Crossing domain-specific boundaries in search of innovation:

Exploring the potential of 'pyramiding'

Marion K. Poetz* and Reinhard Prügl**

Working Paper

A later version of this paper has been published in the
Journal of Product Innovation Management 27(6), 897-914, 2010

*Assistant Professor, Department of Innovation and Organizational Economics
Copenhagen Business School
Kilevej 14 A
2000 Frederiksberg, Denmark
Phone: (+45) 3815-2914
E-mail: mp.ino@cbs.dk

** Junior Professor, Chair of Innovation, Technology and Entrepreneurship
Zeppelin University
Am Seemooser Horn 20
88045 Friedrichshafen, Germany
Phone: (+49) 7541 6009-1283
E-mail: reinhard.pruegl@zeppelin-university.de

Authors' note: Both authors contributed equally. We would like to thank Christian Fabsich and Pascal Staud for their valuable help in realizing this study. We also thank Christian Lüthje, Serden Özcan, Roberto Verganti and the participants in the International Product Development Management Conference 2009 (IPDMC) and the User and Open Innovation Conference 2009 for their comments and feedback on earlier versions of this article. Finally, we are grateful for having received funding from the Danish Enterprise and Construction Authority (EBST) for this research initiative.

Abstract: For many years, it has remained unquestioned that developing innovation mainly happens within the boundaries of organizations' own R&D and/or marketing departments, i.e. is an activity based on (re-)using local expertise. The negative effect of this local search behavior on the novelty of the outcome, however, is one of the reasons why researchers and innovation managers are increasingly discussing the idea of opening up innovation processes by drawing on external problem solvers. In particular, problem solvers located in contextually distant but *analogous domains* (i.e. domains linked by similar problems) are capable of contributing to overcoming 'local search bias': As they do not suffer from 'functional fixedness' but experience a similar ('analogous') problem, they are capable of coming up with highly novel solutions. In theory, a recently introduced search approach known as 'pyramiding' holds great potential for crossing domain-specific boundaries and identifying problem solvers from contextually distant domains. Although initial practical applications of this search method, for example in the course of applying the lead user method, provide anecdotal evidence, systematic research on the potential of pyramiding for crossing domain-specific boundaries is still lacking to date. This study addresses this gap by analyzing 1,147 interviews conducted in the course of pyramiding search processes in eight lead user studies. The authors find that pyramiding is an apt means of systematically crossing domain-specific boundaries: More than one third of those interviewees who were able to provide a valid referral in their interview performed the creative task of referring into one or more analogous domains *previously unknown* to the searching organization. The interviewees' levels of expertise as well as their domain origins influence the likelihood of a domain-crossing referral. Moreover, the type of industry in which the search field is located is found to moderate the effect of expertise on the likelihood of a referral into an analogous domain.

Introduction

In their search for innovations, organizations can either exploit their *internal* expertise and knowledge bases ('local search') or systematically explore new knowledge located *outside* of their boundaries (March 1991). Although local search behavior is still a very dominant and often useful approach in generating innovations (e.g. Nelson and Winter 1982, Stuart and Podolny 1996), organizations have started recognizing the downside of this strategy, which is known as *'local search bias'*: Relying too heavily on internal expertise might block organizations from finding alternative, potentially more successful solutions to innovation-related problems (Helfat 1994, March 1991, Martin and Mitchell 1998, von Hippel 1994). Organizations thus increasingly draw on various distributed sources of innovation by collaborating with *external* problem solvers to enhance their innovation capabilities (e.g. Agerfalk and Fitzgerald 2008, Fleming and Waguespack 2007, Jeppesen and Frederiksen 2006, Nambisan and Sawhney 2007, Pisano and Verganti 2008). Recent empirical research shows that how *widely* a firm explores external knowledge strongly influences its performance in creating new products and services – at least to certain degree (e.g. Atuahene-Gima et al. 2005, Huston and Sakkab 2006, Katila and Ahuja 2002).

However, even if organizations open up their innovation activities, 'they too often look only where they always look. That won't get them anywhere' (Bessant, Möslein, and von Stamm 2009, p. R4). These authors illustrate such attitudes toward searches with the man from a well-known joke who can't find his keys. When his friend asks him why he's looking for the keys under the lamppost when he dropped them over on the lawn, he responds 'Because there's more light over here'. With novelty being a distinguishing factor of successful innovation (e.g. Amabile et al. 2005), the *distance* between the context of the organization facing the problem and the context of potential problem solvers seems to be an important factor in 'getting somewhere' in the search for innovations (e.g. Lakhani et al. 2007).

Especially problem solvers from *analogous domains* are capable of contributing to this task: As they do not suffer from 'functional fixedness' (Duncker 1945) but experience a similar ('analogous') problem, they tend to be capable of coming up with highly novel solutions and may thus help to overcome 'local search biases' (e.g. Rosenkopf and Nerkar 2001, Stuart and Podolny 1996) in generating innovations. Recent empirical research strongly supports the idea that solutions created by problem solvers from analogous domains score significantly higher on novelty than solutions developed by problem solvers belonging to the target domain (e.g. Franke and Poetz 2008, Lilien et al. 2002).

The remaining challenge lies in the fact that finding problem solvers located in contextually[1] distant domains (e.g. analogous markets or industries) can be difficult because 'discovering the relevance of a particular analogous domain is itself a creative act' (von Hippel 2005, p. 135). Thus, the logical next step is to systematically identify external problem solvers from analogous domains and integrate them into corporate innovation efforts – which is obviously not an easy task. More generally speaking, the need to identify actors with very specific, rare expertise (e.g. stemming from a relevant analogous field and being capable of contributing (at least parts of) a successful solution) in an economical manner within large, poorly-mapped search spaces is a frequently encountered problem among innovation researchers and managers (e.g. Olson and Bakke 2001, Lilien et al. 2002, von Hippel, Franke and Prügl 2009).

One search method which has been found useful in this regard is called 'pyramiding' (von Hippel, Thomke and Sonnack 1999, von Hippel, Franke and Prügl 2009). Pyramiding is a search process based upon the idea that people with a strong interest in a given attribute or quality, for example a particular type of expertise, will tend to know of people who *know*

[1] In this study the term 'contextually distant' is used to avoid any confusion with geographical distance. Problem solvers from contextually distant domains may be located in both close and distant geographical areas. For example, a medical firm searching for innovations related to infection prevention in surgery might find potential solutions in other domains where it is important to avoid air pollution or contamination, such as computer chip production. A potential problem solver from the computer chip industry might be geographically located in the same area or somewhere else on the globe.

more about and/or have more of that attribute than they themselves do (von Hippel, Thomke and Sonnack 1999). The pyramiding process is quite simple in concept: One simply asks an individual to identify one or more others who she thinks have higher levels of the attribute sought – or better information regarding who such people might be. The researcher then poses the same question to the persons so identified, and continues the process until individuals with the desired high levels of the attribute (the 'top of the pyramid') have been identified (von Hippel, Franke and Prügl 2009). Recently, von Hippel, Franke and Prügl (2009) showed empirically in a number of experiments that pyramiding is a highly efficient search method for the identification of actors with specific rare characteristics or expertise (e.g. being a leading-edge user or an expert in a certain field) within large, poorly-mapped search spaces under various conditions. In addition to this efficiency advantage, pyramiding also holds two potential method-specific advantages: (1) It provides an opportunity to learn from each actor contacted and to use this learning to improve the search 'on the fly' in the course of data collection by modifying the search question continuously, and (2) it allows (or even invites) referrals to potential problem solvers *outside* of a predefined population (or domain; von Hippel, Franke and Prügl 2009).

In this article, the authors elaborate on the latter potential of pyramiding described above, which clearly requires further study. For example, in the pyramiding process, one could ask subjects, 'Who in your organization *or elsewhere* do you think has more insight on this problem?', whereas other search methods (e.g. screening) are restricted to a predefined population. The ability of pyramiding to cross domain-specific boundaries has already found practical applications in lead user studies (von Hippel, Thomke and Sonnack 1999; Lilien et al. 2002; Hienerth, Poetz and von Hippel 2007). Lead users at the top of the pyramid in a given target market often lack information and exchange possibilities in their own field and are thus likely to be networked with various other ('analogous') fields (von Hippel 2005).

Figure 1 provides a schematic illustration of such a 'pyramiding search' yielding referrals to actors outside a predefined population and thus crossing domain-specific boundaries.

Insert Figure 1 about here

Given the theoretical foundation and the fact that it seems to work in certain practical applications, there is a need for more systematic empirical research on the potential of the pyramiding search method for crossing domain-specific boundaries in search of innovation. Basically, three important questions need to be answered: 1) Does the pyramiding search method systematically provide a means of crossing domain-specific boundaries in search of innovation? If yes, 2) how can these domain-crossing referrals be characterized? Most importantly, (3) what drives the likelihood of domain-crossing referrals? In this article, these questions are empirically addressed by analyzing the pyramiding search processes used in eight lead user studies conducted between 2005 and 2008. Following a qualitative content analysis approach (Strauss and Corbin 1990), the authors were able to draw on and code 1,147 pyramiding interview transcripts in order to examine the existence of domain-crossing referrals and their drivers and characteristics.

It is believed that empirical insights into these questions will contribute to a better understanding of how organizations can access and leverage distributed innovation sources located outside the boundaries of their own knowledge domain (market or industry) – an issue that is increasingly discussed by academics and practitioners. As novelty is a key driver of successful innovation, organizations which manage to cross domain-specific boundaries and collaborate with problem solvers from contextually distant (but specifically analogous) domains are likely to be more successful in their search for innovations. The theoretical contribution of this research is thus twofold. (1) Organizational search theory is extended by addressing the aspect of search into domains previously unknown to the searching organization, and (2) organizations' search toolboxes are enriched by adding a search

approach for accessing contextually distant knowledge. In doing so, the authors discuss the implications of how to deal with the functional fixedness of organizations not by increasing absorptive capacity per se, but by improving absorptive capacity on a meta-level, that is, enabling organizations to use their knowledge about search mechanisms in the development of new products and services.

Background: Crossing domain-specific boundaries in search for innovation

The value of overcoming local search biases

As outlined above, 'the absence of effective search ensures that organizations may never see or react successfully to external stimuli with important implications for organizational performance' (Hrebiniak and Joyce 2002, p. 1). Ways to search for (external) knowledge located in various distributed sources of innovation have thus seen increasing attention in innovation research and practice. Huston and Sakkab (2006), for example, report that Procter & Gamble's open innovation strategy 'connect + develop' aimed – among other objectives – to develop at least 50 percent of innovations outside the boundaries of P&G's own R&D labs. As a result, more than 35 percent of new products in the marketplace include elements originally developed outside P&G. Furthermore, 45 percent of initiatives within the product-development portfolio include externally discovered core elements. Through the 'connect + develop' initiative, R&D productivity was increased by approximately 60 percent, the success rates of new products almost doubled, and R&D costs were reduced from 4.8 percent in 2000 to 3.4 percent in 2006 (Huston and Sakkab 2006). In a similar vein, Lilien et al. (2002) refer to encouraging results in working with lead users as distributed problem solvers. In their study comparing the performance of lead user-generated ideas versus ideas generated using a traditional in-house approach within 3M, they find that lead user-generated ideas score

significantly higher on novelty, strategic importance and sales potential, and that such ideas generate radical, breakthrough concepts at a higher rate.

More generally, crossing organizational boundaries makes it possible to access and leverage a larger and more diverse set of distributed sources of innovation, thus helping to overcome the negative effects of prior knowledge on the novelty of outcomes (known as 'functional fixedness' at the individual level, Duncker 1945, and 'local search bias' at the organizational level, e.g. Stuart and Podolny 1996). Katila and Ahuja (2002) add to this discussion by analyzing the effects of exploiting company-internal expertise versus exploring external knowledge on new product performance in the global robotics industry. They find that using and re-using existing internal knowledge does foster the generation of new products, but the relation is curvilinear, indicating that beyond a certain point the additional exploitation of internal expertise will lead to a drop in new product output. At the same time, they find that how widely a firm explores external knowledge has a positive and linear effect on new product innovation. Poetz and Schreier (2010) provide a first empirical test related to the value of integrating external knowledge using a crowdsourcing process. They report that ideas generated by crowdsourcing among users outperform ideas generated in-house by a firm's professional marketers, engineers and designers (for the same innovation-related problem) in the dimensions of novelty and customer benefit.

Based on the insight that novelty is a key factor in successful innovation (Amabile et al. 2005), the ability to access and leverage distributed sources of innovation has a positive influence on innovation performance. As already indicated in the examples mentioned above, distributed sources of innovation are located among different groups of problem solvers (users, universities, suppliers, etc.) and vary in terms of distance to the context of the organization facing the problem: They may be located within an organization's own industry or *outside* its boundaries (e.g. Klevorick et al. 1995, von Hippel 1988). Overcoming not only

organizational but also domain-specific boundaries (e.g. industry or market boundaries) makes it possible to access potential problem solvers who are located at a greater distance from the problem context of the organization and will thus bring about higher novelty in the outcomes (Lakhani et al. 2007).

Tapping into the knowledge of distant domains (industries/markets) which share a similar ('analogous') problem appears to be a promising approach to generating successful innovations. For example, the antilock braking system (ABS) – which is standard equipment in cars nowadays – was developed by systematically searching for advanced analogous markets which face similar and even more extreme braking needs. Car manufacturers found this analogous market in the aircraft industry and succeeded in transferring the solution to their target market (von Hippel 2005). In a similar vein, von Hippel, Thomke and Sonnack (1999) report on a lead user study which focuses on medical imaging (e.g. in order to detect very small features such as early-stage tumors). During the search process, the project team identified a number of radiologists who were working on the most challenging medical imaging problems and were thus lead users within the target market. It turned out that those target market lead users knew about people who were even further ahead in all important areas of imaging, like specialists in pattern recognition and specialists from the semiconductor chip industry who were working on images that show even the finest details of computer chips. In the end, lead users from pattern recognition in the military sector had tremendous solution knowledge on computerized pattern recognition methods. These lead users from an analogous domain had already developed ways to enhance the resolution of the images by adapting pattern recognition software accordingly (von Hippel, Thomke and Sonnack 1999).

As they do not suffer from the same 'functional fixedness' (Duncker 1945) as the searching entity, distributed problem solvers from analogous domains (e.g. industries, markets, etc.) come up with highly novel solutions and thus help to overcome 'local search biases' in

generating innovations. Recent empirical research strongly supports the idea that solutions developed by problem solvers from analogous domains score significantly higher on novelty than solutions generated by problem solvers belonging to the target market (e.g. Franke and Poetz 2008, Lakhani et al. 2007). The more contextually distant an analogous domain is, the more novel the solutions developed by problem solvers from that domain will be (Hienerth, Poetz and von Hippel 2007). The type of similarity between two contexts (in this study industries/markets) may vary with the distance (near vs. far) between the base and the target context and influence the novelty of solutions accordingly (Dahl and Moreau 2002, Hienerth, Poetz and von Hippel 2007, Lakhani et al 2007). Following the cognitive concepts of near vs. far analogies (e.g. Genter et al. 1997, Perkins 1997, Ward 1998), near analogous markets can thus be considered to exhibit similarities based on surface-level attributes, whereas far analogous markets show similarities in deep-structure attributes (Dahl and Moreau 2002).

Selected approaches for systematically tapping into the knowledge of contextually distant domains

Contextually distant knowledge domains for solving target domain problems can either be assessed cognitively within the entity facing the problem or by systematically searching for problem solvers located in contextually distant domains (markets/industries). For the cognitive approach, company-internal individuals might be stimulated to apply an analogous-thinking strategy (e.g. Dahl and Moreau 2002) by using techniques such as brainstorming (Osborn 1941), synectics (Gordon 1961), or TRIZ (e.g. Terninko, Zusman and Zlotin 1998). The 'search for external problem solvers' strategy, which is directly relevant to the research of this study, refers to asking problem solvers from contextually distant domains for solutions to a problem in a certain target domain (Lilien et al 2002, Franke and Poetz 2008).

Existing research provides only limited answers to how organizations can systematically search for knowledgeable problem solvers located in contextually distant domains.

Nevertheless, from a theoretical point of view, two approaches – namely the 'broadcast search' and 'pyramiding search' methods – seem to have the strongest potential and have already been used in initial practical applications. The first approach draws on Linus' Law ('Given enough eyeballs, all bugs are shallow'), indicating that every problem will be transparent to somebody – who is not necessarily from the same field (Raymond 1999). Broadcasting a problem to a large and diverse crowd of potential problem solvers might trigger self-selection among this crowd based on the recognition of problem similarities. Jeppesen and Lakhani (2009) first studied the broadcast search method based on the Innocentive.com business model. Innocentive.com acts as a knowledge broker between organizations which face certain problems and a large crowd of potential problem solvers (> 80,000 independent scientists from 160 countries). The authors found that around 30 percent of the problems broadcast to the group of scientists were solved by members of this crowd (note that the organizations were not able to resolve the problems broadcast internally for six months to two years). Additionally, Jeppesen and Lakhani (2009) were able to show that the provider of the 'winning solution' spends an average of only 70 hours developing this solution to an 'unsolvable problem' for the respective organization. Furthermore – and most importantly for this research project – they found that successful solutions are often provided by problem solvers located *outside* the focal problem area with a large (contextual) distance between the problem and the solver's own field of expertise. This finding indicates that the broadcast search method holds the potential to attract problem solvers from various distant (and presumably analogous) domains.

The second approach relates to identifying rare characteristics or expertise using a system of referrals from the ‘bottom to the top of the pyramid’. In a first empirical exploration of the efficiency of 'pyramiding searches', von Hippel, Franke and Prügl (2009) found that this search approach is effective *and* efficient under many conditions. By conducting four

experimental studies, the authors find that (1) pyramiding is able to identify the best solution within the search space in each case, and (2) by running several Monte Carlo simulations they show that even in a very restrictive and thus conservative setting, an average of only 28% of the effort required for mass screening (i.e. sending out a questionnaire to a predefined population) is needed in order to reach the best solution within the search space.

An important attribute of the pyramiding search method (not explored or tested in von Hippel, Franke and Prügl 2009) is that it allows (or invites) referrals to people *outside* a predefined population, whereas other search methods such as mass screening of a certain population for a certain type of knowledge are restricted to a predefined population. This holds true for the previously described broadcast search method as well, as the effects of self-selection are restricted to the crowd to which the problem is made visible. The (so far theoretical) ability of pyramiding to cross population boundaries has already found practical applications in lead user studies (von Hippel, Thomke and Sonnack, 1999; Lilien et al 2002; Hienerth, Poetz and von Hippel 2007). For example, in the case of a lead user study in the field of medical imaging already mentioned above, leading-edge radiologists from the target market were able to refer to lead users in the military sector (analogous market) with tremendous solution knowledge on computerized pattern recognition methods. Lead users at the 'top of the pyramid' in a certain target market under study often lack information and exchange possibilities in their own fields and are thus likely to be networked with various other (analogous) fields (von Hippel 2005), indicating that the level of expertise might be a driver for the likelihood of referrals into analogous markets (see figure 1). Furthermore, the functional fixedness of the searching entity affects the ability to break out of the familiar context not only in generating innovations but also in seeing the similarities between different contexts (Perkins 1997) and subsequently the ability of target domain individuals or organizations to refer to contextually distant domains. This is specifically an issue when very

distant analogous domains (where similarities are based more on deep-structure than on surface-level attributes) need to be accessed (Bhatta and Goel 1994).

Given the theoretical potential of pyramiding to cross (sub-)population boundaries and the anecdotal evidence from real-world innovation projects, it is concluded that there is a strong need to fill this gap with a first systematic and empirical analysis of this search method's potential for crossing domain-specific boundaries in search of innovation.

Research Method

Due to the lack of prior empirical research on this method's potential for crossing domain-specific boundaries in search of innovation, this study opted for a qualitative content analysis to answer the research questions. The research design was based on Strauss' grounded theory approach (Strauss and Corbin 1990). Therefore, insights were not a result of a linear process, but an iterative-cyclical process. The phases of data collection, coding and categorization as well as data analysis were closely linked and alternated several times. Consequently, a systematic presentation of the actual research process is neither meaningful nor possible. Hence the phases mentioned above are described separately, but they did not involve a strict order of sequential steps.

Research context

The context for this empirical study refers to eight lead user studies conducted between 2005 and 2008. All of those projects aimed to generate radical innovation concepts by systematically integrating leading-edge users from various domains via the well-known lead user method originally developed by Eric von Hippel (1986). The key challenge of this method – the effective and efficient search for lead users – was addressed both in the target market and in analogous domains by employing pyramiding search and broadcast search methods. The search processes yielded an average of 15 lead users per project who ranked

high in both lead user characteristics (e.g. Franke, von Hippel and Schreier 2006) and were willing and able to participate in the final lead user workshop. On average, nine of these lead users were invited to the respective workshops. The goal of these workshops was to develop innovative concepts for breakthrough products and services in a collaborative setting with lead users and company employees interacting in concept generation.

All of the lead user studies included in the sample of this study were conducted with well-established companies from various industries and of different sizes in terms of employees and sales volumes. Table 1 gives an overview of the lead user projects analyzed, including the respective search fields and examples of the analogous domains identified.

Insert Table 1 about here

All lead user studies followed the same methodological approach, applying the same type of search and selection methods based on a standardized implementation procedure. The search and selection processes were carried out by a search team consisting of six people on average. Decision-making (e.g. which lead users are to be invited to the final lead user workshop) took place in the course of steering board meetings. The search team presented intermediary results and discussed the decision for the next project steps in cooperation with steering board members from marketing and R&D departments. All eight projects were guided and supervised by the same expert in lead user methodology. In total, four projects (A, B, E and G) aimed to generate breakthrough innovations in *industrial* goods markets, whereas the other four projects (C, D, F and H) dealt with *consumer* goods markets.

Data collection and analysis

Data collection was based on the documentation of the above-mentioned lead user projects. The documentation for each project contained, among other things, the thoroughly and carefully prepared interview transcripts from the pyramiding search processes for lead users.

Of the 1,197 interview transcripts, 50 were excluded from the analysis because they lacked relevant information[2]. Therefore, the analyses presented below on the pyramiding search method's potential for crossing domain-specific boundaries are based on the remaining 1,147 transcripts.

For data coding purposes, these interview transcripts were consecutively numbered from 1 to 1,147 and coded according to nine different aspects: (1) the ID of the lead user project in which the interview was conducted (codes ranging from 1 = project A to 8 = project H); (2) the *type of industry* in which the search field was located (1 = consumer goods market or 2 = industrial goods market); (3) the *domain origin* of the respective interviewee in the pyramiding search process (0 = interviewee is from the target domain or 1 = interviewee belongs to an analogous domain; (4) the starting point of the referral chain (interview conducted within a referral chain started in the target domain = 1 or in an analogous domain = 2); (5) the *level of expertise* of the interviewee (1 = top-level expertise (lead user) or 0 = below top-level expertise (non-lead user)); (6) the existence of referrals (0 = interviewee provided no referral at all or 1 = interviewee provided one or more referrals); (7) the total number of referrals given by the interviewee (coded with the respective number); (8) the *existence of referrals into analogous domains* (0 = interviewee did not provide any referral into analogous domains or 1 = interviewee did provide referrals into analogous domains); and (9) the total number of referrals into analogous domains given by the interviewee (coded with the respective number).

In total, the 1,147 interviewees provided 1,097 referrals throughout the pyramiding search processes in the eight lead user studies examined. All referrals were numbered consecutively

[2] These transcripts refer to situations where a (potential) interviewee to whom the interviewer was referred to within the search process, either (1) could not be reached at all or (2) was not willing/able to complete the interview. As part of the interviewer training, the interviewers were asked to also document their *attempts* to perform the interviews in the respective interview protocols.

from 1 to 1,097 and coded according to three different aspects: (1) the *direction* of referral (1 = from target domain to target domain, 2 = from target domain to analogous domain, 3 = from analogous domain to target domain, 4 = from analogous domain to the same analogous domain or 5 = from analogous domain to another analogous domain; see figure 3 in appendix A); (2) the *explicitness* of the referral (1 = the interviewee's statement implicitly and unconsciously comprised a referral or 2 = the referral was given explicitly and consciously by the interviewee) – an example of an implicit referral reads as follows: 'In the aerospace industry, the problem is solved like this…', whereas a typical explicit referral looks like this: 'You should really talk to Ms. X'; and (3) the *level of detail* of the referral (how precisely a referral was given, indicating the amount of research necessary to contact the next interviewee, where 4 = referral to a concrete person, 3 = referral to a company or institution, 2 = referral to a mere domain or profession or 1 = others (including referrals to things such as events, online communities, literature, technologies or products in various analogous domains).

In addition, the *distance* between the analogous and the target domain (i.e. the one where the search field was located) was coded with 1 = referral into a *near* analogous domain or 2 = referral into a *far* analogous domain. In coding this kind of contextual distance, an approach outlined by Dahl and Moreau (2002) had been followed. A referral was seen as one into a near analogous domain when the similarities between the target and the analogous domain were based on surface-level attributes (of the product and its use context and the trends identified in the lead user study). It was considered a referral into a far analogous domain if these similarities were based more on deep-structure attributes. If at least one of the predefined surface-level attributes of the respective target domain could be identified in the respective analogous domains, the referral was coded as a referral into a near analogous domain. If no relation to the target market based on surface-level attributes was given, the

referral was coded as one into a far analogous domain. A detailed demonstration of how a typical referral chain was coded for this research can be found in appendix B.

For the entire coding process, a three-step approach was used: (1) First, two geographically separate coders independently rated all of the variables assigned. While the first coder had substantial contextual knowledge, the second coder was intentionally given only basic information in order to ensure a practically 'context-free' and thus completely unbiased view of the data. The result of this stage was an individual rating from both coders. (2) Before the coders assessed the interview transcripts in more detail, they were given training with regard to the evaluation criteria as well as their definition and proper application (Krippendorff 2004, Hayes and Krippendorff 2007). (3) After the individual evaluation, the coders had the opportunity to discuss differences in their assessments and to change their individual ratings based on their joint discussion, if desired.

Intercoder reliability was assessed by calculating Krippendorff's alpha for each variable. Krippendorff's alpha is a conservative index that measures agreement among multiple raters and is considered to be a highly rigorous measure for assessing intercoder reliability (values of .67 and greater are generally considered to be satisfactory; Krippendorff 2004). The values for this reliability measure range from .84 to 0.98 throughout all coding categories and are thus well above the recommended threshold levels.[3]

[3] Krippendorff's alpha for (1) domain origin: .98; (2) starting point of referral chain: .95; (3) existence of referrals: .98; (4) existence of referrals into analogous domains: .84; (5) direction of referral: .89; (6) explicitness of referral: .98; (7) level of detail of referral: .87; (8) distance to target domain: .94. The interviewees' levels of expertise (lead users vs. non-lead users) had already been coded by the respective search teams, as this was part of the search and selection process for lead users during the lead user projects. The search teams coded each interview transcript of a potential lead user according to the interviewee's lead user characteristics (on 5-point rating scales ranging from 1 = low to 5 = high). The two lead user components 'trend position' and 'expected benefit' (e.g. Franke, von Hippel and Schreier 2006) were first individually coded by the search team members and then discussed in the team. Finally, a lead user index was calculated on the basis of team agreement regarding the two individual components.

Description of sample

In this section, the sample is briefly described using (1) the number of interviews conducted and (2) the number of pyramiding referrals provided by the interviewees as research objects. Table 2 provides an overview of the main sample characteristics.

Insert Table 2 about here

(1) Number of interviews conducted: Overall, 61.8% (709) of the interviews were conducted in the four projects that aimed to generate innovations in the consumer goods markets, whereas 38.2% (438) of the interviews took place in the four projects located in industrial goods markets. While 35.6% (408) of the interviewees originated from the target domain, 64.4% (739) came from analogous domains. Concerning their levels of expertise, 10.7% (123) of all interviewees were identified as lead users (top-level expertise) by the respective project team, thus 89.3% (1,024 interviewees) were not. Of the 1,147 interviews in total, 34.4% (394) were conducted in the course of referral chains that started in the target domain, whereas 65.6% (753) had their starting point in analogous domains.[4] The longest referral chain contained six interviewees and thus five referrals. Of the 1,147 interviewees, 52.3% (600) provided at least one referral. This percentage ranges from around 40% to 60% in the individual projects, indicating no mean difference between industrial and consumer goods markets.

(2) Number of pyramiding referrals given: Altogether 1,097 referrals to further contacts were given, resulting in 0.96 referrals per interview overall and 1.83 referrals per interview with referrals. The maximum number of referrals given by a single interviewee came to 15. While 62.2% (682) of the referrals to further contacts arose in consumer goods projects, 37.8% (415) were provided in industrial goods cases. Concerning the interviewees' domain origins, 33.5%

[4] The initial starting points for both the pyramiding and broadcast searches were identified in a structured brainstorming and subsequent secondary data analysis process within the search team.

(367) of the referrals stemmed from interviewees from the target domain, 66.5% (730) from interviewees from analogous domains. Top-level experts (lead users) accounted for 8.5% (93) of all referrals to further contacts, while 91.5% (1,004) of the referrals were given by interviewees with a lower level of expertise (non-lead users). Of the 1,097 referrals to further contacts, 31.6% (347) arose in interviews conducted in the course of referral chains started in the target domain, whereas 68.4% (750) were provided within referral chains which originated in analogous domains.

Overall, the 600 interviewees that provided at least one pyramiding referral yielded 1,097 referrals. Of those referrals, the following were excluded from the subsequent analyses: (1) the 278 referrals (25.3%) from target domain interviewees and (2) the 371 referrals (33.8%) from analogous domain interviewees which led to their own domain (within-domain referrals), and (3) 122 referrals (11.1%) from analogous domains back to the target domain. In this way, a sample of referrals that only includes 'true' boundary-crossing achievements was formed: referrals from target domain interviewees into analogous domains and referrals from analogous domain interviewees into other analogous domains (see table 3).

Insert Table 3 about here

Findings

In the following, the study findings are presented according to the three research questions outlined in the introductory section of this article.

Research question 1: Does the pyramiding search method systematically provide a means of crossing domain-specific boundaries in search of innovation?

The results indicate that the pyramiding search method is a suitable means of crossing domain-specific boundaries. Overall, 211 interviewees (35.2% of the 600 interviewees who

provided a referral at all and 18.4% of the total sample of 1,147 interviewees) were able to perform the creative task of referring into an analogous domain. In sum, those 211 interviewees provided 326 referrals into analogous domains ranging from one referral per interviewee (46.6%) to seven referrals per interviewee (1.7%). These 'true' boundary-crossing referrals consist of 89 referrals from target domain interviewees into analogous domains (27.3%) and 237 referrals (72.7%) from analogous domain interviewees into other analogous domains.

Research question 2: How can these domain-crossing referrals be characterized?

Upon closer inspection of these referrals into analogous domains, it is first found that more than half of the 326 referrals into analogous domains were very concrete: Exactly 100 referrals (30.7%) are directed towards concrete persons, and 92 referrals (28.2%) explicitly name organizations (companies, institutions, etc.) in analogous fields. The remaining 134 referrals (41.1%) provide a lower level of detail, either pointing to analogous domains in general, to a profession within such domains, or to other events, technologies, products or literature from various analogous fields. As far as the level of expertise is concerned, no statistically significant differences in observed vs. expected frequencies between lead users and non-lead users with regard to the level of detail in their referrals are found (Chi-square = 4.639, p = .200). The same is true of the effect of domain origin on the level of detail of a referral (Chi-square = 2.179, p = .536). Although it can descriptively be observed that more referrals with respect to a search field in industrial goods markets (and less in consumer goods markets) than expected yielded a pyramiding referral to a concrete person, the difference is statistically not significant (Chi-square = 5.253, p = .154).

Second, the results indicate that 274 of the 326 referrals into analogous domains (84.0%) were given explicitly (e.g. an interviewee in Case D stated 'actually I am not a big expert in cooling...but three former colleagues of mine who work at company O. know more than me,

they already worked on a project concerning packaging closures, their names are Dr. T., Dr. B. and Dr. W.'), whereas 52 referrals (16.0%) were more implicit in nature (e.g. in case D an interviewee, when asked for a solution to the problem stated in the search field, answered 'PET bottles could hardly be opened with one hand in the past…it's noticeable that they have been improved a lot' and thus implicitly pointed to the plastic bottle industry as a field that might share a similar – analogous – problem). Compared to referrals into analogous domains, referrals within the same domain or back into the target domain (n = 771) account for a larger percentage (93.1%) of explicit referrals. Significantly fewer domain-crossing referrals (and more referrals within the domain and back to the target domain) than expected were given explicitly (Chi-square = 2.181, $p < .001$). Neither the level of expertise and domain origin nor the type of industry in which the search field was located has an impact on the explicitness of a referral (all p-values > .10).

Finally, the results indicate that 131 of all domain-crossing referrals (40.2%) point to far analogous domains (as compared to 195 into near analogous fields), providing first insights that pyramiding is indeed able to tap into very distant knowledge domains. For example, in Case E (mounting/dismounting of transportable forklifts) one referral pointed to G.W. GmbH in the field of mounting systems for agricultural devices on tractors (a near analogous market because of similar surface-level attributes: mounting/dismounting of a device on a vehicle) and another one to K. GmbH in the area of event technology (e.g. assembly/disassembly of concert stages). The latter field is a far analogous industry, as similarities are mainly based on deep-structure attributes. Contrary to what was expected, level of expertise and domain origin had no impact on the likelihood of a referral to point to near vs. far analogous domains (all p-values > .10). For the type of industry in which the search field is located, it can again be observed descriptively that more far referrals (and less near referrals) than expected were given when the search field was located in a consumer goods industry (and vice versa in

industrial goods markets), but the difference is not statistically significant (Chi-square = 1.658, p = .198).

Research question 3: What drives the likelihood of domain-crossing referrals?

Analyzing the factors that influence the likelihood of a referral into an analogous market, the results first indicate that within the group of interviewees *with* top-level expertise (lead users), 52.8% (28 of the 53 lead users who provided at least one referral) were able to provide a referral into an analogous domain (see table 5). In contrast, only 33.5% of interviewees *without* top-level expertise (non-lead users) could cross their market boundaries (in absolute numbers: 183 of the 547 non-lead users who provided at least one referral). Thus, cross-tab analysis shows that significantly more interviewees *with* top-level expertise (and fewer interviewees *without* top-level expertise) than expected provided referrals into analogous domains ($p < .01$).

Second, it is found that the domain origin of an interviewee (i.e. coming from the target domain or from an analogous domain) also influences the likelihood of domain-crossing referrals. In total, 54 of the 201 target domain interviewees who were able to provide a referral at all (26.9%) provided a referral into an analogous domain, whereas 39.3% of the interviewees from an analogous domain (157 of the 399 interviewees who were able to provide a referral at all) provided a domain-crossing referral (see table 4). Again, on the basis of a cross-tab analysis this pattern is found to be statistically significant: More interviewees from analogous domains (and fewer from the target domain) than expected were able to provide one or more referrals into analogous fields ($p < .01$).

Insert Table 4 about here

Furthermore, the results provide some indication that the relationships of level of expertise and domain origin with the likelihood of crossing domain-specific boundaries seem to be

moderated by the type of industry in which the search field was located (consumer goods vs. industrial goods, see figure 2).

Insert Figure 2 about here

However, testing the influence of level of expertise and domain origin by including the type of industry and the respective interaction effects using a logit regression model (see table 5) reveals that only the interaction between level of expertise and the type of industry has a statistically significant effect ($p < .01$). Interviewees from analogous markets are generally more likely to refer into (other) analogous domains compared to interviewees from the target domain ($p < .05$, see model 4).

Insert Table 5 about here

In the following section the main findings of this study will be critically discussed, possible future research building on this exploratory work will be outlined, and the managerial implications arising from this research effort will be highlighted.

Discussion

The aim of this article was to explore the potential of the pyramiding search method for crossing domain-specific boundaries in search of innovation. Pyramiding represents a search approach that – through a process of referrals from the 'bottom to the top of a pyramid' – is able to identify rare characteristics or expertise in actors located both within and outside a predefined population (domain).

By analyzing 1,147 interview transcripts drawn from eight lead user projects in which pyramiding was used to identify top-level experts (lead users), it is found that more than one third (35.2%) of those interviewees who provided a referral performed the creative task of crossing domain-specific boundaries and referring into an analogous domain *previously*

unknown to the searcher. The level of expertise of interviewees and their domain origins both influence the likelihood of a boundary-crossing referral. Moreover, the type of industry in which the search field is located is found to moderate the effect of expertise on the likelihood of a referral into an analogous domain. The study results also indicate that referrals into analogous domains are to a great extent given explicitly and provide very concrete contact information (about persons or companies/institutions in analogous domains). Finally, it is found that almost half (40.2%) of all referrals into analogous domains contain information about far analogous fields (as opposed to near analogous fields), providing first insights that pyramiding is indeed able to tap into contextually very distant knowledge domains. These findings hold important theoretical as well as managerial implications.

Theoretical implications

As already outlined in the introductory section, the findings contribute to theory development in two ways. First, they extend organizational search theory (e.g. March 1991, Katila and Ahuja 2002) by addressing the aspect of search into domains previously unknown to the searching organization. Second, by empirically exploring the potential of pyramiding, the tools available to researchers and managers are enriched by adding a new search mechanism for accessing contextually distant knowledge for the sake of innovation. In doing so, the study presents an alternative way to deal with the functional fixedness of organizations not by increasing absorptive capacity (Cohen and Levinthal 1990) per se, but by improving absorptive capacity *on a meta-level*, that is, enabling organizational entities to use their knowledge about search mechanisms in the development of new products and services.

Managerial implications

One central managerial implication directly related to aspects of new product development is that pyramiding is a powerful tool which enables organizations to systematically reduce 'local

search biases'. The empirical findings of this study show that pyramiding makes it possible to access even very distant knowledge domains, which in turn is an important – and to date not satisfactorily fulfilled – precondition for systematically generating radical new products and services (e.g. Franke and Poetz 2008, Keinz and Prügl 2009). Finding that referrals are (1) rather detailed (naming concrete persons in a considerably large proportion of referrals) and (2) made to a great extent in an explicit manner clearly supports the idea that this search mechanism can be very effective when it comes to identifying knowledge in contextually distant domains. At the same time, practitioners carrying out pyramiding searches should be aware that contextual factors such as the type of industry, the interviewees' domain origin or their level of expertise will influence the likelihood of obtaining truly domain-crossing pyramiding referrals.

A second important implication for the new product development realm is that pyramiding should not be started exclusively with interviewees from within the target domain. The 'starting configuration' should already include interviewees from contextually distant domains previously known to the searching organization (e.g. through search team brainstorming, content analysis or broadcast searches; Hienerth, Poetz and von Hippel 2007). This already appears to be common knowledge among innovation researchers and practitioners carrying out lead user studies, but is now strongly underpinned by empirical evidence.

Limitations and further research

Unfortunately, no research effort is without its limitations. In this study the authors were 'spoiled' in that they were able to use a very rich data set consisting of real-life cases. The external validity of the study findings can therefore be considered high. At the same time, this research setting holds potential weaknesses due to the limitations of real-life settings.

First of all, the question is to what extent the study findings reflect more general patterns. In

this study, referrals in lead user studies were tracked only. The extent to which the typical context of a lead user project drives 'referral likelihood' in one direction or another is not known. Further studies in other contexts where access to analogous domains is crucial (e.g. in technology competence leveraging projects; Danneels 2007, Keinz and Prügl 2009) could provide additional insights on this issue.

Second, another concern is a potential bias due to self-selection effects. Naturally, the interviewees contacted throughout the eight lead user studies had some degree of interest in the search field of the respective study and more or less time to participate in those projects. Furthermore, although careful and standardized interviewer training was given to all interviewers, there may still be interviewer effects which influence the likelihood of a referral.

The third issue concerns the effect of a potential sample selection bias: There is no data available to check whether the composition of this study's sample is systematically different from the entire population of interest. Finally, another limitation is that the data coding did not consider whether pyramiding referrals into contextually distant domains (specifically referrals into far analogous domains) consist exclusively of referrals into analogous domains. They could possibly also 'just' relate to referrals 'out of the target domain' (without any similarities based on surface-level or deep-structure attributes between the domains).

A number of striking observations leave room for further research. For example, the study shows that there is a difference between consumer and industrial goods markets regarding the 'referral providing behavior' of interviewees. This raises some basic questions: Why is that the case? Which – possibly competing – explanations can be found, and what are their implications? Another puzzle to be solved in future research efforts is the question of why interviewees with top-level expertise (in this study lead users) provided *fewer* pyramiding referrals in general, but *more* referrals into analogous domains. One potential explanation not tested in this study is that people with a high level of expertise within the domain may have

the tendency to believe (or make others believe) that 'there is no better person than him/her' in that field of expertise – meaning that a conscious or unconscious vanity effect could be one key to solving this puzzle.

Finally, while looking at the potential of pyramiding for crossing domain-specific boundaries in search of innovation, a number of additional questions that have not yet been explored but might be highly relevant to the further advancement of this research field occurred during the research process. Issues such as the effect of interview styles (i.e. directly asking for referrals into analogous domains vs. not doing so) or comparisons of the broadcast search and pyramiding search method regarding their performance when tapping into knowledge from contextually distant domains have strong theoretical as well as practical implications and thus warrant further research.

References

Agerfalk, Pär J. and Brian Fitzgerald (2008). Outsourcing to an unknown workforce: Exploring opensourcing as a global sourcing strategy. *MIS Quarterly* 32(2), 385-409.

Atuahene-Gima, Kwaku, Stanley F. Slater, and Eric M. Olson (2005). The contingent value of responsive and proactive market orientations for new product program performance. *Journal of Product Innovation Management* 22(6), 464-482.

Amabile, Teresa M., Sigal G. Barsade, Jennifer S. Mueller, and Barry M. Staw (2005). Affect and creativity at work. *Administrative Science Quarterly* 50, 367-403.

Bessant, John, Kathrin Möslein, and Bettina von Stamm (2009). In search of innovation. *The Wall Street Journal* (June 22), accessed online at: http://online.wsj.com/article/SB10001424052970204830304574133562888635626.html (August, 26, 2009).

Bhatta, Sambasiva R. and Ashok K. Goel (1994). From Design Experiences To Generic Mechanisms:

Model-Based Learning in Analogical Design. In: *Proceedings from the AID-94 workshop on Machine Learning in Design*, August 1994. Lausanne, Switzerland.

Cohen, Wesley M. and Daniel A. Levinthal (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly* 35, 128–152.

Dahl, Darren.W. and Page Moreau (2002). The influence and value of analogical thinking during new product ideation. *Journal of Marketing Research* 39 (2), 47-60.

Danneels, Erwin (2007). The process of technological competence leveraging. *Strategic Management Journal* 28, 511-533.

Duncker, Karl (1945). On Problem Solving. Translated by Lynne S. Lees. *Psychological Monographs* 58 (5).

Fleming, Lee and David M. Waguespack (2007). Brokerage, boundary spanning, and leadership in open innovation communities. *Organization Science* 18(2), 165-184.

Franke, Nikolaus, Eric von Hippel, and Martin Schreier (2006). Finding commercially attractive user innovations: A test of lead user theory. *Journal of Product Innovation Management* 23(4), 301-315.

Franke, Nikolaus and Marion Poetz (2008). The Analogous Market Effect: How users from analogous markets can contribute to the process of idea generation. Working Paper, Vienna: Vienna University of Economics and Business.

Genter, Dedre, Sarah Brem, Ron Ferguson, Philip Wolff, Arthur B. Markman, and Ken Forbus (1997). Analogy and Creativity in the Works of Johannes Kepler. In: *Creative Thought.* T.B. Ward, S.M. Smith and J. Vaid. Washington, DC: American Psychological Association, 403-459.

Gordon, William J. J. (1961). *Synectics: The development of creative capacity*. Scranton: Harper Collins College Div.

Hayes, Andrew F. and Klaus Krippendorff (2007). Answering the call for a standard reliability measure for coding data. *Communication Methods and Measures* 1, 77-89.

Helfat, Constance E. (1994). Firm-specificity in corporate R&D. *Organization Science* 5, 173-184.

Hienerth, Christoph, Marion K. Poetz, and Eric von Hippel (2007). Exploring key characteristics of lead user workshop participants: Who contributes best to the generation of truly novel solutions? DRUID Summer Conference. Copenhagen.

Hrebiniak, Lawrence G and William F. Joyce (2002). Organizational search: Analysis of the factors affecting search in complex organizations. Working Paper No. 02-13. Dartmouth: Tuck School of Business.

Huston, Larry and Nabil Sakkab (2006). Connect and develop. Inside Procter & Gambles's new model for innovation. *Harvard Business Review.* March 2006, 58–66.

Jeppesen, Lars Bo and Lars Frederiksen (2006). Why do users contribute to firm-hosted user communities? The case of computer-controlled music instruments. *Organization Science* 17(1), 45-64.

Jeppesen, Lars Bo and Karim R. Lakhani (2009). Marginality and problem solving effectiveness in broadcast search. *Organization Science*, forthcoming.

Katila, Riita and Gautam Ahuja (2002). Something old, something new: A longitudinal study of search behavior and new product introduction. *Academy of Management Journal* 45(6), 1183-1194.

Keinz, Peter and Reinhard Prügl (2009). A Community-Based Approach to Technological Competence Leveraging. *User and Open Innovation Conference*, Hamburg, Germany, June 2009.

Klevorick, Alvin K., Richard C. Levin, Richard R. Nelson, and Sidney G. Winter (1995). On the sources and significance of interindustry differences in technological opportunities. *Research Policy* 24, 185-205.

Krippendorff, Klaus (2004). *Content Analysis: An Introduction to its Methodology* (2nd edition). Thousand Oaks, CA: Sage Publications

Lakhani, Karim R., Lars Bo Jeppesen, Peter A. Lohse, and Jill A. Panetta (2007). The value of openness in scientific problem solving. Working Paper No. 07-050. Boston, MA: Harvard Business School.

Lilien, Gary L., Pamela D. Morrison, Kathleen Searls, Mary Sonnack, and Eric von Hippel (2002). Performance assessment of the lead user idea-generation process for new product development. *Management Science* 48(8), 1042-1059.

March, James G. (1991). Exploration and exploitation in organizational learning. *Organization Science* 2(1), 71-87.

Martin, Xavier and Will Mitchell (1998). The influence of local search and performance heuristics on new design introduction in a new product market. *Research Policy* 26, 753-771.

Nambisan, Satish und Mohanbir Sawhney (2007). A buyer's guide to the innovation bazaar. *Harvard Business Review*. June 2007, 109–118.

Nelson, Richard R. and Sidney G. Winter (1982). *An Evolutionary Theory of Economic Change*. Cambridge, MA: Belknap Press.

Olson, Erik L. and Geir Bakke (2001). Implementing the lead user method in a high technology firm: A longitudinal study of intentions versus actions. *Journal of Product Innovation Management* 18 (2), 388-395.

Osborn, Alex F. (1941). *Applied Imagination: Principles and Procedures of Creative Thinking*. New York: Scribner.

Perkins, David N. (1997). Creativity's Camel: The Role of Analogy in Invention. In: *Creative Thought*. T. Ward, S. Smith und J. Vaid. Washington, DC: American Psychological Association, 523–538.

Pisano, Gary P. and Roberto Verganti (2008). Which kind of collaboration is right for you?. *Harvard Business Review* 86(12), 78-86.

Poetz, Marion K. and Martin Schreier (2010). The value of crowdsourcing: Can users really compete with professionals in generating new product ideas? *Journal of Product Innovation Management*, forthcoming.

Prügl, Reinhard and Martin Schreier (2006). Learning from leading-edge customers at The Sims: Opening up the innovation process using toolkits. *R&D Management* 36 (3), 237–250.

Raymond, Eric. S. (1999). *The Cathedral and the Bazaar*. Sebastopol: O'Reilly.

Rosenkopf, Lori und Atul Nerkar (2001). Beyond local search: Boundary-spanning, exploration and impact in the optical disk industry. *Strategic Management Journal* 22, 287-306.

Strauss, Anselm L. and Juliet Corbin (1990). Grounded Theory Research: Procedures, Canons and Evaluative Criteria. *Zeitschrift für Soziologie* 19, 418-427.

Stuart, Toby E. and Joel Podolny (1996). Local search and the evolution of technological capabilities. *Strategic Management Journal* 17(1), 21-38.

Terninko, John, Alla Zusman, and Boris Zlotin (1998). *Systematic innovation: An introduction to TRIZ.* Boca Raton: CRC Press.

von Hippel, Eric (1986). Lead users: A source of novel product concepts. *Management Science* 32 (7), 791-805.

von Hippel, Eric (1988). *The Sources of Innovation*. New York: Oxford University Press.

von Hippel, Eric (1994). "Sticky information" and the locus of problem solving: implications for innovation. *Management Science* 40(4), 429-439.

Von Hippel, Eric, Thomke, Stefan and Mary Sonnack (1999). Creating breakthroughs at 3M. *Harvard Business Review* 77, 47–57.

von Hippel, Eric (2005). *Democratizing Innovation*. Cambridge: MIT Press.

von Hippel, Eric, Nikolaus Franke, and Reinhard Prügl (2009). Pyramiding: Efficient search for rare subjects. *Research Policy*, forthcoming.

Ward, Thomas B. (1998). Analogical Distance and Purpose in Creative Thought. In: *Advances in Analogy Research.* K. Holyoak, D. Genter and B. Kokinov. Sofia: New Bulgarian University Press, 221-230.

Figure 1: Schematic illustration of a pyramiding search into analogous domains

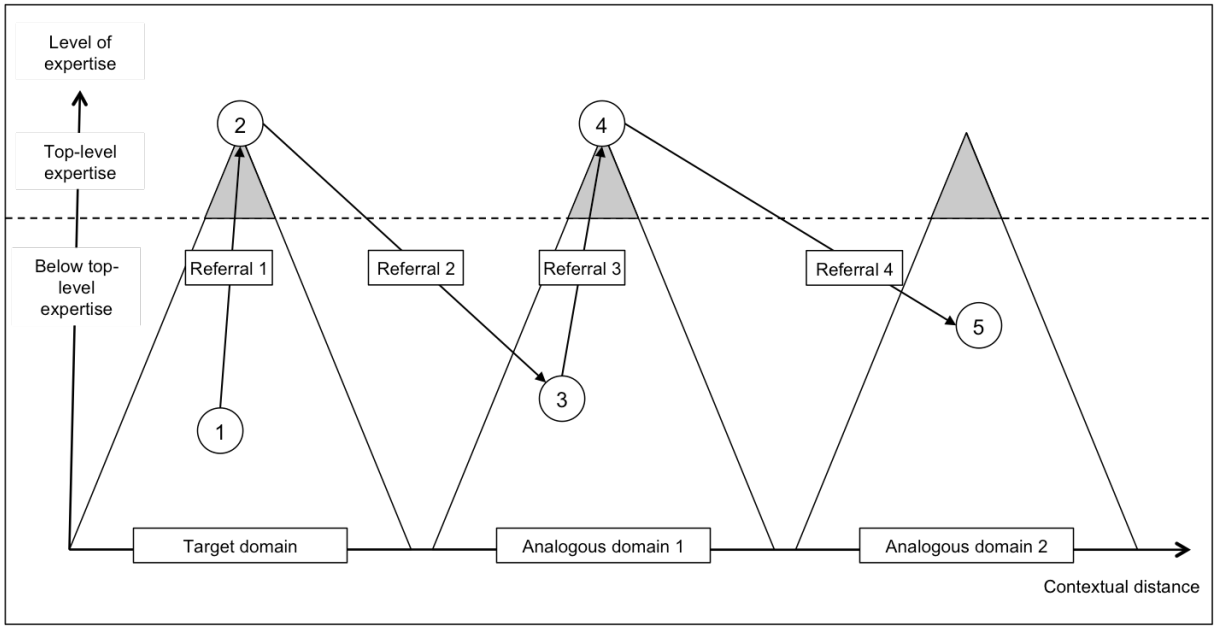


Figure 2: Influence of type of industry on effects of interviewee's level of expertise and domain origin

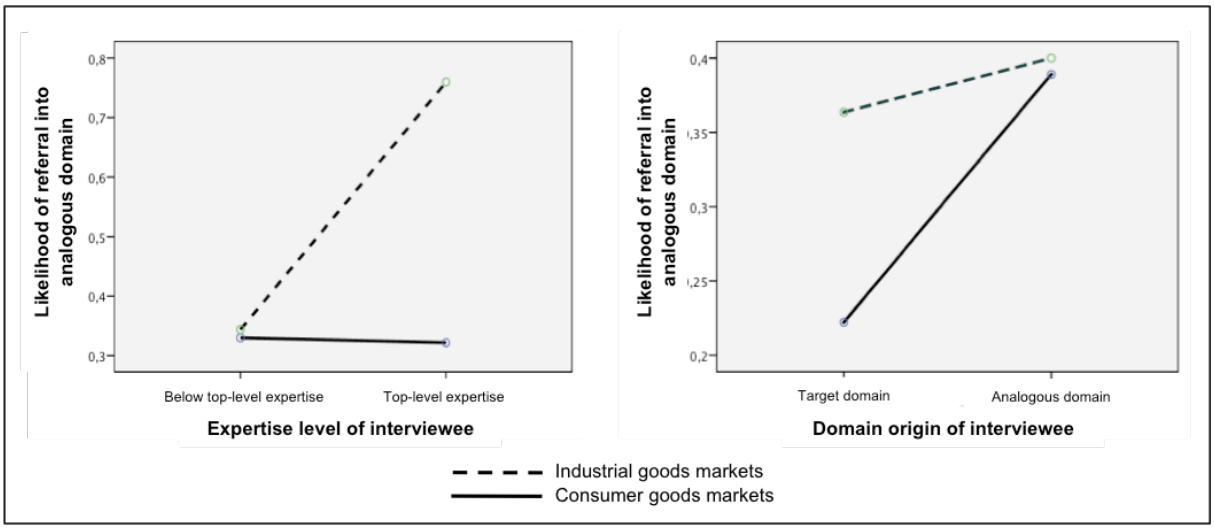


Table 1: Overview of lead user studies analyzed*

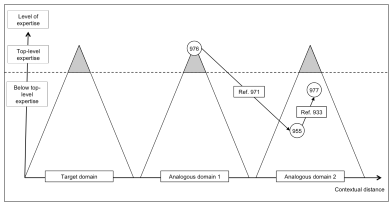
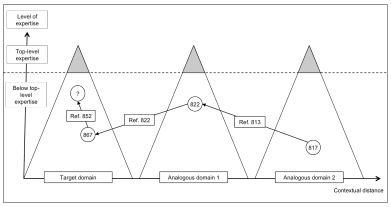
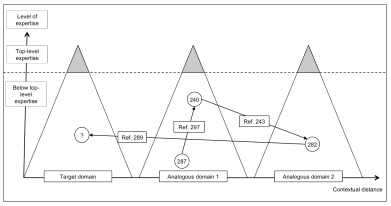
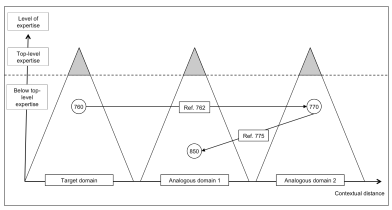
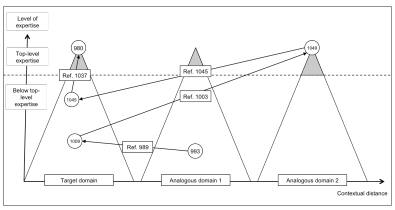
Project	Industry	Employees	Sales volume (EUR)	Search field	Examples of analogous domains
A	Lifting, loading and handling systems	3,860	695.6 M	Stability monitoring for truck cranes	- Industrial machinery - Sailboats - Computer simulation
B	Escalators and elevators	390	89.5 M	Step chain systems	- Conveyor belts - Ropeways - Mining
C	Automotive	53,000	10,324.0 M	Crush protection for passenger cars	- Elevators - Doors and gates - Robotics
D	Beverages	217	74.6 M	Added value for beer cans	- Biotechnology - PET bottles - Toy industry
E	Lifting, loading and handling systems	3,860	695.6 M	Mounting, transport and dismounting of portable forklifts	- Event technology - Model making - Bike racks
F	Baby care	30	4.5 M	Reducing uncertainty of parents around childbirth	- Veterinary medicine - Entrepreneurship - Care of the elderly
G	Electronics	15	1.4 M	Energy-efficient systems for electronic equipment in office and home areas	- Cinema - Power plants - Aerospace industry
H	Food	465	102.0 M	Storage and handling of herbs and spices	- Pharmacy - Home improvement - Barkeeping

* Based on 2007 data from the Aurelia database.

Table 2: Description of sample

Sample characteristic	Unit of analysis – Total number of …	…interviews (n=1,147)	…referrals (n=1,097)
Type of industry	Consumer goods	709 (61.8%)	682 (62.2%)
	Industrial goods	438 (38.2%)	415 (37.8%)
Domain origin	Target	408 (35.6%)	367 (33.5%)
	Analogous	739 (64.4%)	730 (66.5%)
Level of expertise	Top-level (lead users)	123 (10.7%)	93 (8.5%)
	Below top-level (non-lead users)	1,024 (89.3%)	1,004 (91.5%)
Overall	Interviews with referrals	600 (52.3%)	
	Referrals per interview	0.96	
	Referrals per interview with a referral	1.83	

Table 3: Examples of pyramiding referral chains*

(a) Referral chain from lead user from near analogous domain to far analogous domain	*(b) Referral chain from non-lead user from far analogous domain to near analogous domain to target domain*	*(c) Referral chain from non-lead user from near analogous domain to far analogous domain to target domain*
		
(d) Referral chain from non-lead user from target domain to far analogous domain to near analogous domain	*(e) Referral chain from non-lead user from near analogous domain to target domain to lead user in far analogous and finally back to lead user in target domain*	
		*Intentionally left blank*

*Only referrals between these pyramids, i.e. 'cross-domain referrals', were coded as referrals into analogous domains and are thus subject to further analysis in this article. Referrals within pyramids, i.e. 'within-domain referrals' or referrals back to the target domain are not included in the analysis.

Table 4: Level of expertise and domain origin vs. likelihood of referral into analogous domain

(Results of cross-tab analysis)

	Level of expertise		Domain origin	
	Top-level (lead users) (n = 53)	Below top-level (non-lead users) (n = 547)	Target (n = 201)	Analogous (n = 399)
	Observed frequency (Expected frequency)	Obs. (Exp.)	Obs. (Exp.)	Obs. (Exp.)
One or more referrals into analogous domains	28 (18.6)	183 (192.4)	54 (70.7)	157 (140.3)
No referral into analogous domain	25 (34.4)	364 (354.6)	147 (130.3)	242 (258.7)
Chi-square	7.955		9.135	
(p-value, two-sided)	(.005)		(.003)	

Table 5: Explanation of likelihood of crossing domain-specific boundaries

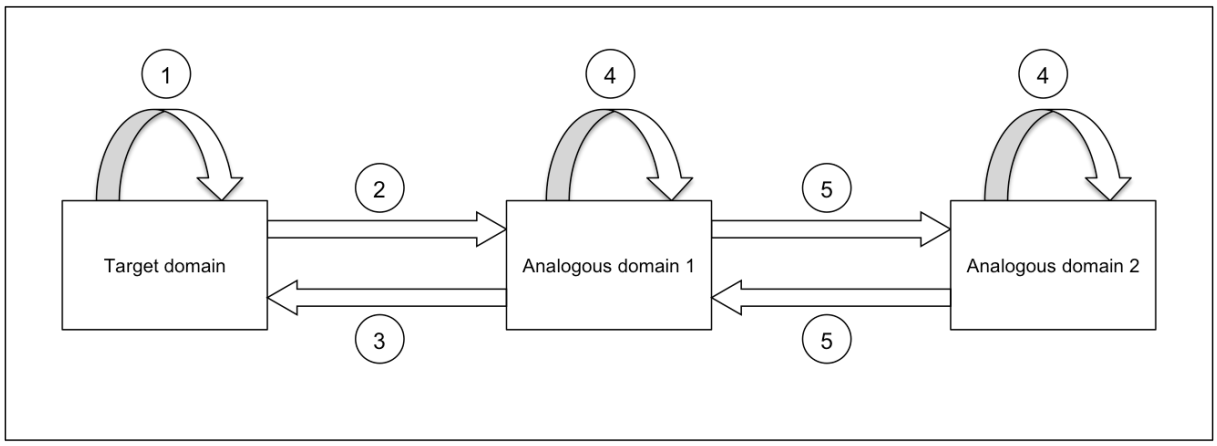
(Results of logit regression analysis)

	Dependent variable: Likelihood of referral into analogous domain (0|1)							
	Model 1		Model 2		Model 3		Model 4	
	Coeff.	*Std.err.*	*Coeff.*	*Std.err.*	*Coeff.*	*Std.err.*	*Coeff.*	*Std.err.*
Level of expertise[1]	.811**	.294	-1.886†	.982	.812**	.294	-1.833†	.986
Domain origin[2]	.572**	.191	.581**	.193	1.472*	.581	1.408*	.584
Type of industry[3]	.202	.178	.023	.189	.667*	.332	.463	.344
Level of expertise x Type of industry			1.868**	.652			1.822**	.652
Domain origin x Type of industry					-.651†	.393	-.606	.400
Cox&Snell R^2	.031		.045		.035		.049	
Nagelkerkes R^2	.042		.062		.048		.067	
-2 Log-Likelihood	48.548		39.514		45.811		37.232	
Chi-square	18.629		27.663		21.366		29.945	
Df	3		4		4		5	
p-value	.000		.000		.000		.000	

n=600, two-sided tests; †p < .10, *p < .05, **p < .01, ***p < .001
[1]0=below top-level expertise, 1=top-level expertise
[2]0=target domain, 1=analogous domain
[3]1=consumer goods markets, 2=industrial goods markets

Appendix A: Possible direction of referrals

Figure 3: Direction of referrals

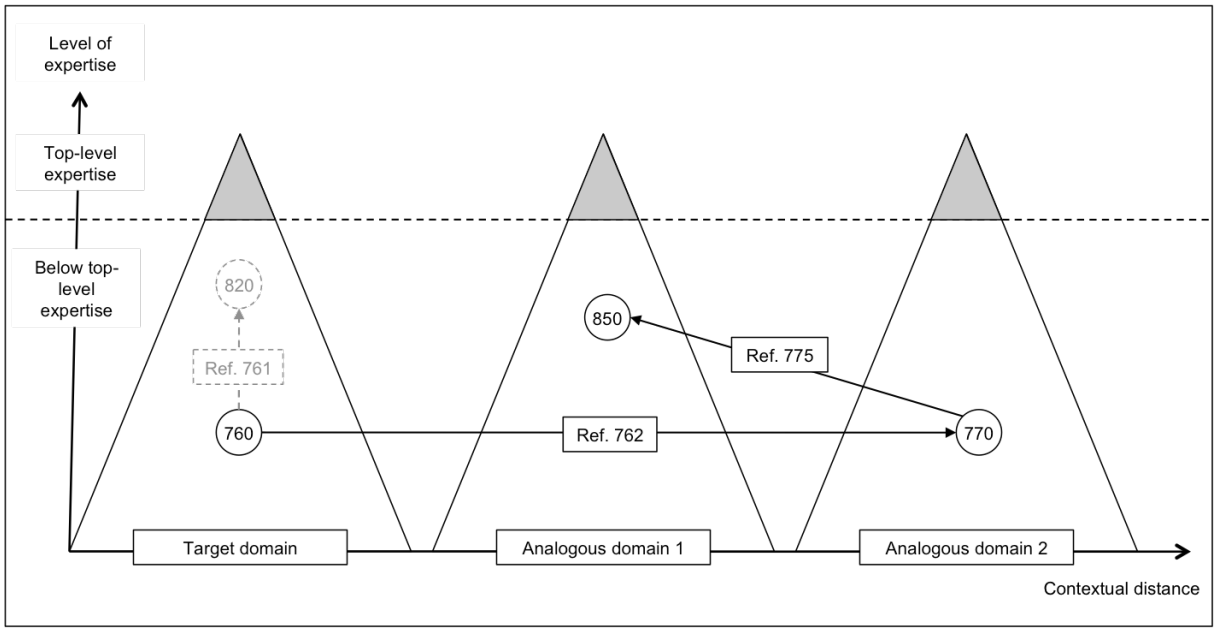


(1) Referral from target domain to target domain; (2) referral from target domain to analogous domain; (3) referral from analogous domain to target domain; (4) referral from analogous domain to same analogous domain; (5) referral from analogous domain into another analogous domain.

Appendix B: Demonstration of how a typical referral chain was coded

In this section, it is presented how a typical referral chain was coded for the purposes of this study. The referral chain illustrated in figure 3 stems from project G, which involves a search field in an industrial goods market.

Figure 4: Example of a typical referral chain from this study's sample (taken from project G)



The interviews and referrals within this full pyramiding chain were coded as follows:

Int. Nº	Project	Industry type	Domain origin	Starting point of referral chain	Level of expertise
760	7	2	0	1	0
	Existence of referrals	Number of referrals	Existence of referrals into analogous domains	Number of referrals into analogous domains	
	1	2	1	1	

The first interviewee in the pyramiding chain dealt with digital homes as well as digital offices and thus came from the target domain. Consequently, the pyramiding chain started in

the target domain.[5] The interviewee was not identified as a top-level expert (lead user). The person was able to give two referrals in total, one of them referring into an analogous domain. The other referral (ref. number 761 referring to interviewee number 820) stayed within the target domain and created another pyramiding chain.

Ref. N°	Text excerpt	Direction	Explicitness	Level of detail	Domain distance
762	Mr. V. B.	2	2	4	2

The first referral in the pyramiding chain given by interviewee number 760 explicitly referred to the network theorist V. B. As the search field dealt with energy-efficient systems for electronic equipment in office and home areas, this person comes from an analogous domain. This analogous domain was coded as a far analogous domain since it was not connected to the target market by any of the predefined surface-level attributes but shared deep-structure similarities, as intelligently networking electronic devices plays a role when saving energy in home and office spaces.

Int. N°	Project	Industry type	Domain origin	Starting point of referral chain	Level of expertise
770	7	2	1	1	0
	Existence of referrals	Number of referrals	Existence of referrals into analogous domains	Number of referrals into analogous domains	
	1	1	1	1	

[5] It is, of course, true that the starting point of the referral chain is in the target domain for all other interviews within this pyramiding chain; therefore, this will not be indicated in the coding description for the remaining interviews.

The second interviewee in the pyramiding chain, Mr. V. B., was not a top-level expert (lead user) either. He came from the analogous domain of network theory and provided one referral that led to another analogous domain.

Ref. Nº	Text excerpt	Direction	Explicitness	Level of detail	Domain distance
775	N. S.	5	2	4	1

The second referral in the pyramiding chain given by interviewee number 770 explicitly referred to a person named N. S., who works with with smart living, however not in connection with energy efficiency' (Interview transcript number 850, p. 1). Hence, Mr. S. came from another analogous domain than the network theorist providing the referral. This analogous domain shared a predefined surface-level attribute with the target domain (electronic equipment in buildings other than offices or homes) and was thus coded as a near analogous domain.

Int. Nº	Project	Industry type	Domain origin	Starting point of referral chain	Level of expertise
850	7	2	1	1	0
	Existence of referrals	Number of referrals	Existence of referrals into analogous domains	Number of referrals into analogous domains	
	0	0	0	0	

The third interviewee in the pyramiding chain, Mr. N.S., came from an analogous domain and was not a top-level expert (lead user). He did not provide any referrals at all, which means that the pyramiding chain ended at that point.

Biographical sketches

Marion Poetz is an assistant professor at the Department of Innovation and Organizational Economics at Copenhagen Business School. Her research focuses on the mechanisms and effects of distributed innovation. She is particularly interested in aspects of search for innovation-related knowledge located outside the boundaries of the searching organization and investigates the role of contextual distance in innovation performance.

Reinhard Prügl is junior professor and holder of the Chair of Innovation, Technology and Entrepreneurship at Zeppelin University Friedrichshafen, Lake Constance. His research is anchored in the areas of user and open innovation, technology transfer and technological competence leveraging, emphasizing aspects of search for innovation-related knowledge. He is particularly interested in gaining a deeper understanding of mechanisms and effects of different approaches towards a systematic search for innovation.