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Distances in Organizations: Innovation in an R&D Lab

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The distance between actors in an organization affects how they interact with each other, and particularly whether 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: by being more innovative, for instance. 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, Th. (1956). *American Psychologist*, 11, p. 575). Knowledge that 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 that a focal actor receives from alters who are at a greater 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. Secondly, this paper is the first study to test empirically the expectations about how seven different measures of distance affect an actor's innovative performance. Innovative performance is measured as both creative contribution and contribution to knowledge that has immediate commercial use (patents). In the setting of a large research lab, it is found, contrary to expectations, that distance does not hurt individual innovative performance and sometimes helps it in unexpected ways.

Distance between actors in an organization is believed to affect whether they will interact with each other to exchange knowledge (Akerlof, 1997). In the literature, interaction and knowledge exchange are firmly expected 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, Finch and McMaster, 2011). Because of distance between individuals, there may not be interaction or exchange of knowledge, and the knowledge that is exchanged can be more easily misunderstood. Since innovation comes from the 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, particularly 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 and Mortensen, 2005; Martins, Gilson and Maynard, 2004; Maznevski and Chudoba, 2000; O'Leary and Cummings, 2007; Olson and Olson, 2000). The idea in this line of research is that 'out of sight, means out of sync' (Hinds and 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 affects individual innovativeness and performance. Knowledge received from alters in one's proximity may be too similar to the knowledge that one already has, while knowledge received from alters who are more distant is more different and may 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 benefits expected 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 decreases 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 and Kadushin, 1976). Individuals exchanging over greater 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 test empirically the expectations about how seven different instantiations of distance affect 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 type 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 and contribution to knowledge that has immediate commercial use (patents).

Theory: distances in organizations

Despite being little conceptualized (cf. Lechner, 1991; Wilson *et al.*, 2008), distance between individuals has been acknowledged to have 'considerable influence on a variety of organizational outcomes' (Monge *et al.*, 1985). The impact is believed to be mostly negative: distance decreases trust between individuals, increases the likelihood and effects of conflicts, and will make people in an organization interact less frequently (Hinds and Bailey, 2003; Hinds and Kiesler, 1995; Monge *et al.*, 1985). The performance of individuals distanced from other individuals and of an organization where individual employees are at a distance to others 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 (Cummings, 2004; DiStefano and Maznevski, 2000; Martins, Gilson and Maynard, 2004; O'Leary and Cummings, 2007). 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 or a managerial point of view. Although there is some acknowledgement that different dimensions to distance may need to be recognized, each of which will affect communication in general, and knowledge transfer in particular (Boschma, 2005; Danson, 2000; Napier and

Ferris, 1993), affecting a large number of organizational performance outcomes (Monge *et al.*, 1985), in empirical studies 'distance' has mostly been analysed for one dimension only: spatial distance (Monge *et al.*, 1985; Rogers and Larson, 1984; Saxenian, 1991; Singh, 2005).

Some studies focus on cognitive distance (Gilsing *et al.*, 2008; Nooteboom, 2000), as it is clear that even those who are co-located may not readily understand each other if individuals have, for instance, 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, Kapur and McHale, 2008), as communication using electronic means has grown more common, and spatial distance can be overcome using different technical means. In line with this, even being in the same team or social community may not mean that individuals actually interact and exchange knowledge. Some, therefore, focused on network distance between individuals (Alba and Kadushin, 1976; Reagans and 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, Dolfsma and Leenders, forthcoming).

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, Kapur and McHale, 2008; Breschi and Lissoni, 2009). Few studies have conceptualized why some forms of distance may be beneficial, and others may be detrimental to knowledge exchange.

We submit that distance between exchanging parties can affect 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 may have multiple instantiations suggests that, while cognitive distant can offer larger expected benefits, in other respect the distance between cognitively distant individuals may be large as well. A study that does not conceptually acknowledge and methodologically include this possibility may attribute findings for the one distance measure included that are in actual fact caused by other distance measures. Reduced opportunities for exchange may be compensated for by increased expected benefits of knowledge exchange over a distance. Not recognizing the different instantiations of the concept of distance may leave these dynamics unnoticed.

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) finds 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 and 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) point 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 and Robert, 2000; Moran and Ghosal, 1996; Nahapiet and Ghosal, 1998; Osterloh and Frey, 2000; Powell *et al.*, 1996, Starpoli, 1998; Tsai and Ghosal, 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 also been mentioned as a factor to determine personal distance between individuals. Larger personal distance between focal actors and their alters will, ceteris paribus, negatively affect 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: (1) distance created by unit boundaries; and (2) distances due to hierarchy. Units boundaries in an organization can create hurdles for knowledge exchange, even when individuals are co-located (Gulati and 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 and 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 and Patterson, 2009) and ethnic groups (Barth, 1969). Identities, status and what knowledge is taken for granted depend on boundaries (DiMaggio, 1997; Douglas, 1966; Hsu and Hannan, 2005; White, 1992; Zuckerman, 1999). The division of labour 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, Dolfsma and Leenders, forthcoming; Macdonalds and Williams, 1993a,b). Knowledge that crosses unit boundaries, and the messenger that has brought it, may actually be regarded with suspicion (Dolfsma, Finch and McMaster *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 and Ferris, 1993). Faultline theory (Bezrukova *et al.*, 2009) suggests that interactions and exchange between individuals may 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 and Hambrick, 2005; Postuma and 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 and Cross, 2003; Jung, Chow and Wu, 2003; Napier and 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 and Schippers, 2007), and the amount of knowledge moving between individuals decreases.

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, Dolfsma and Koppius, 2014; Amin and Cohendet, 2004), reaching beyond what Reagans and McEvily (2003, p. 247) call 'institutional, organizational or social boundaries', thus reducing one's distance to others with whom one may usefully communicate and exchange knowledge, which is likely to result in interaction with a 'different body of knowledge' (Reagans and 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 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, Dolfsma and Koppius, 2014; Aalbers *et al.*, 2013; Breschi and Lissoni, 2009; Burt, 2004; Hansen, 1999; Sparrowe *et al.*, 2001). Focal actors that are thus closely connected to many others, have better opportunities to exchange, and will see their innovative performance enhanced (Borgatti and Cross, 2003; Oh, Labianca and Chungh, 2006; Reagans and Zuckerman, 2001, 2003). Along similar lines of argumentation, focal actors may be able to tap into knowledge in an organization, accessing what is relevant for their innovative efforts, indirectly. By leveraging their direct contacts, focal actors can access knowledge possessed by third parties, at a somewhat larger network distance, which was argued and found to benefit their innovative performance (Aalbers, Dolfsma and Leenders, forthcoming; Burt, 1992; Ingram and 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 may offer would find such support. Also, focal actors can cast a wider net, seeking to obtain knowledge to complement their own if they can access a larger number of alters indirectly, being closer to them. Even though actors are dependent on direct contacts to provide them with indirect knowledge that these may access, the focal actor can try actively to obtain such knowledge.[1]

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

1. spatial distance
2. personal distance
3. organizational unit boundary distance
4. hierarchical distance
5. network distance, direct
6. 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:

> *P1*: Increased distance from a focal actor to others that reduces the opportunities for knowledge exchange decreases the actor's innovative performance.

Expected benefit from knowledge exchange

Some have not claimed just 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 because of differences in the education enjoyed, and the skills or experience accumulated (Borgatti and Cross, 2003; Dougherty, 1992; Reagans and 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 (Hinds and Mortensen, 2005).

Others, however, expect and have found favourable performance outcomes when collaborating individuals cognitively are not in close proximity. Cognitive distance between a focal actor and his or 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, Dolfsma and Leenders, forthcoming; Burt, 1992; Ingram and Roberts, 2000; Reagans and McEvily, 2003; Woodman, Sawyer and Griffin, 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 and Hinds, 2005; Williams and O'Reilly, 1998), enhancing individual performance (Allen, 1977). Exchanging knowledge with such alters will help focal actors to understand and develop their 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

[1] Burt (1992, 2004) focuses on the network as a whole, pointing to the favorable position of bridges connecting 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.

in a larger context. Exchange with another at a cognitive distance, in other words, helps actors to become more innovative (Burt, 2004; Reagans and Zuckerman, 2001; Rodan and Galunic, 2004; Sparrowe *et al.*, 2001). Knowledge exchanged with another 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).

P2: Increased distance from a focal actor to others that reduces the expected benefits of knowledge exchange increases the actor's innovative performance.

Data and method

Research site

The data were 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 is therefore a case study, with known advantages and disadvantages associated with this type of research. Given the exploratory nature of studying the effects of multiple instantiations of organizational distance, this seems 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 be aggregated meaningfully, for instance. 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 €8bn, 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 administered to a total of 195 lab researchers and lab managers. The target population represented all researchers (lab assistants, for example, 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 two purposes: signalling the company's support and avoiding possible technical problems. After three weeks, approximately 55% 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% survey response rate for the target population in three rounds and one month of surveying – a high response rate required by social network analysis (Wasserman and Faust, 1994).

Measures

Data were 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). 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

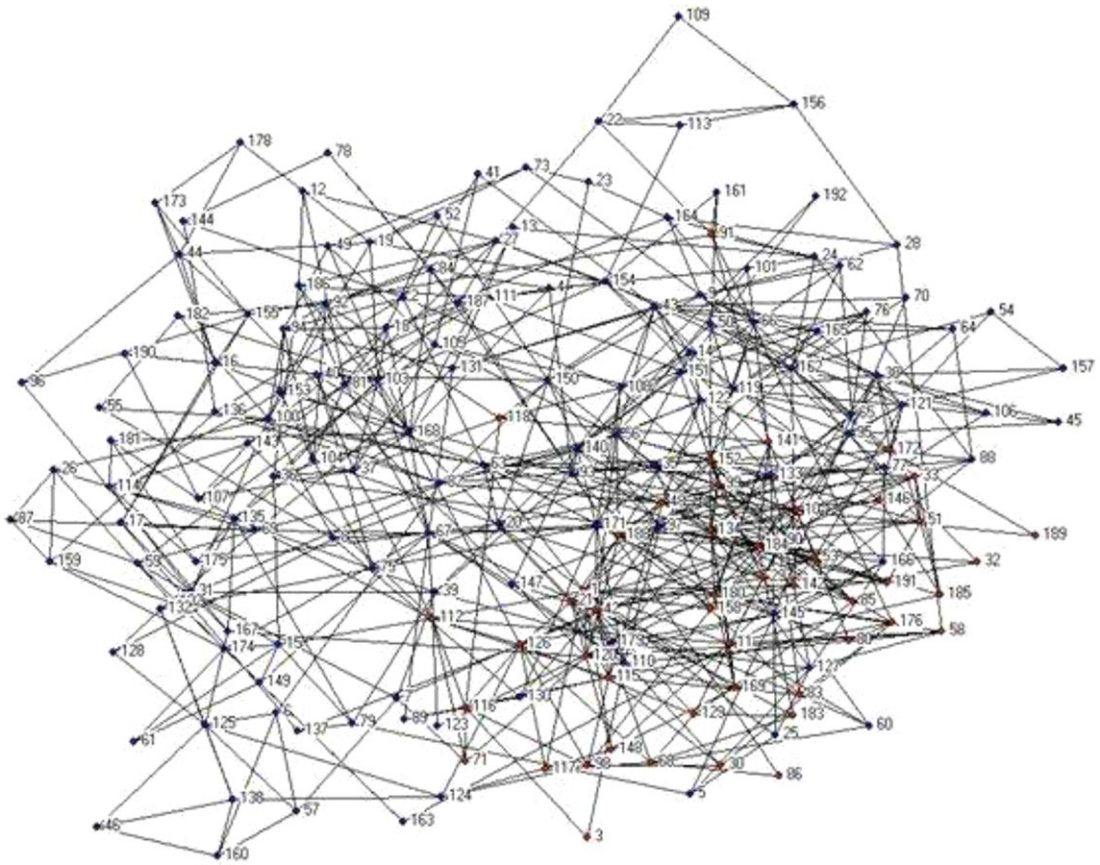

Figure 1. Frequent relations in research laboratory

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 and 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.[2] The connected lab scientists shared 1111 relationships. Six individuals turned out to be isolates. The variables are described below, and a correlation table is provided in the Appendix.

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, carefully to 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?'; use a 1–5 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 in the literature, often requires supervisor (or peer) assessment (Amabile, 1996; Moran, 2005). In line with previous research, the assessment asked managers to assess behaviours rather than attitudes, for a specific period (cf. Tsui,

[2]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.

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 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) and productivity for individual researchers (Bertin and Wyatt 1988). The number of patents scientists have been granted can have a significant impact on their careers (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 difficult, 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, therefore, the 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 the models that we estimate, rather than alternating this measure for distance as we do for the other measures of distance to obtain regression results. In this way, the business unit variable is actually 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 may interfere with that of other variables for distance too, we have included it in six model specifications in Table 1, as if it were a quasi control variable.

Effects found for a lab scientist's innovativeness may be erroneously attributed to a variable such as centrality or unit membership, if in actual fact geographical distance between individuals may be the explanation (Monge *et al.*, 1985). Given how common facilities for employees are provided, we measure geographical distance as a co-location of designated workspaces 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 were drawn from company personnel records. The data were used as a basis for our measure of hierarchal

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

	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.

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 and 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; Nooteboom, 2000; Pelled *et al.*, 1999). The measure was reverse coded (i.e. 4 was recoded as 1, etc.) so that a value increase reflected increased knowledge similarity.

A distance variables has been calculated from the network data collected along the lines explained above (see Aalbers, Dolfsma and Koppius, 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 him or her with direct network distance (Burt, 1984; Marsden, 1987; Reagans and McEvily, 2003). In particular, we adopt Reagans and McEvily's (2003, p. 255) network range indicator, which captures the extent to which individuals maintain weak ties in a diverse network across multiples (Granovetter, 1973). We measure the 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 two-step reach, the number of alters a focal actor has indirect access to in a network, through direct contacts.

Controls

Within the 24 departments in which lab scientists collaborate closely, scale effects in research may emerge. Following Tortoriello (2006), department size was included to control for networking and exchange opportunities, only because of the size of the working group of lab scientists. Scores for the independent variables could be an artefact 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, faultlines, such as gender, can affect 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, 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 are relevant. In addition, since patent innovativeness may have a cumulative element, in that it is firm-specific, tenure is the appropriate control variable. This does treat individuals who have had a career prior to joining this firm similarly 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 did have a statistically significant effect (Table 1). More importantly, however, tenure is known to affect communication patterns (Ahuja and 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 analyse 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, Kapur and McHale, 2008).

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. One is more objective, perhaps, and focuses on outcomes. The other can be more subjective and focuses on the process of innovation.

Proposition 1 suggests that, when distance from the focal actor to others increases such that opportunities for knowledge exchange decrease, individual innovativeness decreases. We have analysed the effects of six 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 ($\beta = 0.0164$. $p<0.05$). 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 affect 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 actually to stimulate patent innovativeness in model 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 affects 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 affects 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 may 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 affects both firm and individual innovativeness, but can be difficult to grasp by any individual in an organization (Aalbers and Dolfsma, 2015). Gender can consistently be seen negatively to affect 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 affects creativity and patent innovativeness, but only for the former in a significant way.

Discussion and conclusion

The concept of 'distance' in an organization has a number of different meanings that are in need of further conceptualization, acknowledging and investigating the complexity of this concept. 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), other 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 understanding of how distance affects social interaction processes and outcomes in an organization.

In this exploratory paper, we conceptualize and empirically test the effect on individual innovative performance of seven different instantiations of distance in an organization. So far, the relevant literature has acknowledged only 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 conceptualize and 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. Distance between individuals is generally believed to hamper knowledge transfer and thus individual innovativeness. We show, however, for the seven different instantiations of distance included 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 may be involved, whereby those lower in rank will actively seek to exchange with those higher in rank, at an exchange rate that can be unfavourable to those lower in rank, in order to be seen in more favourable light (Dolfsma, van der Eijk and Jolink, 2009; Merton, 1968). The favourable effect for knowledge exchange and innovation of more spatial distance may be explained by the more diverse information sources that spatially distant individuals can draw on, while their spatial distance is overcome by the use of means of exchange that reduce the distance between parties in other ways. Granovetter (1973) suggests this implicitly. Allen (1977) finds, for instance, that geographical distance between communication partners can be overcome if they are personally and cognitively close (cf. Crane, 1972; De Solla Price and Beaver, 1969; Wilson *et al.*, 2008). Being at a large spatial distance from another team member geographically may 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 and Wenger, 1991; Wenger and Snyder, 2000). Individuals can (seek to) overcome cognitive distance, by reducing network distance. Interactions between different instantiations of distance in an organization is left for future research, however.

One instantiation of distance expected to have a favourable 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. Perhaps the investment required of an individual to interact with others who are cognitively distant is at the expense of someone's immediate innovative contribution, as ranked by his or her superior. More research is needed here. In particular, being in close network contact with others indirectly is favourable 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. Perhaps knowledge acquired indirectly through one's network contacts is more likely also to be from different departments or from individuals of higher seniority (cf. Aalbers, Dolfsma and Leenders, forthcoming). These interactions effects are, however, impossible to explore in this paper, as we explain below.

This is an exploratory study, bringing together for the first time a number of different instantiations of distance, theorizing and exploring empirically how they affect an individual's performance in terms of innovative contribution. This paper clearly has some limitations. For one, the effect of the different measurements of 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 and Lissoni, 2009; Monge *et al.*, 1985). Causal claims could be firmer if an organization were studied over a longer period of time, and panel data were available. More use could also be made of qualitative data in a subsequent study, to help suggest causal mechanisms. Some may wonder about the use of a relatively low number of observations. We do, however, meet the stringent criteria on the necessary response rate for a social network study (Aalbers and Dolfsma, 2015; Wasserman and Faust, 1994), and far exceed the number of observations used in other studies (cf. Aalbers and Dolfma, 2015).

Owing to these data limitations, however, we refrain in this paper from a more complicated analysis that posits either non-linear effects for each instantiation of distance, or moderation effects whereby different instantiations of distance interact. The former have been alluded to in the literature (e.g. Wuyts *et al.*, 2005), but not empirically explored. We have been unable conclusively to explore empirically the effects of interactions between different instantiations of distance. The findings for interactions between the one measure for expected benefit of distance, on the one hand, and the measures for opportunity for exchange, on the other (available on request from the authors), do not show a consistent picture. We attribute this to data limitations.

Appendix: Correlation table

	Variable	Mean	Std. dev.	n	1	2	3	4	5	6
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	Two step reach (in-degree)	40.9572	20.89781	187	0.081	−0.143	−0.333**	0.371**	1	
6	Cognitive dist.	2.6074	0.51319	192	−0.11	−0.027	0.102	0.067	0.024	1
7	Network range	0.9246	0.05612	187	−0.063	−0.021	0.033	0.039	−0.041	−0.043
8	Personal dist.	3.5015	0.4135	192	−0.096	0.073	0.072	−0.063	−0.183*	0.484**
9	Physical dist.	0.542	0.30588	187	−0.094	−0.093	0.013	−0.08	0.034	−0.012
10	Formal dist:. scientist vs sr. scientist	0.1538	0.36173	195	−0.021	−0.162*	0.104	−0.023	0.067	0.034
11	Formal dist.: scientist vs management	0.3231	0.46886	195	0.066	−0.006	−0.410**	−0.104	0.321**	−0.149*
12	Innovation perf.: patents	1.8519	2.00777	189	0.155*	−0.214**	−0.029	−0.019	0.213**	0.142
13	Innovation perf.: creativity	3.4433	0.93818	194	−0.126	−0.217**	−0.155*	−0.022	0.269**	−0.023

	Variable	7	8	9	10	11	12	13
1	Tenure							
2	Gender							
3	Dept. size							
4	Business unit (BU)							
5	Two step reach (in-degree)							
6	Cognitive dist.							
7	Network range	1						
8	Personal dist.	−0.021	1					
9	Physical 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.

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