

**On the socio-spatial dynamics of personal knowledge networks: formation,
maintenance and knowledge interactions**

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Abstract

Whilst personal knowledge networks between organisations have been argued to be important for regional economic development, their functioning and, within this context, the exact role of spatial proximity has been empirically underexplored. This paper addresses these issues by, first, examining the dynamic mechanisms of the formation, maintenance and knowledge interaction of important knowledge relationships of R&D workers in the Cambridge Information Technology (IT) Cluster. This demonstrates that personal relations tended to transform from an initially professional context into privately governed relationships. Furthermore, the paper argues that a sophisticated understanding of the role of spatial proximity requires an investigation of the spatiality of several stages of the network mechanisms. The results show that permanent spatial proximity and face-to-face interaction are more important for the formation of relationships than for the maintenance stage and, in particular, for work-related knowledge interactions. Finally, it is argued that, in contrast to the emphasis of the literature on communities of practice and epistemic communities, the knowledge relationships does not tend to be anchored in collective groups. Instead, the paper highlights the usefulness of the concept of individualised networks.

1. Introduction

Many recent conceptual developments in the innovation and economic geography literature have emphasised that inter-organisational knowledge relationships are critical (Boggs and Rantisi, 2003, 109; Grabher, 2006; Malmberg and Maskell, 2002; Yeung, 2005b). In particular in high-technology sectors the external sourcing of knowledge through networks has been identified as an important mechanism (e.g. Braun et al., 2002; Cooke, 2001; Krätke, 2010; Lane and Probert, 2007; Mota and de Castro, 2004; Powell et al., 1996). Within this context, it has been widely argued that personal networks across organisations are critical for innovative firms. However, the functioning of personal knowledge networks in terms of the socio-spatial mechanisms remain underexplored.

The novel contribution of this paper is to take a dynamic perspective on the changing social and spatial contexts of personal knowledge relationships. It investigates the socio-spatial dynamics of important personal knowledge networks between organisations in three stages: the formation, the maintenance, and the context of knowledge interaction. More specifically, the aim of this paper is to examine (i) how the private/professional social context develops through the stages, (ii) whether the role of spatial proximity changes through the stages, and (iii) how we can conceptualise personal knowledge networks in the light of the stages. This paper does not discuss the nature of the knowledge transferred but aims to understand the socio-spatial functioning of personal networks that are regarded as an important source of knowledge by R&D (research and development) workers.

The results are based on a survey and interviews with 105 R&D workers—including technology managers and managing directors in micro businesses—in 46 hardware and software companies in the Greater Cambridge Region. This shows that

many of the relationships transformed from an initially professional context into private relationships that are governed outside of professional duties.

Furthermore, the paper argues that rather than relying on static indicators, a more sophisticated understanding of the role of spatial proximity requires an investigation at various stages of network mechanisms. This novel perspective on spatial proximity shows that its role varies for (i) the formation of networks, (ii) the maintenance of network relations and (iii) the transfer of knowledge. In particular, the paper examines, and confirms, the hypothesis that the role of spatial proximity is most important for the formation stage but less important for maintenance and for work-related knowledge interactions.

Moreover, the paper argues that the knowledge relationships of this study do not tend to be anchored in collective groups, which is in contrast to widespread arguments in the literature on communities of practice and epistemic communities (Benner, 2003; Brown and Duguid, 1991; Wenger, 1998). It is maintained that the alternative notion of individualised networks (Wellman, 2002) is suitable because it grasps the non-group-based but person-centred, dyadic operation of knowledge interaction. Furthermore, it is demonstrated that the combination of contexts of formation, maintenance, knowledge interaction and tie characteristics is more variegated than the ideal-types of communality, sociality and communitarity (Grabher, 2004a; Grabher and Ibert, 2006) suggest.

The remainder of this paper is structured as follows. Section 2 discusses unresolved questions in the literature on the mechanisms and spatiality of personal knowledge networks and motivates the research questions. Afterwards, the methodology and the sample are discussed in section 3. Section 4 explores the mechanisms of personal knowledge networks in detail. In the light of this, the role of

spatial proximity is examined in section 5. Section 6 reflects on the conceptual nature of the personal knowledge networks. Finally, section 7 concludes.

2. Mechanisms and spatiality of personal knowledge networks: unresolved questions

2.1. Mechanisms of personal knowledge networks underexplored

Knowledge networks can be defined as a set of actors which are related by knowledge interactions of some sort (knowledge transfer, co-development of knowledge etc.). The discourse on knowledge networks in economic geography and regional studies has tended to privilege inter-organisational networks at the firm-level at the neglect of inter-personal networks across organisations (Grabher and Powell, 2005, xxiii). Although the literature has often cited Granovetter's work on weak ties and the embeddedness of economic action in personal networks (Granovetter, 1973, 1985), the often subtle dimensions of individual-level networks within inter-organisational arrangements have been underexplored (Grabher, 2006; Huber, 2009). Increasingly scholars have criticised and challenged the blackbox 'firm' and emphasise the multiple activities and interests of *individuals* within firms (e.g. Ettlinger, 2003; Grabher and Ibert, 2006; Yeung, 2005b). Individuals in firms can be involved and influenced by ongoing relations with persons within the firm, with persons from other firms and from non-firm organisations (Yeung, 2005b). Importantly, such networks can have an informal character beyond official organisational arrangements.

The literature on individual-level networks in economic geography that does exist involves limitations in terms of revealing the social mechanisms¹ of personal

¹ Social mechanisms can be understood as sequences of causally linked social actions (Mayntz, 2004).

knowledge networks. Many studies discuss and operationalise the idea of external personal networks in unspecific terms such as ‘co-operation’, which does not reveal the processes of social interaction and knowledge flows (e.g. Capello and Faggian, 2005). While surveys on external knowledge relations (e.g. Keeble et al., 1999) are important in revealing general tendencies, they are not able to shed light on specific qualities and mechanisms of personal networks.

A detailed survey by Trippi et al. (2009) that measured personal networks more explicitly highlights that informal contacts are an important source of knowledge in the Vienna software industry.² However, the mechanisms of informal relationships are not examined. Even sophisticated studies on personal knowledge networks such as Grabher and Ibert (2006), Moodysson (2008) or Saxenian (1996) do not investigate the operation of personal networks in terms of their formation and maintenance in detail. In particular, the critical issue of to what extent the functioning of personal knowledge relationships is based on official professional relationships or on private, informal relationships remains unclear. In the existing literature Benner’s (2003) study on Silicon Valley has suggested that formal professional associations can be important for establishing cross-firm learning communities. Moreover, the establishment of personal contacts within the same company in combination with subsequent labour mobility can lead to inter-organisational knowledge transmission as Granovetter’s (1974) influential study on job information has shown. His study has also famously argued that personal knowledge relationships do not require frequent interaction but are often based on ‘weak ties’. Yet, no study, to the best of my knowledge, has systematically analysed the role of professional/private contexts over the course of the network mechanisms of formation, maintenance and knowledge interactions.

² In a web-based survey they measured the number of firms in the Vienna software cluster for which informal contacts with clients, competitors or other software developers online (at various spatial scales) were an important knowledge-transfer channel.

This paper addresses these gaps by examining different stages of network mechanisms and exploring whether social interaction takes place in professional versus private contexts throughout the stages. Hence, the first research question is: *how does the private/professional social context develop through the stages of the formation, maintenance, and knowledge interaction?*

2.2. Lack of empirical work on the spatiality of knowledge networks

In terms of the spatial dimension of knowledge networks, most traditional relational accounts in economic geography have focused on how *local* relational assets influence regional economic development. Increasingly, the literature has highlighted relationships at multiple spatial scales (e.g. Amin and Cohendet, 2004; Bathelt et al., 2004; Bunnell and Coe, 2001; MacKinnon et al., 2002; Yeung, 2005a). Several empirical studies suggest that extra-local knowledge relations are actually important for learning and innovation in industrial clusters (e.g. Arndt and Sternberg, 2000; Britton, 2003; Cumbers et al., 2003; Giuliani and Bell, 2005; Keeble et al., 1998; Moodysson, 2008; Morrison, 2008). Furthermore, Torre and Rallet (Torre, 2008; Torre and Rallet, 2005) have stressed that benefiting from the positive effects of face-to-face interaction does not require permanent co-location but can also take place in contexts of temporary proximity such as in trade fairs (Bathelt and Schuldt, 2008), enabled by business travel (Jones, 2009; Wickham and Vecchi, 2009). Yet, it has been argued that permanent spatial proximity still plays an important role for knowledge production and innovation (e.g. Sonn and Storper, 2008).

However, the empirical contributions on multi-scalar knowledge networks tend to be based on the firm-level and not on personal networks. A prominent exception in this respect is the recent work by Saxenian (2006) that illustrates the importance of transnational personal networks of engineers and entrepreneurs for regional

development. Yet even here, “one wishes for more precise statements of [...] the precise nature of what these networks do in sociological and economic terms” (Storper, 2007, 114). Furthermore, Moodysson (2008) empirically illustrates multi-scalar spatial configurations of well-regulated personal knowledge networks in the Medicon Valley life science industry. Also, Asheim and Gertler’s (2005) and Moodysson et al’s (2008) discussion of the role of ‘analytical’ versus ‘synthetical’ knowledge bases³ has enriched the debate by suggesting that analytical modes of knowledge production tend to be globally distributed whereas synthetic knowledge creation tends to be locally oriented.

Despite the extensive literature on the topic, the role of geographical distance in knowledge transmissions remains unclear (Döring and Schnellenbach, 2006, 388-389). The generally accepted view is that first, local and global relations are important, and second some form of proximity matters (Boschma, 2005).⁴ However, there is a lack of empirical work to substantiate these claims. Although the above-mentioned studies are valuable contributions, a blind spot of the existing literature on knowledge networks is that it does not examine whether the role of spatial proximity can vary for different stages of social mechanisms such as the formation and maintenance of personal knowledge relationships.

In terms of theoretical expectations, the literature sometimes suggests that spatial proximity plays a role mainly for the formation of relationships (e.g. Gallaud and Torre, 2005); however, to the best of my knowledge no empirical study has systematically investigated this proposition.

This paper addresses these issues by examining whether the role of spatial proximity varies for different stages of network mechanisms. Hence, the second

³ An analytical knowledge base is centred on innovation by the creation of new knowledge, whereas a synthetical knowledge base is centred on the application or novel recombination of existing knowledge (Asheim and Gertler, 2005).

⁴ For a detailed discussion on the role of different types of proximity see Huber (forthcoming-b).

research question is: *to what extent does the role of spatial proximity change through the stages of the formation, maintenance and knowledge interaction of personal knowledge relationships?* The paper examines, and confirms, the *hypothesis* that the role of spatial proximity is most important for the formation but less important for maintenance and for work-related knowledge interactions.

2.3. Conceptualisation of personal knowledge networks: unresolved questions

Furthermore, the question arises how to conceptualise personal knowledge networks with a view of the dynamic mechanisms of formation and maintenance. A few recent contributions in economic geography have highlighted the importance of communities of individuals, such as epistemic communities or communities of practice (e.g. Amin and Cohendet, 2004; Benner, 2003). Although there is some conceptual ambiguity (Roberts, 2006), these concepts emphasise collective knowledge sharing and learning processes of groups of knowledge workers (e.g. Knorr-Cetina, 1981; Wenger, 1998).

Furthermore, Grabher and Ibert have developed a more fine-grained typology of modes of networking in project-based work environments (Grabher, 2004a; Grabher and Ibert, 2006). This approach offers an alternative understanding of knowledge networks by going beyond the picture of coherence, stability and clear boundaries that the notions of knowledge communities painted. It differentiates between communality, sociality and connectivity. In short, *communality* refers to strong, trust-based ties based on mutual experience and personal familiarity. *Sociality* denominates ephemeral ties that are primarily based on strategic professional motivations with private interaction as a secondary effect. Finally, *connectivity* refers to thin, information-focused relationships such as online discussion forums or e-mail lists.

Importantly, how do these existing conceptualisations of personal knowledge networks integrate the dynamics of the network mechanisms? The concepts of knowledge communities (epistemic communities, communities of practice) seem to leave it open how exactly the relationships are formed and maintained. However, Grabher and Ibert's approach is more specific and argues that communality, sociality and connectivity tends to be based on certain ways of formation and maintenance of relationships, ties strength and means of communication (cf. the discussion in section 6.2).

To examine the role of these concepts, the third research question is: *how can we conceptualise personal knowledge networks in the light of the dynamic mechanisms of the formation, maintenance, and knowledge interactions?* The paper contributes to the literature by identifying limitations of the above-mentioned conceptualisations and highlighting the significance of the alternative concept of individualised networks.

3. Methodology and sample

3.1. Methodology

Cambridge (UK) has seen a transformation to a leading high-tech region since the 1970s, which has often been referred to as the 'Cambridge phenomenon'. In a 25 miles radius around the city of Cambridge, there are approximately 43,000 people employed in 1,300 high-tech firms (StJohn'sInnovationCentre, 2011). Whilst high-tech firms in various sectors have emerged, notably in biotech, the study focuses on information technology (IT) because it constitutes the dominant sector in terms of the number of innovation-based businesses (LibraryHouse, 2004). Within IT, this study concentrates on the dominant product-based sub-sectors hardware and software (excluding purely service-based companies).

A list of the firms was constructed by merging two existing databases on innovation-based firms from the research and consultancy companies 'Library House Ltd.' and 'Cambridge Investment Research Ltd.'. The target population (sampling frame) at firm-level consists of 220 firms, 156 in software and 68 in hardware, in the Greater Cambridge Region. The sample is constituted by first taking a random sample of 100 firms (70 in software, 30 in hardware; that is, the proportions of the sub-sectors in the sample mirror the target population). Within those the firms were asked to select R&D workers according to the following criteria (if applicable): the managing director if s/he is actively involved in research or development; the director of research or development or chief technology officer; one 'key' engineer/developer who is regarded as most important for the firm; one senior engineer/developer (e.g. project leader); one mid-level engineer/developer; one junior engineer/developer with less than two years of work experience in the industry.

Getting access to the firms was very difficult. After 11 months (January-November 2008), data from 105 individuals in 46 firms were collected. Taking a multi-method approach, I arranged face-to-face meetings with the R&D workers and went with them through structured questionnaires and conducted semi-structured interviews. The interviewees were instructed about the meaning of the terms 'personal networks' for the purpose of this study; in particular it was emphasised that it is about personal relationships which can be private or professional as long as it involves personal acquaintance and the interaction goes beyond official duties.

To understand the functioning of personal networks, I conducted an ego-network analysis and questioned the respondents on who are the most important personal knowledge contacts. The respondents were asked to recall four personal contacts

which were most important in terms of a source of work-related knowledge in the past year.⁵

Overall, the meetings lasted from 20 to 120 minutes (mean 45 minutes). The recorded interview material was fully transcribed. Using ATLAS.ti software, the quotes were systematically coded, and those codes were categorised into meta-concepts.

Only 86 respondents could think of a most important contact. Furthermore, because of limited time during the interview, it was not always possible to collect detailed data on the quality of the personal knowledge relations with all of those 86 respondents. Throughout this paper, the number of respondents is indicated in each table to make this transparent.

3.2. Key characteristics of the sample

Out of 100 firms in the sample, 46 participated, which represents a response rate of 46% of the firms. At the individual level, 58 respondents (55%) are in software, and 47 (45%) in hardware, which shows that that hardware is over-represented (recall that around 70% of the firms in the target population are in software and around 30% in hardware).

In the *nomination* exercise to explore up to four most important contacts outside of the firm in the past year, on average only 2.24 contacts were mentioned (median: 2; N=103). It seems remarkable that 16.5% could not think of a single personal contact, and more than 75.7% could not think of four contacts.

Given the *male dominance* of the industry it is no surprise that 92% of the nominated contacts were male.

Another important characteristic of personal knowledge networks is whether they are part of official inter-organisational relationships, or whether they are of a private

⁵ Most parts of the analysis only focus on the single most important contact. However, occasionally all four contacts are analysed.

nature. An analysis of the most important personal contacts reveals that for 55.4% of the respondents it is a purely private relationship with a person who is not working for any similar technology company (see Table 1). For 13.3% it is a private relationship which involves an occasional contracting relationship. And 31.3% of the relationships are purely anchored in official relationships between the respective firms. This illustrates that the most important personal knowledge contacts are very much of a private nature. This is strengthened by the result that 65.6% have never collaborated with the contact on an official project between the respective firms.

Table 1. Most important contact: type

	Frequency	Percent
OFFICIAL PROFESSIONAL:	26	31.3%
Customer/client	10	12.0%
Collaborating company	7	8.4%
Supplier	5	6.0%
Other uni or research institution - official relation	3	3.6%
Official NHS relationship	1	1.2%
PRIVATE:	46	55.4%
Only private, not working in relevant tech company	36	43.4%
Other tech company (no competitor or business relation)	7	8.4%
Competitor	2	2.4%
Other uni or research institution - only private	1	1.2%
MIX OFFICIAL AND PRIVATE:	11	13.3%
Private + occasional contracting	10	12.0%
Other uni or research institution - mix official/private	1	1.2%
Total	83	100.0%

4. Mechanisms of personal knowledge networks: formation and maintenance

As outlined in section 2, to clarify the mechanisms of personal knowledge networks we need to look at different stages. A focus only on the context when knowledge is transferred does not reveal the whole story. In order to address the research question of how the private/professional social context develops through the

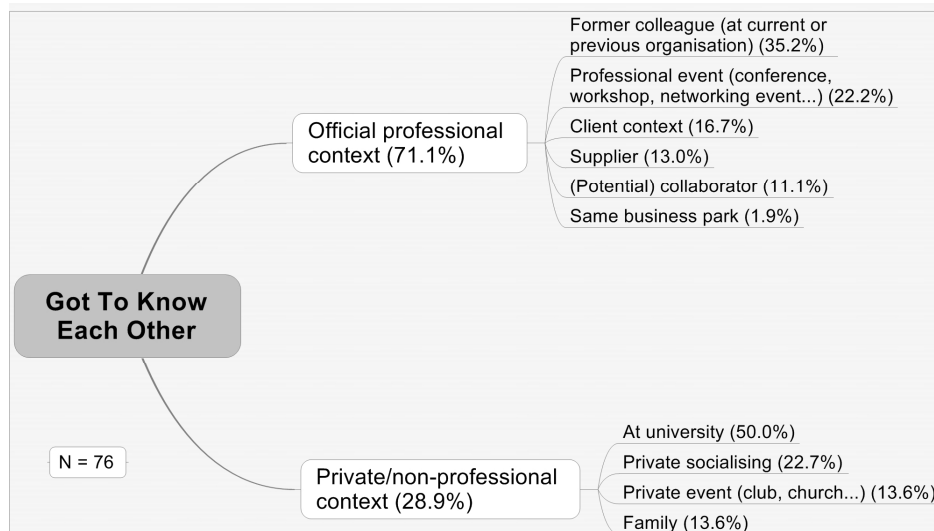
stages, the following sub-sections examine (i) the formation of relations, and (ii) their maintenance.

4.1. Formation of personal networks

On average the respondents got to know their most important contact 9.6 years ago (median 7.0 years, N = 70). That is, most are fairly long established contacts rather than ephemeral ones.⁶

But how exactly did they get to know each other? Overall, 71.1% of the most important knowledge contacts initially formed in the context of official work-related duties (see Figure 1). Most of those (35.2%) emerged as former colleagues at the current or the previous employer. Furthermore, 28.9% initially developed in a non-work-related situation. Most of those (50.0%) formed at university as fellow students (usually in the same field of study); for the rest it was through private socialising, private events (in a club or church) or private family contexts.

Figure 1. Getting to know the most important knowledge contact



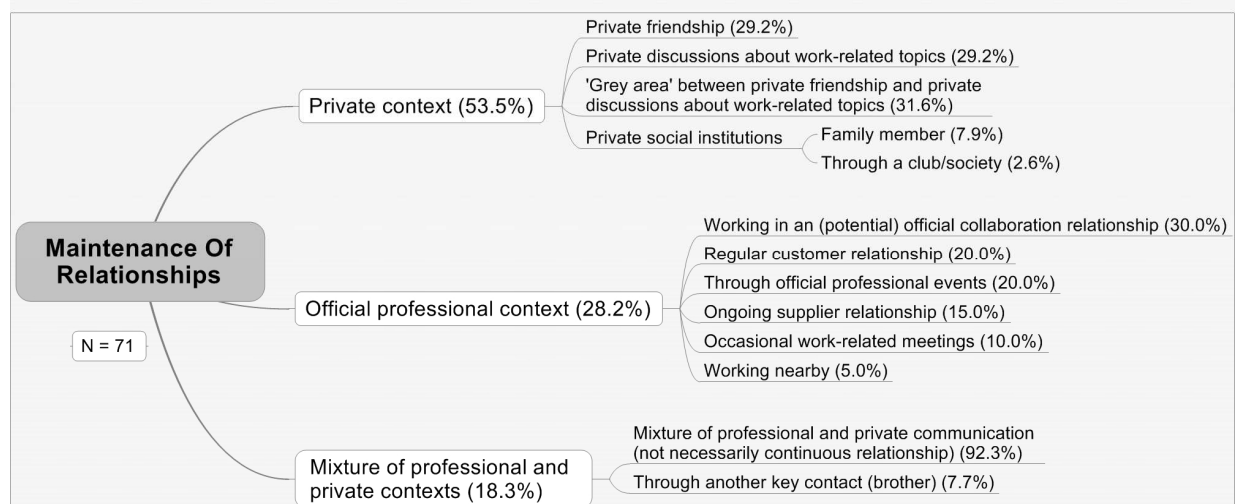
⁶ Although I reminded the interviewees that it does not matter how often they have met, it seems likely that the subjective selection of a 'most important contact for acquiring work-related knowledge in the past year' led to preferences towards long-established contacts.

To sum up, the vast majority of the contacts emerged in a professional context, most of them through working together in the same organisation or at professional events, which mirrors Granovetter’s (1974) results on the importance of official work contexts for subsequent inter-organisational information flows. The most widespread form of developing a relationship in a non-work-related context was being a fellow student. This suggests that shared experiences in contexts that are likely to facilitate a certain shared cognitive background tend to be critical for the formation of important personal knowledge relationships.

4.2. Maintenance of personal networks

An additional aspect is to understand how the relationships, once initiated, are maintained over time so that they can be a source of knowledge (see Figure 2).

Figure 2. Maintenance of the most important relationships



In 53.5% of the cases the contacts were maintained in *private spheres* of life.⁷ The vast majority of those cases is equally split into three groups: first, about 29% are centred on *private friendship* and the relationships were maintained through activities

⁷ However, recall that this is about personal contacts that have acted as a most important source of work-related knowledge in the past year. The category ‘private context’ refers to forms of maintenance that do not occur in official professional contexts.

such as: “We’re drinking partners really; we go to the pub” (junior-developer, small software company). In these cases, what drives the relationship is private friendship, and the receipt of useful work-related knowledge happened as a side-effect. A second, and different, type of private maintenance is *private discussions about work-related knowledge*. Here, the motivation to interact is centred in the interest to discuss work-related topics; but all this happens outside the official workplace and is ‘privately’ organised. This tends to be based on weaker personal ties, since these kinds of relationships can be more instrumentally focused on gaining work-related insights.⁸ Furthermore, a third category represents a ‘grey area’ between the first two categories: the motivation to maintain the relationship seems to come from a mixture of private friendship and private discussions about work-related knowledge, and the interviewees themselves do not seem to know which factor is more important for the relationship. Finally, for only a few respondents, social institutions were the underlying factor, and they interacted as a family member or through a club/society.

Moreover, only 28.2% maintained their relationship through *official professional* interaction. In particular, this was through working in a (potential) official collaboration, through regular customer or supplier relationships, or through attending professional events. These results reveal a time-effect: recalling that initially 71.1% of the relationships developed in official professional contexts, this illustrates that over time many relationships transformed from a professional context to private relationships outside of official work duties.

For 18.3% of the respondents, the maintenance operated through a mixture of professional and private interaction. A typical example for this would be the following:

⁸ Grabher’s (2004b) typology of communality and sociality uses the similar notions of ‘private cum professional’ and ‘professional cum private’ to characterise the first two types of personal relationships. However, as section 6 will discuss, the empirical cases are more variegated than the categories of communality and sociality.

“We both ended up working for Acorn. We were both there for a while, and we played squash regularly ever since then. And we worked together in two other companies. Our paths crossed quite a lot over the years. [...] When not working for the same company, we stayed in touch through squash or private meetings” (senior developer, large software company).

The multiple relationships between actors which has been dubbed multiplexity of ties (Grabher and Ibert, 2006) or overlapping networks (Ettliger, 2003) can have important implications because the actors can switch between the private dimension and the work-dimension. In a few cases this was the case when the private relationship also led to occasional contracting relationships. However, it is worth noting that private interaction does not need to be based on close friendship but is often quite strategic ‘networking’.

4.3. The overall picture: transforming social contexts

Now we are in a position to reflect on the overall picture of how the private/professional social context develops through the stages of the formation, maintenance, and knowledge interaction.

Table 2. Overview of the role of social contexts at various stages of personal networks

	Formation	Maintenance	At the time of gaining work-related knowledge⁹
Official professional context	71.1%	28.2%	31.3%
Purely private/non-professional context	28.9%	53.5%	55.4%
Mixture of professional and private contexts	0%	18.3%	13.3%

⁹ The data in this column are based on Table 1, which reflects the status at the time of gaining work-related knowledge.

Table 2 illustrates that many of the contacts who were initially professionally-centred—such as being a co-worker at the previous company—developed into private relationships (of different strengths) that operate beyond official professional duties. Whereas official professional contexts were important for 71.1% at the formation stage, only 28.2% were maintained through them, and only 31.3% of the contexts of gaining work-related knowledge were based on official professional contexts. The following quotation illustrates such a transition from a professional relationship to a private friendship:

“I maintained it through continuity of work with that customer. And it’s quite interesting, I think, sometimes if you meet someone like that, there’s an initial period where they may feel a little bit threatened by you as an outside consultant. And I think after about a year or two working together that all disappeared. [...] You get a feeling that you become real friends rather than just work colleagues”
(mid-level engineer, micro-sized hardware company).

Such kinds of transformations can subsequently lead to knowledge interactions even if there is no official work-relationship any more.

Overall, the results reveal that the social operation of personal knowledge relationships is dynamic: whilst professional contexts tend to be important for the formation, private contexts tend to become critical for maintaining, and gaining knowledge from, personal relationships.

5. The role of spatial proximity in the light of the mechanisms

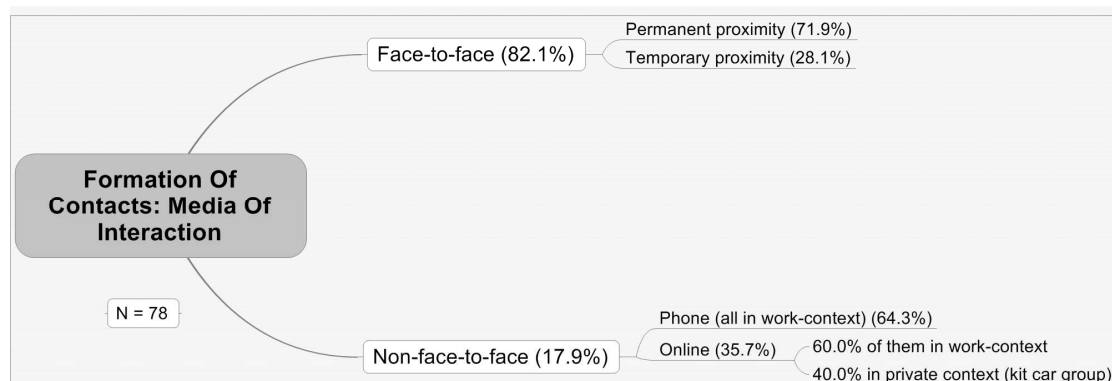
The discussion of the mechanisms of personal knowledge networks can serve as a basis for a fresh perspective on the role of spatial proximity. This enables an analysis that goes beyond a single static indicator of spatial proximity. First, this section discusses the role of spatial proximity for the formation and the maintenance of relationships. Then the current permanent location and the media of communication

for the most important knowledge interactions are examined. This serves as a basis for examining the hypothesis that the role of spatial proximity is most important for the formation but less important for maintenance and for work-related knowledge interactions.

5.1. The role of spatial proximity for the formation of relationships

A first way of exploring the role of spatial proximity is to see where the respondent and his/her most important knowledge contact got to know each other. Generally, 82.1% of the relationships originated in face-to-face situations (see Figure 3). More specifically, of those, 71.9% developed in a context of *permanent spatial proximity*, that is, permanent co-location at that point in time; and 38.5% of the respondents got to know each other in the Greater Cambridge Region. For 28.1% of the face-to-face contexts the formation occurred in a situation of *temporary proximity* (such as at an event). Furthermore, 17.9% of the contacts formed in a situation without any spatial proximity (permanent or temporary spatial proximity). In 64.3% of these cases without spatial proximity, the people initially got to know each other in a work-related telephone conversation; in 35.7% of the cases the relationship was formed online (all of them in a work-related context except of one case of a private online kit car group).

Figure 3. Spatial proximity: formation of the most important knowledge contacts

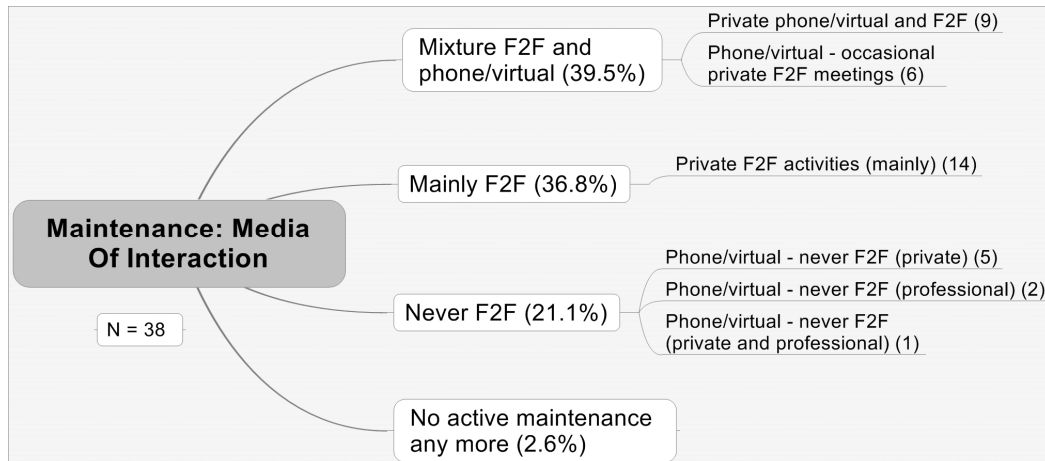


5.2. The role of spatial proximity for the maintenance of personal networks

A second, and different, perspective of spatial proximity is to examine the spatial dimensions of the maintenance practices. Figure 4 illustrates that 39.5% of the respondents maintained their relationship through a mixture of face-to-face meetings and telephone or internet-based communication. Furthermore, for 36.8% of the respondents the maintenance mainly operates through private face-to-face meetings. Interestingly, 21.1% mentioned that they never met face-to-face, but they interacted via telephone or the internet (usually in a private capacity). Also, in one case the relationship stopped and is not maintained any more.

Whilst face-to-face interaction is a key mechanism of interaction, these results suggest that the media of interaction are more diversified for the maintenance stage compared to the formation stage. Overall, 82.1% of the contacts formed initially in a context of temporary or permanent spatial proximity; for maintenance only 36.8% were mainly face-to-face and 39.5% were a mixture of face-to-face and other media of interaction. This confirms the result by Haythornthwaite and Wellman (1998) that very frequently multiple media are used for communication, particularly in close relationships. In other words, the interactions do not tend to fall into neat categories of specific media. Instead, the social interactions at the maintenance stage tend to be based on a complex mixture of media of communication according to the practical needs, wants and tastes of the individuals. Furthermore, there is no clear relationship between face-to-face (and the media of communication in general), and the strength of personal ties. For instance, friends who got to know each other in face-to-face contexts at university, but now happen to work in different geographical locations, can maintain their friendship without frequent face-to-face contacts.

Figure 4. Maintenance of the relationships: media of interaction



5.3. The permanent location of personal knowledge contacts: not so local after all

Let us now look at the most obvious indicator of spatial proximity. Table 3 presents the permanent location of the personal knowledge contacts (at the time of the data collection). For those who have contacts, about two thirds (64.1%) are located outside the Greater Cambridge region.

Table 3. Location of personal contacts. “Location of the personal contacts outside of your firm which were most important as a source of work-related knowledge in the past year”

	1 st contact	2 nd contact	3 rd contact	4 th contact	All 4 contacts	All 4 contacts
Greater Cambridge Region	29.1%	24.3%	19.4%	7.8%	20.2%	35.9%
Rest of London-Oxford-Cambridge triangle	18.5%	10.7%	4.9%	4.9%	9.7%	64.1%
Rest of UK	16.5%	13.6%	12.6%	6.8%	12.4%	
Rest of Europe	8.7%	6.8%	7.8%	1.9%	6.3%	
USA	9.7%	4.9%	1.9%	1.0%	4.4%	
Rest of the world	1.0%	4.9%	2.9%	1.9%	2.7%	
Do not know	0.0%	1.9%	0.0%	0.00%	0.5%	100%
Total contacts	83.5%	67.0%	49.5%	24.3%	56.1%	
No contact	16.5%	33.0%	50.5%	75.7%	43.9%	
Total	100% (N=103)	100% (N=103)	100% (N=103)	100% (N=103)	100% (N=412)	

This reinforces the survey results in Keeble et al. (1999) that for Cambridge high-technology companies the extra-firm ‘sources of innovating activities’ are strongly non-local. However, my findings highlight that also many personal (usually informal)

knowledge networks are non-local.¹⁰ The results confirm, but are even more pronounced than, the findings by Waters and Lawton Smith (2008) that a significant number of highly skilled scientists and engineers in Oxfordshire and Cambridgeshire have no social networks (generally defined), and non-local networks are more frequent than in-county networks.

The issue of whether the above percentages of non-local personal networks are surprising depends on the theoretical lens. On the one hand, some of the traditional literature, as mentioned in section 2.2, would tend to suggest that, because of the importance of regular face-to-face interaction, the non-local tendency is rather remarkable. According to this theoretical strand, co-location in the same region enables frequent face-to-face interaction, which facilitates communication and learning (e.g. Morgan, 2004; Storper and Venables, 2004). As it has often been argued, this process is also facilitated by a shared regional culture and shared institutions (e.g. Capello and Faggian, 2005; Lawson and Lorenz, 1999).

On the other hand, however, one could argue that given the rather small population of the Cambridge region—in particular if compared to the frequently mentioned ‘role model’ Silicon Valley—it is not surprising that so many contacts are located somewhere else. Furthermore, the vast majority of the most important personal knowledge networks are still within the UK, and, in particular for the first contacts, a high percentage is within the London-Oxford-Cambridge triangle (in fact, 58% of the existing most important contacts). This suggests that spatial proximity in a broader sense still matters. In particular, this illustrates that, despite IT being a relatively globalised industry, the national context is still prevalent for personal knowledge networks (recall that the vast majority of respondents are UK citizens). And given that much of the innovation-based IT activity in the UK is located within

¹⁰ By “local” I denote the Greater Cambridge Region.

the London-Oxford-Cambridge triangle¹¹, it is perhaps not that surprising that the contacts tend to be within this larger region. A detailed discussion on the question whether proximity in the Greater Cambridge region is beneficial for the R&D workers can be found in Huber (forthcoming-a, forthcoming-b).

Furthermore, a facet worth noting is that for purely private relationships, 51% of the single most important contacts are located within the Greater Cambridge region, whereas for professional contacts (including a mixture of private and professional) only 21% are within the Greater Cambridge region. This highlights that purely private contacts require more permanent spatial proximity than professional ones which can also be sustained over longer distances. No significant spatial differences were found in terms of analytical versus synthetic modes of knowledge creation (Asheim and Gertler, 2005; Moodysson et al., 2008).¹²

5.4. Media of communication for acquiring most valuable knowledge

A further dimension of the socio-spatial functioning of personal knowledge networks is which media of communication they have used for acquiring the most valuable piece of knowledge in the past year.¹³ As outlined in Table 4, most frequently they communicated face-to-face (49.4%).

¹¹ An indicator for this is that London, Oxford, Cambridge and parts of the Thames Valley receive over half of total venture investment in the UK (LibraryHouse, 2006)

¹² This was measured by investigating the type of knowledge which is rated most highly for contributing to the competitiveness of the firm. "Cutting-edge knowledge can be an important source of competitiveness for firms. With regard to the product you are working on: to what extent does your firm hold cutting-edge knowledge in the following areas that contributes to its competitiveness?". For contrasting analytic versus synthetic knowledge bases, the following types of knowledge were rated on a 7-point Likert scale from "1=very much" to 7="not at all": "Technological knowledge" versus "Specific knowledge about market needs gained from feedback from customers or suppliers".

¹³ Recall that this is based on nominations of 'most important' personal contacts. For some this concerns sourcing business/commercial knowledge, for others technological knowledge.

Table 4. Most valuable knowledge: how communicated?

	Frequency	Percent
Face-to-face	39	49.4%
Telephone	14	17.7%
Email	7	8.9%
Phone and email	7	8.9%
Face-to-face and email	6	7.6%
Face-to-face and phone	2	2.5%
Blog and email	1	1.3%
Closed online discussion group	1	1.3%
Instant messenger	1	1.3%
Phone and instant messenger	1	1.3%
Total	79	100.0%

One frequently mentioned reason why face-to-face communication is regarded as more efficient than other means is the ability to draw ideas on a board or on a piece of paper while discussing.

The second most frequently used medium is telephone (17.7%) followed by email (8.9%), a combination of phone and email (8.9%), a combination of face-to-face and email (7.6%) and a combination of face-to-face and phone (2.5%). Again, this illustrates that the respondents often used a combination of different media. Furthermore, one has to bear in mind that the event of ‘acquiring the most valuable piece of knowledge in the past year’ only reflects a snapshot in the sequence of communication. That is, additional work-related communication with different media of communication might have taken place before this specific event.

Because setting up face-to-face meetings is more time-consuming and often not quick enough, phone calls are preferred by several respondents. A crucial aspect is that even if the people regularly meet face-to-face, work-related communication can be via phone:

“Definitely it would have been over the phone. The problem is if you meet face-to-face you’re so busy doing things, oh let’s go to the cinema, let’s go to the theatre, whatever. So, you never really have time to sit down and have a sort of personal

communication. So, it's mostly over the phone" (mid-level developer, medium-sized software company).

That is, face-to-face helps to maintain the relationship, but does not lead to work-related knowledge gains.

Furthermore, next to email, several software engineers use *instant messenger* to communicate work-related matters:

"It would almost certainly have been instant messenger, almost certainly. Yes, we tend to be too drunk when we meet face-to-face to pass useful knowledge in one way or the other" (development director, medium-sized software company).

Again, this quote also highlights the spatial difference between the maintenance of the relationships and work-related communication, the latter of which is often not based on face-to-face.

5.5. The overall picture: the role of spatial proximity varies

Let us now reflect on the previous sections and discuss whether the role of spatial varies for the stages of network mechanisms (see Table 5). Overall, whilst permanent spatial proximity is very widespread at the formation stage of the contacts (59%), later on it becomes less important: only 35.6% of the contacts are permanently located within the Greater Cambridge region at the time of the data collection.

Furthermore, in terms of the means of communication, 82.1% formed their relationship in a face-to-face situation. For the maintenance of the relations over time the role of face-to-face communication remains pretty high (76.3%) but often in combination with other media: only 37.8% were mainly face-to-face and 40.5% were a mixture of face-to-face and other media of interaction. Interestingly, for gaining the most important piece of knowledge in the past year, 59.4% happened in a face-to-face context, which is still rather high but significantly less than in the previous contexts.

That is, whilst face-to-face plays a dominant role in particular for the formation stage and still a significant role for the maintenance stage, it is less important for the actual practices of work-related knowledge interactions. Hence, we can confirm the hypothesis that the role of spatial proximity is most important for the formation stage.

Table 5. Overview of the role of spatial proximity at various stages of personal networks

	Formation	Maintenance	At the time of gaining work-related knowledge
Permanent spatial proximity	59%		35.6% within the Greater Cambridge region
Face-to-face communication	82.1% face-to-face 59% permanent spatial proximity + 23.1% temporary spatial proximity	76.3% face-to-face (purely or a mixture) 21.1% never face-to-face (only telephone online)	Most important piece of knowledge: 59.4% face-to-face (either purely or in combination with email or telephone) 40.6% entirely non-face-to-face (telephone or online)

Also, it has to be highlighted that the distinction between the maintenance of personal network relations and knowledge flows through these relations is critical for understanding the role of face-to-face interactions. Several interviewees—a few quotations in the previous section above illustrate this—maintain their social relationship through private face-to-face activities (such as going to the cinema or getting drunk in the pub) but communicate work-related knowledge in non-face-to-face situations via telephone or the internet.

In conclusion, the role of spatial proximity varies according to the stage of the network mechanism. The results confirm the hypothesis that the role of spatial proximity is most important for the formation stage. More specifically, whilst spatial proximity is very important for the formation of networks, maintenance tends to operate as a combination of face-to-face and telephone or online communication. For

gaining the most important pieces of work-related knowledge, the role of face-to-face is still widespread but considerably less important than for the formation or maintenance of relations.

6. Conceptual nature of personal knowledge networks: beyond collective communities

Let us now turn to the broader question of how we can conceptualise the personal knowledge networks in the light of the dynamic stages of social interaction. This section critically discusses to what extent the prominent concepts of communities of practice/epistemic communities and communality/sociality/connectivity are appropriate characterisations and argues for an alternative concept of individualised networks.

6.1. The social architecture: beyond collective communities, towards individualised networks

Let us first explore whether the social architecture of the personal relationships can be characterised by group interaction, as often emphasised by the notions of communities of practice/epistemic communities. The interviewees were asked to indicate whether the nominated personal contacts know each other. If yes, I also inquired whether they are communicating with them as a group/community or on a one-to-one individual basis.

The empirical results show that the most important extra-firm knowledge relationships are of a highly dyadic (one-to-one) nature. Given up to four nominated contacts, the maximum possible number of personal acquaintance among those contacts is six. If they mention three contacts, the maximum possible number of potential relationships among them is three, and if they nominate two contacts,

obviously the maximum number of is one. Overall, among those who mentioned more than one contact, only one relationship exists among the contacts on average, and most frequently (45.6%) no relationship exists at all (see Table 6 for further details).

Table 6. Most important contacts: number of pairs who know each other (max. 6)

	Frequency	Percent
0	31	45.6%
1	20	29.4%
2	9	13.2%
3	7	10.3%
4	1	1.5%
Total	68	100.0%

A comparison of the number of actual relationships among the nominated contacts to the maximum number of possible relationships shows that only 29% of the potentially possible relations actually exist. Given these insights, it seems that the social organisation of most important personal knowledge relationships is rather individualised in one-to-one relations rather than in collective communities.

Yet, clearly the respondent and the contact might discuss in group situations with other people that are not mentioned on the list. However, the vast majority of the respondents commented that in terms of gaining work-related knowledge they interacted with the nominated contacts in one-to-one contexts and never in group-situations including online communities (88%). Only very few (12%) discussed in group contexts at work or in private meetings among friends (in pubs etc.).

Furthermore, the dyadic relationships could still be part of coherent knowledge communities through sequential one-to-one communication. Yet, nearly all of the respective respondents emphasised that this was not the case. With regard to work-related knowledge gained from the contacts, the dyads do not seem to be part of a coherent group: the respondents do not see any typical features of community interaction such as mutual engagement as a group or a collective sense.

Given these results, it appears that the knowledge practices in personal networks with people outside of the company do not tend to be based on collective group interactions as emphasised by the discourse on communities of practice/epistemic communities. Instead, individualised network relations that operate on a one-to-one level are predominant. This seems to be part of the important social trend in modern societies that persons increasingly construct their contact networks around them in an individualised way. Wellman (2002) has called this phenomenon *networked individualism*: a transformation from a group based society to a society based on individualised personal networks. Each individual person actively manages her network of personal contacts according to her needs, wants and tastes.

However, this does not obliterate the general social character of knowledge production, which is rooted in situated social practices (e.g. Ibert, 2007): first, the R&D workers are embedded in work groups within their firm, and many of them are also active in online communities or other forms of professional interaction through professional events or publications. And second, personal knowledge relationships between organisations, even if they are dyadic, can link knowledge communities in different organisations (bridging structural holes according to Burt, 2005).¹⁴ Dyadic relationships can still build up a web of relationships that can lead to diffusion of knowledge. Granted, the ego-network analysis is not able to investigate how those personal relationships are embedded in broader network structures. Yet, all this does not undermine the argument that the most important personal knowledge relationships (as nominated by the interviewees) tend to operate on a dyadic level rather than collectively on a group-level or in an online community.

To conclude, the social organisation of knowledge interaction in this study seems to be best described by *individualised networks* that are governed by individuals

¹⁴ However, as discussed in more detail in Huber (forthcoming-a), there seem to be surprisingly few personal relationships that lead to technological knowledge transmission between firms in the Cambridge Cluster.

rather than collective groups. Although knowledge work is inherently a social activity, the results suggest that typical features of coherent communities such as a collective sense or mutual engagement as a group or online community tend to be absent for those knowledge relationships.

6.2. Communality, sociality, connectivity?

As discussed in section 2.3, Grabher and Ibert (Grabher, 2004a; Grabher and Ibert, 2006) have developed an alternative typology of modes of networking in project-based work environments. This contribution de-homogenises knowledge networks by differentiating between the ideal-types of communality, sociality and connectivity.

Whilst the data contained several cases which seem to operate exactly as communality, sociality or connectivity, these concepts do not cover the majority of the empirical cases in the study. The main reason for this is that the stylised notions of communality, sociality and connectivity seem to combine specific elements of (i) the formation of networks, (ii) the maintenance of networks, and (iii) the type of knowledge transferred through networks and (iv) other qualities of personal relations. For instance, communality combines the formation of networks typically through “shared experience at school or university”, which evolve “into enduring bonds that embrace mutual acquaintance with family members and friends” (Grabher, 2004a, 115). Such relations are based on trust-based ‘thick ties’, which lead to knowledge flows about “contemplating career decisions, discussing conflicts within the core team, exchanging experiences with specific tools and methods and reflecting on technical and organizational issues beyond the day-to-day project frenzy” (Grabher, 2004a, 115). In particular, the project workers use these ties as a confidential “sounding board for frustrations and tensions that cannot be discussed openly with colleagues, let alone supervisors or project partners” (Grabher and Ibert, 2006, 259).

The majority of the cases of the personal knowledge relationships show a *combination* of the formation, maintenance, knowledge flows and tie characteristics that is *different* to the ideal-types of communality, sociality and connectivity. For instance, there are several relationships which formed on the basis of a shared experience in school or university but did not develop into ‘thick ties’ (in contrast to communality). Several of those relationships which were ‘thick ties’ in terms of high levels of tie strength did not lead to the transfer of confidential knowledge but rather of more superficial types of knowledge (therefore we cannot call it communality). Conversely, socially ‘thin’ strategic ties sometimes lead to chats about confidential knowledge. Furthermore, several relationships which show otherwise typical characteristics of communality or sociality were not maintained through face-to-face interaction (as suggested by communality and sociality, see Grabher, 2004a, 115) but through other media of communication. Moreover, several relationships show typical tie characteristics of sociality and yet lead to task-oriented know-how transfer which would be typical for connectivity. Also, in two cases personal contacts that are communicating work-related knowledge with their most important knowledge contact via online discussion forums also meet each other face-to-face (contrary to the notion of connectivity).

Overall, the data suggests that the combinations of the formation, the maintenance, the type of knowledge interaction and the tie characteristics are more variegated than the notions of communality, sociality and connectivity suggest. This confirms the view, noted by the authors themselves (Grabher, 2004a, 114; Grabher and Ibert, 2006, 258-259), that these concepts have to be treated as ideal-types. In real-world examples there is a complex continuum and interpenetration of types of networks and modes of networking that can be changing over time. Again, the notion

of individualised networks helps to understand the complex ways in which R&D workers manage their personal knowledge relationships.

7. Conclusions

This paper aimed to fill two interrelated voids in the literature: a lack of understanding of the detailed social mechanisms of extra-firm personal knowledge networks and a lack of empirical research on the exact role of spatial proximity for personal knowledge networks. The novel perspective of this contribution is to adopt a dynamic perspective on the socio-spatial functioning of personal knowledge networks: the paper argued that rather than looking at static characteristics of personal knowledge relationships, to understand the phenomenon and the social mechanisms of networks, we need to differentiate between and analyse (i) the formation and (ii) the maintenance of personal knowledge networks, and (iii) the contexts of knowledge interaction. The study focused on personal contacts which were nominated by the interviewees to be the most important extra-firm knowledge contacts in the past year.

The first contribution of the paper is to clarify how the private/professional social context develops through the stages of the *formation, maintenance and knowledge interaction*. The vast majority of the contacts emerged through a professional context, most of them through working together in the same organisation or at professional events. Most of those contacts that initially developed in a non-work-related context were formed at university as fellow students. That is, a common past experience—either through working at the same organisation or studying at the same source—seemed to shape a common cognitive context, which seems to serve as a foundation for subsequently useful personal knowledge relationships (cf. Huber, forthcoming-b). However, the majority of the respondents maintained their relationship with the most important knowledge contact through purely private interactions. That is, many of the

contacts transformed from an initially professional context—such as being a co-worker at the previous company—into private relationships beyond official professional duties. These results contribute to a more subtle understanding of the formal versus informal dimension of knowledge networks by highlighting the dynamic nature of network mechanisms.

The second contribution of this paper is to clarify the role of *spatial proximity* for personal knowledge relationships. Critically, the novel perspective is to link the discussion of spatial proximity with the discussion of the dynamic mechanisms of networks. The results showed that the role of spatial proximity varies for the formation of networks, the maintenance of network relations and the transfer of knowledge. Specifically, the hypothesis was confirmed that permanent spatial proximity and face-to-face interaction are most important for the formation of relationships; face-to-face interaction is less important for the maintenance stage and, even less important for work-related knowledge interactions. This new perspective on spatial proximity in the light of dynamic social mechanisms leads to a more elaborate understanding of the spatiality of knowledge networks. This highlights that the focus of the existing literature on static dimensions of spatial proximity and knowledge flows is limited and only a dynamic perspective on the stages of social mechanisms can reveal the significance of space for knowledge relationships.

Finally, the third contribution of the paper is to discuss an appropriate theoretical conceptualisation of the personal knowledge networks in the light of their mechanisms. The results demonstrated that the personal knowledge relationships of the study do not tend to be based on collective interaction in groups or online communities as the concepts of communities of practice and epistemic communities have often highlighted. Instead, the paper argued that the alternative notion of *individualised networks* (Wellman, 2002) grasps the non-group-based but person-

centred, dyadic operation of network practices. Furthermore, it was discussed that the ideal-types of communality, sociality and communitary by Grabher and Ibert (Grabher, 2004a; Grabher and Ibert, 2006) are important in highlighting the variety of personal knowledge networks but do not explain the majority of the knowledge relationships in this study: the combination of the contexts of formation, maintenance, knowledge interaction and tie characteristics in the data tends to be more complex. All this leads to a more nuanced understanding of the conceptual architecture of personal knowledge relationships, and it highlights the individualised operation of personal relationships.

Since the empirical results are based on a specific industry in an exceptional high-technology cluster, uncertainty remains about the generalisability of the findings. One might argue that the role of permanent spatial proximity is less important for regions that do not constitute such a significant agglomeration of innovative firms. However, whether the results reflect more general tendencies regarding the socio-spatial practices of knowledge workers needs to be addressed by further studies.

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