is mentioned as a contact, is more reliable (Sparrowe et al. 2001; Tsai 2001; Wasserman & Faust 1994). To obtain a better understanding of what the relevant network in this organization looks like, Figure 1 offers a visual representation of the structure of the network of contacts in the

research laboratories.[4] The connected lab scientists shared 1111 relationships. Six individuals turned out to be isolates. The variables are described below and a correlation table it provided in the Appendix.

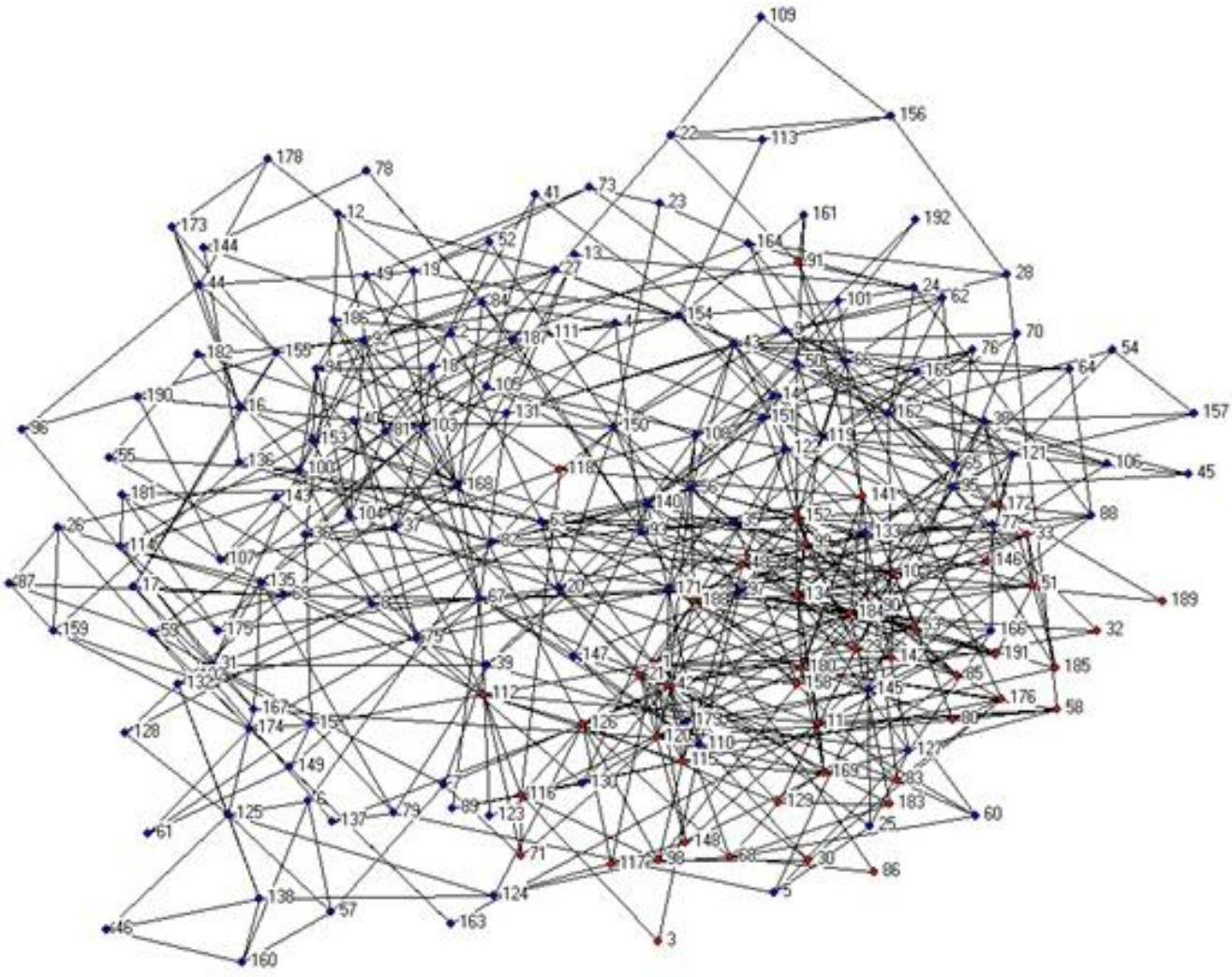

Figure 1: Frequent Relations in Research Laboratory

Dependent variable. As suggested by Rodan and Galunic (2004) individual innovation performance was measured by means of a performance item which asked managers, drawing from company records, to carefully rate the researcher's creativity over the last 6. [To what extent is this person particularly creative: someone to come up with novel and useful ideas, using a 1-5

[4] Figure 1 only includes the 798 frequent (daily and weekly) interactions; using Multi-Dimensional Scaling techniques nodes that were 'more similar' -listing one another and sharing the same alters- are positioned closer together.

scale, from weak to outstanding]. The use of this *Idea Performance* measure to ascertain innovativeness followed the notion that measurement of innovativeness at the individual level, as pointed out by literature, oftentimes requires supervisor (or peer) assessment (Amabile 1996; Moran 2005; Avery and Murphy 1998). In line with previous research the assessment asked managers to assess behaviors rather than attitudes, for a specific period (cf. Tsui 1984). Interviews with senior managers in the organization suggested that line management would be most appropriate for ascertaining a researcher's individual innovation performance, given their direct involvement with and formal responsibility to rate these researchers. As the the table with descriptive statistics in the Appendix shows, subjective innovation performance varied considerably across the 195 person lab. This indicates that managers can and do differentiate between the innovative contribution that individual lab scientists make. The extent to which the supervisor's evaluation is subject to social pressures or the inclination to avoid conflict, for instance, can thus be perceived as limited. The judgment, taken from company records, is not merely 'subjective'.

More objective, perhaps, is *Patent Performance.* In order to complement our individual level data we sought an alternative way of measuring individual innovativeness. Patents are granted for knowledge that is thought to have industrial or commercial application (Griliches 1990). The application needs to be spelled out in some detail in the patent application. The number of patents per researcher was used as an admittedly less than perfect proxy for innovative output. This approach is consistent with the existing practice to measure via patents, in an indirect way, both the technological competence of a firm (Narin *et al*. 1987) as well as productivity for individual researchers (Bertin & Wyatt1988). The number of patents a scientists has been granted can have a significant impact on his career (Dietz et al. 2000), yet patenting is motivated quite differently in different scientific domains with immediate financial incentives playing a minor role (Sauermann *et al.* 2010). Since the number of patents applied for is cumulative over time, controlling for tenure is warranted.

Alternatively using two performance outcome measures as dependent variables offers the opportunity to determine how robust the finding for each is. The more subjective innovation measure of idea performance is statistically unrelated to the more objective innovation measure of patent performance as the correlation table in the Appendix shows.

Distance variables. At the very least what can be indicated is that distance lacks a uniform meaning and has been conceptualized or used to signify different things: geographical, cognitive, organizational (unit boundaries, hierarchy), network, and personal distance. Based on network

data of who exchanges innovative knowledge with whom, we determine how different forms of distance contribute to an individual's innovativeness in subjective (evaluation by supervisor) as well as in objective (patent applications) terms.

The boundary of departments may create opportunities for joint production within a department or unit, but may also make cooperation across Business Unit boundaries more difficulty, for instance from a formal point of view. Membership of a Business Unit is a measure for organizational distance separate from other measures. In a way, thus, *Business Unit* can be conceived of as a measure of organizational distance. At the same time, however, this measure cannot be changed by the, possibly joint, actions of communicating individuals. For this reason we decided to include this measure for distance, as a dummy variable, in all of the models we estimate, rather than alternating this measure for distance as we do for the other measures of distance to obtain regression results. This way, the Business Unit variable in actual fact is a control variable. The laboratory studied has two Business Units. Based on company records, respondents could each be traced to their respective Business Unit (0 = Business Unit A; 1 = Business Unit B). Since this variable is a dummy variable, and since its effect might interfere with that of other variables for distance too, we have included it in 6 model specifications in Table 1, as if a quasi control variable.

Effects found for a lab scientist's innovativeness might be erroneously attributed to a variable such as centrality or unit membership if in actual fact *geographical distance* between individuals might be the explanation (Monge *et al*. 1985). Given how common facilities for employees are provided, we measure geographical distance as co-location of designated work-spaces on the same floor in the same building.

The hierarchical position of the respondents was included for its potentially explanatory power with regard to performance. Centrality in a network such as the knowledge transfer network can, but need not, be related to ego's formal position in the organization's hierarchy. Data for our *hierarchy* measure of organizational distance was drawn from company personnel records. The data was used as a basis for our measure of hierarchal level [scientist, senior scientist and science manager]. These possible values were converted into a dummy variable [0= scientist, 1 = senior scientist, 2= manager].

In line with Marsden & Campbell (1984) and Burt (1992) respondents were asked to reflect on the personal bond with each of their alters. The *personal distance* variable measures how the focal actor perceives to be personally close to his alters. ["How close is your working relationship with the person in question?" Scale 1-5; 1= very strong, 2= strong, 3= neutral, 4= weak, 5= very weak]. Building on a measure developed by Rodan and Galunic (2004)

respondents were asked to assess the extent to which the knowledge base of the reported alter was similar or dissimilar to their own ["How similar or different is your knowledge from your contact's knowledge?" Scale 1-4; 1= very similar, 2 = similar, 3= different, 4=very different.] The measure for *cognitive distance* taps into the idea that innovation is facilitated by bringing together different, though not too different, knowledge bases (Burt 2004; Pelled et al. 1999; Nooteboom 1992, 1999, 2000). The measure was reverse coded (that is 4 was recoded as 1, etc.) so as to have a value increase reflect increased knowledge similarity.

A distance variables has been calculated from the network data collected along the lines explained above (see Aalbers et al. 2014). A focal actor's position in the network brings it close to others if the tie strength of the connections of the focal actor to a diverse set of other actors, across expertise areas, provides her with direct *network distance* (Burt 1984; Marsden 1987; Reagans & McEvily 2003). In particular we adopt Reagans & McEvily's (2003, p.255) network range indicator that captures the extent to which individual maintains weak ties in a diverse network across multiple (Granovetter 1973). We measure diversity of a focal actor's network contacts by the number of ties that cross department boundaries. The two Business Units included in our study together have 24 departments. Indirect network distance is measured as 2-step reach, the number of alters a focal actor has indirect access to in a network, through her direct contacts.

Controls. Within the 24 departments in which lab scientists colaborate closely, scale effects in research may emerge. Following Tortoriello (2006) *Department Size* was included to control for networking and exchange opportunities due only to the size of the working group of a lab scientists. Scores for the independent variables could be an artifact of working in a larger department. Information about the *Gender* of the respondent, as a demographic attribute with possible explanatory value, was gathered using the survey instrument (dummy variable: female =1, male =0). As Bezrukova *et al*. (2009) indicate, fault lines, such as gender, can impact interactions within a group and performance outcomes for groups. Respondents were asked to report their *Tenure* in the organization (years), as a possible explanation for performance. One may expect differences in the way in which newcomers interact and perform, when compared with those who are already socialized into an organization having established relations over time (Gundry 1993). We decided to use duration of a person's tenure rather than age, since company specific experience and contacts is relevant. In addition, since patent innovativeness may have a cumulative element in it that is firm-specific, tenure is the appropriate control varialbe. This does treat individuals who have had a career prior to joining this firm similar to engineers who may just have graduated, however. Age of the respondent was nevertheless gathered using the survey

instrument (in years). Including Age as a variable in the regressions had no statistical effect, while Tenure does have a statistically significant effect (Table 1). More importantly, however, tenure is known to impact communication patterns (Ahuja & Galvin 2003).

Estimation. The descriptive statistics –provided in the Appendix- do not indicate statistical problems that would require the use of more complex and less straightforwardly interpretable statistical regression methods than OLS. Multicollinearity, statistically, is not an issue – VIF values are well below acceptable levels. Despite this, we have opted to analyze the effects of distance on individual innovative performance separately for conceptual reasons. Since the different distances are sometimes at odds, sometimes complimentary and sometimes overlapping, and since their effects have not been studied in a single study, including different measures for distance in an organization into a single regression would leave the results difficult to interpret (Agrawal *et al.* 2008).

3. Results

We find difference instantiations for distance to have different, and unexpected effects on individual innovativeness in the knowledge intensive context of a research laboratory. Effects can differ between perceived creativity and patent application. The one is more objective, perhaps, and focuses on outcomes. The other can be more subjective and focuses on the process of innovation.

Hypothesis 1 suggests that when distance from the focal actor to others increases such that opportunities for knowledge exchange decrease, individual innovativeness decreases. We have analyzed the effects of 6 such distance related opportunities for knowledge exchange. Since Business Unit membership is a fundamental variable that both captures distance in some sense, but is also a given for employees, we have included this variable in all the models we estimate. Among the control variables Business Unit membership turns out not to have an effect on innovativeness (models 1a, 1b). Organizational distance created by Business Unit boundaries seems either to be irrelevant, or is overcome by lab scientists creating opportunities for exchange by reducing distance in other respects. The last suggestion may have some value in it, given that the beta for Business Unit in model 7b, where indirect network distance is added, is negative and significant (β==0.0164. $p<0.05$). Geographical distance has no effect on individual innovativeness, contrary to what others have found (see models 2a and 2b). Contrary to expectations, hierarchical distance actually stimulates innovativeness, as shown in models 3a and 3b, both of the patent and of the creativity kind, also if the hierarchical distance is large (scientist

vs. science management). Personal distance does not impact innovativeness (models 4a and 4b). Direct network distance (range) actually has a negative effect on patent innovativeness, though not significantly so. Creativity innovativeness is positively affected by network distance, but again not significantly so. The results for indirect network distance – a positive and significant effects on both patent and creativity innovativeness - suggest that contacts to a large number of divers contacts can be maintained through the direct contacts one has.

Despite the fact that we have multiple measurements to indicate the opportunity to exchange knowledge in an organization, we find that the hypothesized effect of these impacting individual innovativeness negatively does not hold. We find that proposition 1 cannot be supported, a finding that contrasts sharply with what is broadly argued in the literature.

Cognitive distance is seen to actually stimulate patent innovativeness in models 5a for the more objective patent measure: the disadvantage of having to translate between cognitive domains is outweighed by the benefit of combining knowledge from different sources. Creativity may be affected negatively (model 5b), but this effect is not statistically significant. We find tentative support for proposition 2.

In addition, we draw attention to the findings for the controls included. Consistently tenure negatively and significantly impacts *creativity* innovativeness. Patent innovativeness is, however, positively impacted by tenure, at least in the base model. Once measures for distance are included, this relation disappears, however. Although we cannot make claims about causality about how tenure impacts an actor's innovativeness, some caution seems to be in place before dismissing the contribution of employees with longer tenure. Their contribution to innovation outcome is not negative, and their contribution to the innovation process might be lost to their immediate supervisor as that contribution may be due to their overall contribution to the dynamics in the network in an organization. Overall network dynamics impacts both firm and individual innovativeness, but can be difficult to grasp by any individual in an organization (Aalbers & Dolfsma 2015). Gender can consistently be seen to negatively impact individual innovativeness, both of the patent and of the creativity kind. Our final control variable, department size, controlling for the effect of scale in an R&D department, negatively impacts creativity and patent innovativeness, but only for the former in a significant way.

4. Discussion and Conclusion

In this exploratory paper we conceptualize and empirically test the effect on individual innovative performance of a number of different instantiations of distance in an organization. So far, the relevant literature has acknowledged some of these measures of distance, but has rarely included more than a single one in a study. In the relevant context of communication and transfer of knowledge in a setting that is highly dependent on such activity, we study the effects of instantiations of distance that affect the opportunity for knowledge transfer on the one hand, and the expected benefits of knowledge transfer on the other hand. Distance between individuals is generally believed to hamper knowledge transfer and thus individual innovativeness. We show, for the seven (7) different instantiations of distance we include in our study, that the effects can be quite unexpected. We find that instantiations of distance that some explicitly believe to hamper individual innovativeness – most pertinently geographical and hierarchical distance - actually stimulate knowledge transfer and innovation. Rather than reducing the opportunity to exchange knowledge and hamper innovation, these increase such opportunities. In the case of hierarchical distance, the Merton effect might be involved whereby those lower in rank will seek to exchange with those higher in rank, at an exchange that is unfavorable to those lower in rank, in order to be seen in more favorable light (Dolfsma et al. 2009). The favorable effect for knowledge exchange and innovation of more spatial distance might be explained by the parallel use of other means of exchange reducing the distance between parties in other ways. Interactions between different instantiations of distance in an organization is left for future research in this exploratory study. One instantiation of distance expected to have a favorable effect on knowledge exchange and individual innovativeness – cognitive distance – only has that effect on the outcome of innovation (patents) and not on the process of innovation (creativity). This is contrary to the arguments used to support proposition 2. More research is needed here too. Particularly being in close network contact with others *indirectly* is favorable for knowledge transfer and innovation. It would be useful to determine what knowledge actually is exchanged in this indirect manner, to establish why indirect rather than direct contacts matter.

The concept of ‘distance’ in an organization has a number of different meanings that are in need of further conceptualization. There is surprisingly little research on this topic – this paper offers a small first step. While some instantiations of distance stimulate innovation in an organization (measured in two different ways) others measures of distance do not. Our findings depart quite substantially from what the literature suggests. Findings in this exploratory study thus show that measuring distance in an organization is not a mere methodological concern. Replicating our analysis in different contexts, possibly with different performance outcomes

studied, and allowing for interactions and non-linear effects, will help to understand how distance impacts social interaction processes and outcomes in an organization.

This is an exploratory study, for the first time bringing together a number of different instantiations of the concept of distance, theorizing and exploring empirically how they affect an individual's performance in terms of innovative contribution. This paper has some **limitations**, clearly. For one, the effect of the different measurements for distance one can imagine may differ by context and dependent variable studied. Findings in a setting that is less knowledge-intensive than an R&D lab could present a different picture (cf. Allen 1977; Breschi & Lissoni 2009; Monge *et al*. 1985). Causal claims can be firmer if an organization would be studied over a longer period of time and panel data would be available. More use could be made of qualitative data as well, to help suggest causal claims. Some may wonder about the use of a relatively low number of observations. We do, however, meet the stringent criteria about the necessary response rate for a social network study (Wasserman & Faust ; Aalbers & Dolfsma 2015), and far exceed the number of observations used in other studies (REFS).

Due to these data limitations, however, we refrain in this paper from a more complicated analyses that either posits non-linear effects for each instantiation of distance, or moderation effects whereby different instantiations of distance interact with each other. The former have been alluded to in the literature (e.g. Wuyts et al. 2005), but not empirically explored. There might be different ways to overcome one kind of distance, as Granovetter (1973) suggests implicitly, by reducing distance in another sense for instance because the same knowledge background or education is shared (Wilson *et al*. 2008; Crane 1972; De Solla Price & Beaver 1969). Allen (1977) has found, for instance, that geographical distance between communication partners can be overcome if they are personally and cognitively close. Being at a large distance from another team member geographically might also not be problematic if one is able to reach the other, using technical means, because of close personal or network distance, engaging in 'action at a distance' with alters (Ensign 2009; Lave & Wenger 1991; Wenger & Snyder 2000) . Individuals can (seek to) overcome cognitive distance, by reducing network distance. We have empirically explored the possibility of the expected benefits of individuals being at a distance positively moderating the reduced opportunity to do because of a reduced opportunity to exchange as a consequence of distance. The findings, available upon request from the authors, do not show a consistent picture. We attribute this to data limitations.

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Table 1: Distance and Individuals' Innovativeness

Model:	1a Patents	1b Creativity	2a Patents	2b Creativity	3a Patents	3b Creativity	4a Patents	4b Creativity
Controls:								
Tenure	0.126*	-0.232***	0.096	-0.214***	0.112	-0.203***	0.103	-0.22***
Gender	-0.18**	-0.26***	-0.212***	-0.258***	-0.143*	-0.19***	-0.187**	-0.235***
Dept. size	-0.002	-0.197***	-0.026	-0.208***	0.054	-0.15*	-0.013	-0.197***
Independents								
Business Unit (BU)	-0.048	-0.085	-0.062	-0.101	0.002	-0.052	-0.037	-0.085
Spatial dist.			-0.083	-0.095				
Formal dist.: Scientist vs. Sr. Scientist					0.229***	0.24***		
Formal dist.: Scientist vs. Management					0.196**	0.163**		
Personal dist.							0.029	-0.049
Cognitive dist.								
Network dist. (range)								
R^2	0.063	0.116	0.074	0.118	0.114	0.162	0.057	0.108
Adj. R^2	0.042	0.097	0.047	0.093	0.085	0.135	0.031	0.084
Overall F	2.991	4.417	2.777	4.675	3.914	5.846	2.22	4.425

***, **, *: significant at 1, 5 and 10% levels.

Table 1: Distance and Individuals' Innovativeness (ctd.)

Model:	5a Patents	5b Creativity	6a Patents	6b Creativity	7a Patents	7b Creativity
Controls:						
Tenure	0.119	-0.219***	0.097*	-0.194**	0.128*	-0.231***
Gender	-0.177**	-0.238***	-0.205***	-0.244***	-0.153*	-0.232***
Dept. size	-0.032	-0.196***	-0.008	-0.211***	0.057	-0.127*
Independents:						
Business unit (BU)	-0.057	-0.078	-0.041	-0.1	-0.123	-0.164**
Spatial dist.						
Formal dist.: Scientist vs. Sr. Scientist						
Formal dist.: Scientist vs. Management						
Personal dist.						
Cognitive dist.	0.159**	-0.023				
Network dist. (direct)			-0.095	0.085		
Network dist. (indirect)					0.246***	0.276***
R^2	0.081	0.107	0.072	0.119	0.111	0.177
Adj. R^2	0.056	0.082	0.046	0.093	0.086	0.154
Overall F	3.216	4.34	2.722	4.689	4.424	5.37

Two tailed; ***, **, *: significant at 1, 5 and 10% levels.

Appendix: Correlation table.

	Variable	Mean	Std. Dev.	n	1	2	3	4	5
1	Tenure	15.5794	11.37251	189	1				
2	Gender	0.2256	0.41908	195	-0.293**	1			
3	Dept. size	2.4213	0.61441	195	-0.131	0.086	1		
4	Business unit (BU)	0.2564	0.43777	195	0.056	-0.064	-0.282**	1	
5	Cognitive dist.	2.6074	0.51319	192	-0.11	-0.027	0.102	0.067	1
6	Network range	0.9246	0.05612	187	-0.063	-0.021	0.033	0.039	-0.043
7	Personal dist.	3.5015	0.4135	192	-0.096	0.073	0.072	-0.063	0.484**
8	Spatial dist.	0.542	0.30588	187	-0.094	-0.093	0.013	-0.08	-0.012
9	Formal dist. Scientist vs. Sr. Scientist	0.1538	0.36173	195	-0.021	-0.162*	0.104	-0.023	0.034
10	Formal dist. Scientist vs. Management	0.3231	0.46886	195	0.066	-0.006	-0.410**	-0.104	-0.149*
11	Innovation Perf.: Patents	1.8519	2.00777	189	0.155*	-0.214**	-0.029	-0.019	0.142
12	Innovation Perf.: Creativity	3.4433	0.93818	194	-0.126	-0.217**	-0.155*	-0.022	-0.023

Two tailed; ***, **, *: significant at 1, 5 and 10% levels.

Appendix: Correlation table (ctd.)

	Variable	7	8	9	10	11	12	13
1	Tenure							
2	Gender							
3	Dept. size							
4	Business unit (BU)							
6	Cognitive dist.							
7	Network range	1						
8	Personal dist.	-0.021	1					
9	Spatial dist.	0.288**	-0.062	1				
10	Formal dist.: Scientist vs. Sr. Scientist	-0.153*	0.074	-0.087	1			
11	Formal dist.: Scientist vs. Management	0.072	-0.255**	0.02	-0.295**	1		
12	Innovation Perf.: Patents	-0.094	0.008	-0.073	0.200**	0.114	1	
13	Innovation Perf.: Creativity	0.075	-0.056	-0.024	0.178*	0.13	0.125	1

Two tailed; ***, **, *: significant at 1, 5 and 10% levels.