Creative imitation: exploring the case of cross-industry innovation

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In cross-industry innovation, already existing solutions from other industries are creatively imitated and retranslated to meet the needs of the company's current market or products. Such solutions can be technologies, patents, specific knowledge, capabilities, business processes, general principles, or whole business models. Innovations systematically created in a cross-industry context are a new phenomenon for theory and practice in respect of an open innovation approach. While the cognitive distance between the acquired knowledge and the problem to be solved was regarded as a counterproductive factor in older research, recent theory regards it as positively related to innovation performance. Following the latest theory, we examine 25 cross-industry cases to ascertain cognitive distance's influence on innovation performance. Our study reveals that there is no direct correlation between a higher or a closer distance and a more explorative or exploitative outcome.

1. Introduction

Most innovation is a recombination of existing knowledge (Schumpeter, 1939). This recombination is mostly limited to knowledge or technology developed within the own company or, at least, within value chain partners in the own industry. In a study with 8,180 observations, Guiri et al. (2007, p. 1116ff.) show that internal (to the organization) sources' assumed importance for inventions is still three times higher than that of external sources. Additionally, the study demonstrates that partners within the own value chain, like customers, users, competitors and suppliers, are still among the most important sources of knowledge applied to develop inventions. Enriching the company's own knowledge base by integrating suppliers, customers, and external knowledge sources can increase a company's innovativeness (Chesbrough, 2003; Gassmann, 2006; Laursen and Salter, 2006; Lettl et al., 2006; Piller and Walcher, 2006).

Nevertheless, innovation studies do not recognize the value of partners outside the value chain (see, e.g., the community innovation survey or the OECD scoreboard). Drivers of innovation, such as technology fusion, shorter innovation cycles, the mobility of workers across industries, and the global availability of knowledge, make accessing external technologies imperative as well as easier. Furthermore, since the publication of Penrose's (1959) work, it has been known that resource heterogeneity within strategic alliances is an important source of performance (Porter, 1990; Prahalad and Hamel, 1990; Hagedoorn and Schakenraad, 1994; Smith Ring and van de Ven, 1994). Nevertheless, the innovation advantages to be gained from partner heterogeneity have not been well researched. The so-called cognitive distance between innovation partners is therefore mostly regarded as a threat instead of an opportunity (Mowery et al., 1996, 1998; Stuart, 1998; Penner-Hahn and Myles Shaver, 2005; Tanriverdi and Venkatraman, 2005). When learning is discussed, cognitive distance is mostly understood as learning to cope with transnational differences by accumulating experience in cross-border collaboration (Barkema et al., 1997), instead of being perceived as a potential source of learning. The literature has largely focused on the negative effects of cognitive distance and therefore overly stresses homogeneous resources' benefits and neglects their negative effects or their limited novelty value. The first studies on the optimal cognitive distance between alliance partners find that in industry or field of experience, distance is not counterproductive but can be a source of both disruptive and incremental innovation (Majchrzak et al., 2004; Wuyts et al., 2005; Nooteboom et al., 2007).

2. Cross-industry innovation potential

Theory has only started to recognize and systematize the value of knowledge, technologies, and partners with a high cognitive distance, also called cross-industry innovation. There are many successful examples of technological spillovers from other industries: BMW's iDrive system was transferred from the game industry, while Nike's shock absorbers were adapted from Formula One racing technology. Studies on the cross-industry innovation phenomenon focus on analogical thinking as a source of competitive advantage. Recent studies have emphasized the importance of analogies for radical product innovation (Keane, 1987; Dahl and Moreau, 2002) and increased firm performance (Gavetti et al., 2005). Analogical thinking, particularly when applied across industry boundaries, could contribute significantly to the development of highly novel innovations (Holyoak and Thagard, 1995), while simultaneously limiting the risks of uncertainty (De Bono, 1990). Non-obvious analogies may require highly novel solutions, because the combination of more distant pieces of knowledge is associated with higher innovative potential (Holyoak and Thagard, 1995; Hargadon and Sutton, 1997).

2.1. Cross-industry innovation

Besides including external knowledge in the own enterprise, cross-industry innovation can also be used as a tool for transferring own technologies or patents to foreign industries. While the outside-in process leads to higher innovativeness, the inside-out one generates additional turnover with relatively little effort (Enkel and Dürmüller, 2008). Nevertheless, a successful search for analogical solutions and their subsequent retranslation and multiplication require new or adapted processes, tools and competencies in technology, and innovation management. Gassmann et al. (2004) conceptualize the phenomenon of cross-industry innovation in respect of the automotive industry. These authors specifically focus on cross-industry cooperation between small start-up firms and established enterprises. Herstatt and Kalogerakis (2005) as well as Herstatt and Engel (2006) discuss possible cross-industry process steps and tools from an analogous perspective. Gassmann and Zeschky (2008) demonstrate that cross-industry distances enable analogical thinking and can be used for product innovation at the firm level (for a more detailed literature review on analogical thinking, see Gassmann and Zeschky, 2008). Enkel and Lenz (2009) point out that different industry distances could motivate external experts to engage in cross-industry innovation efforts or hinder them from doing so.

However, there is limited insight into how cognitive distance with regard to analogical thinking is responsible for an innovation effort's outcome. More aptly, the literature lacks empirical insight into how a higher cognitive distance between the source of knowledge and the applying company should be assessed, given that it could result in a disruptive rather than an incremental innovation. Therefore, our research question is: what influence does a higher or a lower cognitive distance have on the outcome of analogical thinking in cross-industry innovation? If we can answer this research question, we would be able to recommend the most suitable search mechanisms or other methods for creating disruptive innovation rather than incremental innovation.

2.2. Cognitive distance

In order to evaluate cognitive distance, we build on the work of Nooteboom et al. (2007), who conceptualize cognitive distance between strategic partners in alliances. These authors' work is based on the evaluation of the cognitive distance between people who need to share a certain interpretation system (Weick, 1979, 1995), a system of shared meanings (Smircich, 1983), or an organizational focus (Nooteboom, 2000). The evaluation was ascertained by means of the relevant people's shared, fundamental categories of perception, interpretation, and evaluation as inculcated by their organizational culture (Schein, 1985). Nooteboom (1992, 1999) suggests that there is an inverted U-shaped relationship between cognitive distance and innovation performance. Because cognitive distance increases, it has a positive effect on learning through interaction. 'When people with different knowledge and perspective interact, they stimulate and help each other to stretch their knowledge for the purpose of bridging and connecting diverse knowledge' (Nooteboom et al., 2007, p. 1017). Therefore, a certain degree of cognitive distance enhances opportunities for novel combinations of complementary resources or knowledge. Too much cognitive distance precludes sufficient mutual understanding, which is needed to utilize those opportunities (Gulati, 1995). The challenge of cross-industry innovation is, therefore, to find analogical solutions or knowledge at a sufficient cognitive distance to include something new, but not so distant as to preclude mutual understanding.

2.3. Exploration versus exploitation

In order to evaluate cross-industry innovation's performance, we distinguish between the exploration context (breakthrough or disruptive innovation) and the exploitation context (incremental innovation, March, 1991).

Following the argument raised before, we expect a higher cognitive distance to have a positive effect on the novelty value, as in exploration. Consequently, we expect a low cognitive distance between analogical knowledge to result in exploitation. Exploitation can be characterized as routinized learning, adding to the firm's existing knowledge base, and competence set without changing the basic nature of its activities (Rowley et al., 2000; Hagedoorn and Duysters, 2002). Cognitive distance creates uncertainty and complexity, which are undesirable in such a setting. Nevertheless, some cognitive distance may be required to make minor adaptations. Exploration means breaking with an existing dominant design and shifting away from existing rules, norms, routines, and activities to allow novel Schumpeterian combinations. Firms have to move beyond local search by reaching for novel contexts to overcome the limitations of a contextually localized search (Almeida and Kogut, 1999; Fleming, 2001; Rosenkopf and Almeida, 2003).

Keeping this theoretical discussion in mind, we hypothesize:

Hypothesis 1: *Analogical solutions with a high cognitive distance to the adapting problem will have a stronger positive effect on exploration than on exploitation.*

Subsequently, our second hypothesis states:

Hypothesis 2: *Analogical solutions with a low cognitive distance to the adapting problem will have a stronger positive effect on exploitation than on exploration.*

3. Methods

This paper will draw on inductive theory building through multiple case-study analysis to provide insights into cognitive distance's influence in respect of exploration and exploitation. Following previous research's specifications, we consider this methodology an appropriate approach to our research question, as there is limited theoretical knowledge of the cross-industry collaboration phenomenon and its application to, specifically, the simultaneous exploration and exploitation research domain (Siggelkow, 2007). Further, we suggest that this research design will allow us to define relationships patterns, which quantitative data would not easily reveal (Eisenhardt and Graebner, 2007).

We use a cross-case analysis to obtain a richer insight into how different settings could influence cognitive distance and the identified analogical solutions. The case firms were identified in the course of a 2-year research project focusing on firms' use of analogies for radical new product innovation. This sample was complemented by cases drawn from the literature and Web publications (see Table 1 in the appendix). Overall, 25 cases of cross-industry innovation were compared. The case firms are internationally dispersed, although the majority of the companies have their headquarters in Germany or Switzerland. The cases were chosen on the grounds of their companies' acknowledged outstanding innovation performances and their specific recognition in respect of cross-industry developments. All the cases occurred between 2005 and 2009 (see Table 1 for a case summary).

3.1. Research context

Our selection of cases complies with random sampling in order to provide settings that are particularly suited to reveal our proposed relationships and to ensure that the various constructs are logically linked (Eisenhardt and Graebner, 2007, Yin, 1994). The driving criteria for the industry, company, and project selection were therefore their substantiated pursuit of an innovation by

Table 1. Cross-industry cases in our research sample and companies of origin

Innovation	Company (industry), challenges, source of innovation, result
1. Fine print technology	Alcan Inc. (aluminum manufacturer). *Challenges*: fraud-resistant packaging for medicine; integration into common packaging process possible; no customized adaptation needed. *Source of innovation*: development of new printing techniques based on banknotes and passport documents' print technologies. *Result*: new fine print technology with Ncrypt system.
2. B-Pillar technology	Alcan Inc. (aluminum manufacturer). *Challenges*: thin-walled, large surface casting pieces of aluminum for automotive mass production; weight reduction for gas reduction; elimination of porosity. *Source of innovation*: in cooperation with several partners from different industries developed the High-Q-Cast technology that enables the production of assembly-ready casting pieces. *Result*: the die-casting and laser-welding technique for the Audi A2; winning the aluminum-casting award; elimination of porosity.
3. Aramid rope	Schindler group (elevator manufacturer), *Challenges*: replacement of steel cables in elevators, reduction of space needed to furl the steel cable, reduction of weight. *Source of innovation*: for his thesis, a Master's student working for Schindler evaluated different rope materials, including aramid ropes used for mountain climbing, and combined this with a study on the possible future use of aramid. *Result*: aramid ropes with integrated carbon fibers allowed steel cables to be replaced, saved space and weight, and allowed the abrasion of ropes to be remotely controlled; consequently, totally new services; over 20 patents and licensing fees for non-elevator applications that cover all the technology development costs.
4. Active ride control	Schindler group (elevator manufacturer). *Challenges*: improvement of elevator movement characteristics by providing elevators with guide rails, thus replacing the passive stabilizing systems that use bulk to absorb vibration; increasing ride comfort, weight, and durability. *Source of innovation*: adaptation of the active chassis control from the automotive industry, which balances perturbation (e.g., used for ASR, ESP, transaction control). *Result*: breakthrough increase in riding comfort; decrease in horizontal vibrations down to 10 mg; several patents.
5. Go-One encasement bike	Beyss (plastic material techniques). *Challenges*: frames of chaise longue bikes are too heavy; need for a single-layer carbon fiber structure (i.e., five times lighter, twice as hard) instead of steel. *Source of innovation*: The Formula One monocoques used as the central part of the bike, with all other parts fixed to this; high shock absorbance. *Result*: Go-One vehicle, ultra lightweight bicycle with self-supporting chassis; weight reduction of 30 kg; acceleration of > 50 km/hr possible.
6. PredatorPulse	Adidas (sport articles). *Challenges*: more power and control in football shoes; more shock control and absorbance; in cooperation with the University of Calgary searched for analogies in other sports. *Source of innovation:* the principle of mass distribution as found in tennis and golf; creative imitation and retranslation of the "sweet spot" in respect of football shoes. *Result*: in 2004 introduced shoes with a 5% increase in ball speed; best-selling football shoe worldwide.
7. Centurion	Thielert Aircraft Engines (aircraft engines). *Challenges*: reduction in gas consumption of small business aircrafts. *Source of innovation*: a friend of the owner complained about the poor quality and high gas consumption of small aircrafts – analogous to the automotive diesel engine; after 2 years of development and a 3.3 million euros investment, Thielert finished the development of the first aircraft diesel engine. *Result*: Centurion 1.7, an aircraft with an adapted Mercedes Benz engine (normally used for the A-series of Mercedes) that uses 70% of the original automotive components; the new engine started a major technical change in the small aircraft mass market with its 60% reduction in gas consumption; highly robust and has additional advantages regarding electronics and altitude.
8. Easy.com	EasyJet group (airline). *Challenges*: adaptation of the Easy Jet business model of successfully reducing services to just those absolutely necessary ones, the efficient use of infrastructure, maximum use of assets, yield management, no frills with regard to other industries.

Table 1. (Contd.)

Innovation	Company (industry), challenges, source of innovation, result
	Source of innovation: systematic scan of markets, questioning their cost model and services; identification of markets with high prices, a price-elastic demand curve and high potential to increase customer integration; mainly focusing on markets with high fixed costs and low marginal costs per customer. *Result*: many successful or promising new business models: easyInternet, easyMoney, easyBus, easyCar, easyCinema, easyMobile, easyWatch, easyHotel, easy4men, easyPizza, easyMusic.
9. New businesses for PTFE technologies	W.L. Gore (PTFE technologies). *Challenges*: applications for PTFE and ePTFE technologies that have high isolation capabilities, thermal resistance (−180°C to +260°C); inflammability and UV resistance. *Source of innovation*: focus on the core characteristics of the technologies instead of the product. *Result*: diversification into fabrics, industrial, medical, and electronic products e.g., micro filters used in car ventilation is now used for electronic tools like mobile phones.
10. Soil-release jacket	W.L. Gore (PTFE technologies). *Challenges*: development of a jacket for rail workers that is more resistant to grease, graphite, and other dirt for increased safety through better reflection characteristics. *Source of innovation*: to adapt, in cooperation with the lead users (Swiss railway SBB), the characteristics of PTFE technology and the lotus-effect identified in nature. *Result*: a soil-release effect as the surface structure of the jacket enables a longer life cycle from months to years; improved wearing comfort through breathable Gore-Tex membrane; the new jacket is used by most of the rail companies in Europe.
11. Power box	Reichle & De-Massari (ICT cable). *Challenges*: transfer of the insulation displacement contact technology (IDC) from the telecom industry to electricity connections of >230 V. *Source of innovation*: customer requests for higher contact security and easier handling. *Result*: a power box that handles easily.
12. Glass fiber glue	Reichle & De-Massari (ICT cable). *Challenges*: new method to connect glass fibers without using mechanical pressure. *Source of innovation*: in cooperation with Ciba (chemical industry), the adaptation of the chemical industry's adhesion technology in respect of glass fibers. *Result*: adhesion for glass fibers with high glue reliability and durability.
13. Frequent Tuning Ski	Fischer group (sport articles). *Challenge*: reduction of a ski's vibrations at high speeds. *Source of innovation*: the idea is based on the building of violins in which an additional layer in the form of a special grid that reduces the vibrations. Undertaken in cooperation with an acoustician from the Black Forest area of Germany who integrated this metal grid that converges vibration in a string instrument. *Result*: better control of skis' vibration at high speeds.
14. Stitch regulator	Bernina (sewing machines). *Challenge*: the biggest problem for novice sewers is to regulate their speed and adaptation with regard to different textiles. This leads to uneven parts. *Source of innovation:* to adapt, in cooperation with Zühlke, the sensor technology used in optical computer mouse devices that regulate the mouse speed regardless of the direction. *Result:* integration of the sensor in the sewing machine pressure foot that measures and regulates the speed, thus leading to consistent stitches for starters as well.
15. Internet-compliant sewing machine	Bernina (sewing machine). *Challenge*: sewing patterns should be directly downloadable to the sewing machine to facilitate sewing with patterns. *Source of innovation*: driven by customer requests for new patterns on Bernina's web site; adaptation of established internet technology and integration of chips and connectors into the sewing machine. *Result*: the first Internet-compliant sewing machine.
16. Aeroccino	Nespresso (food). *Challenge*: to develop a milk creamer that is easy to clean, specifically the gaskets, which are hard to keep hygienic. *Source of innovation*: adapting the established stir principle used in labs, which uses a contact-free driven beater with magnetic torque transmission. *Result*: the Aeroccino milk creamer that does not need gaskets.
17. Waterless urinal	Geberit (sanitary ware) *Challenge*: waterless urinal for places without a water connection; reduction of odors. *Source of innovation*: established physics principle of the Erlenmeyer flask found in

Table 1. (Contd.)

Innovation	Company (industry), challenges, source of innovation, result
	chemical labs, as the special shape prevents odors and moisture from escaping. *Result*: Geberit's water-free urinal.
18. Sanitary installation	Geberit (sanitary ware). *Challenge*: reduce the time and costs of the planning of sanitary installation. *Source of innovation:* to adapt, in cooperation with Zühlke, a planning tool, originally used for planning power plants. *Result*: Geberit was enabled to plan sanitary installations with huge cost reductions of up to six digits.
19. Shox	Nike (sport articles). *Challenge*: better shock absorption for sport shoes. *Source of innovation*: Formula One shock absorption technologies. *Result*: Nike's Shox shoe with a new shock absorption system.
20. iDrive	BMW (automobiles). *Challenge*: new device for controlling 500 functions within BMW's 7 series. *Source of innovation*: through listening post in Paola Alto contact with the game industry and their new joystick technologies and adaptation of these with the help of a start-up company. *Result*: the iDrive system as new man-machine interface.
21. Fleet management	Hilti (building tools). *Challenge*: finding new business models that increase customer loyalty. *Source of innovation*: automotive fleet management that focuses on long-term service contracts instead of selling the cars. *Result*: Hilti's fleet management in respect of building tools guarantees that building tools in use through service contracts are in optimal shape.
22. Bone stretching motor	Wittenstein (automotive) *Challenge*: using traction technology from automotive to stretch human bones inside of the body. *Source of innovation*: medical demand for a technology that can stretch bones over a longer period of time and can stay inside the body for the process. *Result*: Wittenstein's FITBONE® technology as fully implantable system based on traction technology.
23. Technology transfer to automotive	ESG (military aircraft) *Challenge*: using several technologies but also security system's knowledge created for military aircraft into automotive development. *Source of innovation*: company's own military aircraft division. *Result*: successful automotive supplier and security process service provider.
24. Heat shields for oven	Sevex/Elringklinger (automotive) *Challenge*: commercialize aluminum know-how and welding technology knowledge gained by producing heat shields for automobiles into other profitable mass-production industries without high investment. *Source of innovation*: systematic scanning of mass markets using aluminum for heat protection and analyzing competitive situation. *Result*: investment in new product category heat shields for oven.
25. Sun lotion without zinc	Ciba (chemical industry). *Challenge*: commercialize know-how of sun protection for plastics into personal care market. *Source of innovation:* cooperation with Beiersdorf (cosmetics company) in order to combine chemical know-how with personal care and knowledge about regulations for FDA approval. *Result:* successful sun milk series without whitening zinc.

Source: Interviews, internal and external company documents (2006–2009)

imitating an existing solution in other industries. We examined companies that had received important innovation awards and were ranked among Business Week's 50 most innovative companies in 2008 (evidence of successful exploration) (Andriopoulos and Lewis, 2009). Because the term cross-industry innovation is as yet rather unknown, we scanned company websites and conference participant lists for open innovation projects (the term open innovation is far more present in today's corporate innovation profile).

If the information on the cross-industry project could not be deduced from the website or other archival data, the identified companies were contacted. We then ascertained whether their cross-industry initiative had been undertaken together with a corporate partner or with knowledge obtained from other sources like patents, descriptions, or articles. If so, we asked them to participate in the study, during which we conducted interviews and gathered other data on the case.

3.2. Sample data

While case studies can accommodate a variety of sourcing techniques, we relied on semi-structured interviews as our primary data source, triangulating these interviews with archival data and observations to refute or reinforce findings resulting from the interview data. Interviews are an efficient technique for gathering rich, empirical data that are particularly applicable when the phenomenon under research is episodic (Eisenhardt and Graebner, 2007), which new product development (NPD) is.

Interviews were conducted with the interview partners in person, while follow-up interviews were conducted by telephone. If the informants were difficult to reach, we sent a questionnaire that covered the interview questions in order to obtain a uniform information basis. The interviews lasted for an average of 60–90 min and were tape-recorded and transcribed verbatim to ensure the information's reliability (Bourgeois and Eisenhardt, 1988). In accordance with Glaser and Strauss (1967), we started with a broad research aim, specifying the additional data that we needed to collect as the data analysis unfolded. Information gathering was pursued until no additional information could call the existing findings into question or reveal novel constructs. This was considered the study's point of theoretical saturation (Strauss and Corbin, 1990).

As mentioned previously, we triangulate our findings by gathering (1) additional archival data, both publicly available information and internal documentation, and (2) through corporate observations. Archival data were collected via desk research before the interviews to establish a fundamental understanding of the project's contexts. In addition, if provided by the companies, internal documentation, studies, and reports were used to verify the generated project knowledge (Rowley, 2002). Secondly, documentary observations through, for example, employee shadowing provided an enhanced understanding of the collaboration context (Andriopoulos and Lewis, 2009). Our research is largely based on 25 examples of cross-industry innovation in different companies. These companies range from dynamic industries like ICT, semiconductors, and fast-moving consumer goods, to the elevator, automotive, machine tool, and chemical industries, but also include the more static aircraft, aluminum, and building industries (see Table 2).

3.3. Data analysis

In accordance with previous research, our theory-building process was defined by a recursive cycling of the provided case data, emerging theoretical constructs, and extant literature (Eisenhardt and Graebner, 2007). Consistent with Glaser and Strauss (1967) and Miles and Huberman (1994), we applied the established four-stage process to move from raw interview data to the definition of constructs that guide exploration and exploitation by means of NPD processes.

In a first step, we transcribed each individual case of each NPD project, using the obtained interview data. Furthermore, to increase the reliability of our analysis, we reverted to triangulation by means of the collected archival data, presentations, websites, and internal documents. Having corroborated the case report with the company representatives, we identified the innovation patterns. To categorize each case's raw data, we applied conceptual coding, using *in vivo* codes as advocated by Van Maanen (1979). These offer general insights into the abstraction process and the search for analogical solutions as well as into the selected solution's adaption in respect of the company and product requirements.

Driven by our hypotheses derived from theory, we categorized all the host companies (the solution-searching companies) and the industries in which the solutions originated into industrial fields in a first step. Although previous research had operationalized cognitive distance, for example, between alliance partners by analyzing their patent portfolio (called cognitive proximity in Nooteboom et al., 2007 and Wuyts et al., 2005), we were unable to use patent data as some of the cross-industry innovations had not been patented.

We used the 2002 revision of the Nomenclature statistique des activités économiques dans la Communauté européenne (NACE) (2002) listing, which is the European Union's renowned international industry list of all economic activities, which describes all industries according to the materials or techniques they use. We use the NACE listing as objective criteria to evaluate the distance between the industries. The NACE

Table 2. Sample description

No	Case	Company	Industry	Employees	Founded in	Product lifecycles (years)
1	Fine print technology	Alcan Packaging	Packaging	31,000	1912	2–3
2	B-Pillar technology	Alcan Automotive	Automotive	1,500	1912	4–6
3	Aramid rope	Schindler Elevators	Elevators	45,000	1874	20–40
4	Active ride control	Schindler Elevators	Elevators	45,000	1874	20–40
5	Go-One encasement bike	Beyss	Sports	25	1991	2–3
6	PredatorPulse	Adidas	Sports	38,982	1905	1–2
7	Aircraft diesel engine	Thielert	Aircraft	342	1989	10–20
8	Easy.com	Easy.com	Airline	6,375	1995	5–7
9	PTFE technologies	Gore	Textile	8,000	1958	1–2
10	Mobile phones	Gore	Textile	8,000	1958	1–2
11	Easy Flex	R&M	ICT	676	1964	4–6
12	Glass fiber glue	R&M	ICT	676	1964	4–6
13	Frequent Tuning Ski	Fischer	Sports	1,450	1924	1–2
14	Stitch regulator	Bernina	Sewing machines	1,110	1932	1–2
15	Internet-compliant sewing m.	Bernina	Sewing machines	1,110	1932	1–2
16	Aeroccino	Nestle	Food	14,380	1866	1–2
17	Waterless urinal	Geberit	Sanitary	5,697	1874	2–3
18	Sanitary installation	Geberit	Sanitary	5,697	1874	2–3
19	Shox	Nike	Sports	26,000	1964	1–2
20	iDrive	BMW	Automotive	100,041	1916	4–6
21	Fleet management	Hilti	Construction tools	20,450	1941	6–10
22	Bone-stretching motor	Wittenstein	Automotive	1,400	1949	4–6
23	Technology transfer to cars	ESG	Aircraft	1,200	1963	10–20
24	Heat shields for oven	Sevex/Elringklinger	Automotive	330	1976	4–6
25	Sun milk without zinc	Ciba	Chemical	12,500	1758	10–20

classification is based on the United Nation's International Standard Industrial Classification of all economic activities (ISIC Rev. 3 International Standard Industrial Classification') We consequently listed each applying company and each solution source with its industry numbers and subtracted the one from the other (see Table 3). Following the NACE classification's logic, the farther the industries are from each other and, therefore, the greater the difference between them, the larger the number when the one is subtracted from the other. Because the position within the list (whether the host was more towards the start of the list or at the end) played no role, we handled negative numbers after subtraction in the same way as positive numbers.

In order to operationalize the concept of exploration and exploitation, we adopt Chandy and Tellis's (1998) taxonomy of innovations along the technology and market domains, which is consistent with many other definitions of an innovation's degree of novelty (Garcia and Calantone, 2002). Consequently, incremental innovations involve relatively minor changes in technology and customer benefit. Conversely, market breakthroughs are based on core technologies but provide substantially higher customer benefits. Technological breakthroughs, however, do not provide higher customer benefits, but involve a substantially different technology. Lastly, radical innovations involve substantially new technology as well as providing substantially higher customer benefits (Sorescu et al., 2003). We therefore coded all of the selected cases' outcomes according to Chandy and Tellis's (1998) three categories: incremental, market or technology breakthrough, and radical innovation. We did not differentiate between market and technology breakthrough because both innovation types have the same quality of outcome in respect of our research, while incremental, breakthroughs, and radical innovation can be regarded as lying on a continuum from low novelty to high novelty.

Prior research categorized outcomes according to their type of patent class (e.g., Nooteboom et al., 2007) or according to the product's revenue per year (Laursen and Salter, 2006). Because certain of the selected cases' outcomes had not been patented and the outcomes' revenue could not be compared per industry and per product, we opted for expert evaluation according to the three above-mentioned categories. We asked two industry experts not associated with the involved companies to evaluate the novelty of the cross-

Table 3. Differences in cognitive distance between the source of the solution and the applying company

No	Case	Industry	NACE1	Industry of source	NACE2	Difference
1	Fine print technology	Packaging	28.72	Printing	22.22	6.50
2	B-Pillar technology	Automotive	34.2	Steel industry	27.1	7.10
3	Aramid rope	Elevators	28.11	Sports	17.15	10.96
4	Active ride control	Elevators	28.11	Automotive	34.1	5.99
5	Go-One encasement bike	Sports	35.5	Automotive	34.1	1.40
6	PredatorPulse	Sports	19.3	Sports	20.5	1.20
7	Aircraft diesel engine	Aircraft	35.30	Automotive	34.1	1.20
8	Easy.com	Airline	62.1	easyInternet, easyMoney, easyBus, easyCar, easyCinema, easyMobile, easyWatch, easyHotel, easy4men, easyPizza, easyMusic	60.23	2.13
9	PTFE technologies	Textile	24.7	Medical care	55.1	30.40
10	Mobile phones	Textile	24.7	Mobile phones	32.2	7.50
11	Easy Flex	ICT	32.2	Electronics	31.6	0.60
12	Glass fiber glue	ICT	32.2	Chemical	24.62	7.58
13	Frequent Tuning Ski	Sports	20.5	Music	36.3	6.20
14	Stitch regulator	Sewing Machines	29.41	ICT	33.4	4.01
15	Internet-compliant sewing m.	Sewing Machines	29.41	ICT	32.2	3.21
16	Aeroccino	Food	29.71	Chemical	24.1	5.61
17	Waterless urinal	Sanitary	45.33	Chemical	24.1	21.23
18	Sanitary installation	Sanitary	45.33	Electric power installation	40.1	5.23
19	Shox	Sports	19.3	Automotive	34.1	14.80
20	iDrive	Automotive	34.1	Games	36.5	2.40
21	Fleet management	Construction Tools	45.3	Automotive	71.1	25.80
22	Bone-stretching motor	Automotive	34.3	Medical care	29.41	4.89
23	Technology transfer to cars	Aircraft	35.30	Automotive	34.1	0.20
24	Heat shields for oven	Automotive	34.2	Oven	29.21	4.99
25	Sun milk without zinc	Chemical	24.1	Personal care	24.52	0.42

NACE, Nomenclature statistique des activités économiques dans la Communauté européenne.

industry outcomes on a three-point scale (one incremental innovation, two market or technology breakthrough, and three radical innovation). If the two experts could not agree on the outcome, a third was asked to provide an evaluation.

In addition, the company data were coded according to the company size and age as control variables to avoid bias from the other effects on performance. We expected firm size to enhance exploitative learning (Acs and Audretsch, 1991). Large firms have, for example, the financial resources and technology to invest heavily in R&D and have advantages regarding scale, diversification of risk, and a wider portfolio of activities into which unpredicted R&D outcomes could fit (see Nooteboom, 1994). Thus, we expected cross-industry innovation to be used more in large firms than in small ones. Firm age could have an effect too. Older firms show a greater tendency to build on older technology and more established methods in innovation management than younger firms do. Older firms' innovations are therefore generally less influential than those of younger firms (Sorenson and Stuart, 2000). Companies' competence to generate innovation improves with age, but at the price of their innovations' declining novelty value and importance. Finally, industry or clock speed (Fine, 1998) might have an influence on the pressure that companies experience to innovate. Fast clock speed industries facing product life cycles of 6 months to 2 years are more likely to search for established solutions in other industries in order to decrease the technological risk and time-to-market than companies in slow clock speed industries working in innovation cycles of 20–100 years.

4. Results

4.1. Cognitive distance

Table 1 lists the cases analyzed within the various companies that successfully created and commercialized cross-industry innovations, the origin of the sourced solution, and the result. On analyzing the cognitive distance between a solution's source and the applying company, we find that the distance can range from 1 to 30 points according to the NACE classification of industries (see Table 2, column difference). A 30-point distance means that the source of knowledge or technology in analogue industries is far from its application within the solution-searching company. The largest differences are found in Gore's PTFE technologies adapted from textile industries to their applications in medical care, automotive, and industrial products. Gore did not regard itself as a textile industry company, but as a company with a powerful core technology that was theoretically applicable in all industries featuring this technology (water, heat, and UV-resistance, etc.). This mindset opened up a potential solution space for Gore and enabled new applications positioned far from its existing markets.

Hilti's fleet management also shows a high cognitive distance between the idea's source (automotive) and its application (construction tools). When Hilti was searching for a new business model that would focus on services instead on products, it was clear that this could not be found in the building industry but in more mature, service-oriented industries like the automotive one. Leasing of goods has a long tradition in the automotive industry, although customers show decreasing loyalty and tend to decide in favor of cost advantages. The major success factor in finding and applying the idea of fleet management to construction tools was due to the relevant R&D leader, who realized that improving products or reducing prices would not increase Hilti's market share, but that the company had to change into a service company like Schindler, the elevator company, had.

Other innovations are, for example, Geberit's waterless urinal, which was enabled by cooperation with an intermediary like Zühlke, a technical service provider that, by definition, is not captured in one market but serves many. Such technical service firms employ people from various backgrounds with multiple disciplines, which positively impact finding solutions in areas other than the established ones.

The fourth highest cognitive distance is found in respect of Nike's shox shoes, but this might have been triggered more by marketing than by an objective search for new solutions. Nike needed to find a technical solution that would not only solve the problem of better shock absorption when running on uneven ground, but would also convey the image of state-of-the-art technological development and a certain lifestyle connected with Formula One racing. Consequently, Nike favored solutions that lay in the lifestyle and sport industries.

In respect of the other cases in our sample, the distances are relatively small, ranging from 0.2 to 7.58. According to the NACE industry classification, 21 cases or 84% of the samples used analogical solutions from a close-by industry. Looking back at our initial research question on what influence a higher or a lower cognitive distance has on the outcome of analogical thinking in cross-industry innovation, we need to analyze the results of the innovation efforts and see whether there is a correlation between high cognitive distance and the degree of the result's radicalness.

4.2. Exploration versus exploitation

On analyzing the results of the cross-industry efforts on a scale from incremental to radical innovation, we see that none of the sample cases can be categorized as incremental innovation or pure exploitation of existing products. On examining the sample companies with explorative results, 13 are technological breakthroughs, five are market breakthroughs (including new business models, both coded 2 in Table 4), and seven

Table 4. Evaluation of the cross-industry innovation results

No	Case	Innovation performance
1	Fine print technology	3
2	B-Pillar technology	2
3	Aramid rope	3
4	Active ride control	2
5	Go-One encasement bike	2
6	PredatorPulse	3
7	Aircraft diesel engine	2
8	Easy.com	2
9	PTFE technologies	2
10	Mobile phones	2
11	Easy Flex	2
12	Glass fiber glue	3
13	Frequent Tuning Ski	2
14	Stitch regulator	2
15	Internet-compliant sewing m.	2
16	Aeroccino	2
17	Waterless urinal	2
18	Sanitary installation	3
19	Shox	2
20	iDrive	2
21	Fleet management	3
22	Bone-stretching motor	3
23	Technology transfer to cars	2
24	Heat shields for oven	2
25	Sun milk without zinc	2

of 25 cases were evaluated as radical innovation by the experts (coded 3 in Table 4).

In respect of the sample cases, we cannot confirm that cross-industry innovation always leads to radical innovation. Mostly, it leads to technological breakthroughs. This could be because technological patents or function descriptions are easier to find through patent analysis or problem-solving methods like TRIZ than solutions leading to market breakthroughs. Additionally, the interview data revealed that if two or more cooperation partners were involved, not all the partners evaluated the result the same. Usually, just one partner evaluated it as radical for his company and industry, but the other partner(s) only regarded this as incremental innovation. Our sample data do not allow us to go deeper into this area as most of our cases do not involve co-created innovations. This does, however, seem to be an interesting future research topic.

Returning to our two hypotheses, we want to test whether a higher or a lower cognitive distance is correlated to exploration or exploitation results. On analyzing our sample, we do not find any correlation between the cognitive distance and its impact on the innovation result (Table 5).

Table 5. Correlation between cognitive distance (difference according to NACE) and innovation performance (1 = incremental, 2 = breakthrough, 3 = radical)

No	Case	Difference	Innovation performance
1	Fine print technology	6.50	3
2	B-Pillar technology	7.10	2
3	Aramid rope	10.96	3
4	Active ride control	5.99	2
5	Go-One encasement bike	1.40	2
6	PredatorPulse	1.20	3
7	Aircraft diesel engine	1.20	2
8	Easy.com	2.13	2
9	PTFE technologies	30.40	2
10	Mobile phones	7.50	2
11	Easy Flex	0.60	2
12	Glass fiber glue	7.58	3
13	Frequent Tuning Ski	6.20	2
14	Stitch regulator	4.01	2
15	Internet-compliant sewing m.	3.21	2
16	Aeroccino	5.61	2
17	Waterless urinal	21.23	2
18	Sanitary installation	5.23	3
19	Shox	14.80	2
20	iDrive	2.40	2
21	Fleet management	25.80	3
22	Bone-stretching motor	4.89	3
23	Technology transfer to cars	0.20	2
24	Heat shields for oven	4.99	2
25	Sun milk without zinc	0.42	2

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In respect of the cases with the highest cognitive distance (Gore, Hilti, Geberit, and Nike), the results were evaluated as mainly market or technology breakthroughs, with only the Hilti case assessed as a radical innovation for the industry as a whole. Therefore, we can confirm neither the hypothesis that a higher cognitive distance leads to more exploration nor the one that a lower cognitive distance leads to more exploitative results.

4.3. Control variables

We also controlled for company size and age, as we presumed that larger companies could allocate more resources to finding very distant analogical solutions than small companies could. Furthermore, companies' competence to generate innovation improves with age, but at the price of their innovations' declining novelty value and importance. Therefore, it was surmised that more small and medium than large companies use cross-industry innovation to increase novelty. However, from our sample, we find that the majority of cross-industry innovations were undertaken by large enterprises (21 of 25 cases), and only four cases were undertaken by a medium-sized and small company (see Table 4). Consequently, it seems that larger rather than small companies undertake cross-industry innovation. It should, however, be kept in mind that random samples have a tendency to include cross-industry innovation cases that enterprises with higher budget used in wide marketing efforts rather than those from small companies that cannot allocate such resources to the marketing of a new innovation approach.

Likewise, we cannot confirm that older companies' results are either more or less innovative than those of younger ones. Eighty-eight percent of our sample is established companies founded >20 years ago (see Table 3), and their results range from breakthrough to radical innovation. On the other hand, this also applies to the few younger firms in the sample, such as Beyss, Easy.com, and Thielert.

We furthermore expected that, due to shorter innovation cycles and strong competitive pressure, fast and medium clock speed companies would use cross-industry innovation more often than slow clock speed industries. Thirty-two percent of our sample cases consist of medium clock speed industries with product life cycles of 4–20 years, while 48% are from fast clock speed industries with product life cycles of 6 months to 4 years. Twenty percent, or five companies, are found in slow clock speed industries like the aircraft, elevators, and chemical industries. Therefore, we can confirm that mainly fast and medium companies use cross-industry innovation to reduce time to market and increase innovativeness.

5. Discussion

5.1. Theoretical contribution

Cognitive distance cannot be confirmed as having a positive or a negative effect on the innovation outcome in cross-industry innovation. While one stream of theory conceives cognitive distance as a threat to innovation partners (Mowery et al., 1996, 1998; Stuart, 1998; Penner-Hahn and Myles Shaver, 2005; Tanriverdi and Venkatraman, 2005), the latest literature suggests that it can be a source of both disruptive and incremental innovation (Majchrzak et al., 2004; Wuyts et al., 2005; Nooteboom et al., 2007). Nooteboom et al. (2007) have identified an optimal inverted U-shaped relationship between cognitive distance and innovation performance. In addition, the creativity literature suggests that non-obvious analogies may entail highly novel solutions by combining knowledge pieces associated with a higher innovation potential (Holyoak and Thagard, 1995; Hargadon and Sutton, 1997).

Nevertheless, our results cannot confirm these studies, which were conducted in the field of strategic alliances. As our data reveal, the degree of cognitive distance does not influence the quality of innovation outcomes regarding incremental or radical innovation. We could also show that cross-industry innovation leads mainly to breakthroughs and radical innovation instead of incremental innovation. This is a contribution to cross-industry theory, because the degree of cognitive distance is not correlated to this outcome as theory suggests. Therefore, cross-industry innovation follows a logic that cannot be found in strategic alliances or the creativity literature.

We did not test the market value of the created innovation. In this respect, analogical solutions from close-by fields might be easier for competitors to imitate than analogies from very distant industries. However, a longitudinal analysis could reveal whether there is a correlation between market value and cognitive distance.

Moreover, because we controlled for firm size, age, and clock speed, we could illustrate that a firm's age is not correlated to the use of cross-industry innovation as theory suggests (Sorenson and Stuart, 2000), although a firm's size and clock speed is (Acs and Audretsch, 1991; Nooteboom, 1994; Fine, 1998). The main users of cross-industry innovation are large incumbents from fast and medium clock speed industries, which do so to reduce time to market and increase their innovativeness. This could be due to environmental pressure related to shorter innovation cycles and their scale advantages, the diversification of their risks, and their wider portfolio of activities in which unpredicted R&D outcomes could fit (Nooteboom, 1994).

5.2. Managerial contribution

Our major managerial contribution consists of elucidating the cross-industry innovation phenomenon. Management does, however, know that adapting analogical solutions is a valuable complementation of their innovation portfolio, leading to breakthroughs or radical innovation. Nonetheless, we cannot confirm that looking far from established industries increases the value of innovation, as close distance solutions also enhance the potential for valuable innovation. Therefore, we suggest that cross-industry innovation should be established as a method to systematically explore innovation efforts in incumbent companies.

5.3. Limitations and further research

One important limitation could be inherent in our study. We operationalized cognitive distance with the NACE industry classification in order to apply an objective measure. Other researchers suggest comparing patent portfolios or classifications between alliance partners to estimate distance. Because most of the described innovations have not been patented, we could not use these measures or the novelty of the outcome. By using the European Union's official industry classification to estimate distance and external experts' estimations of the degree of radicalness, we introduced bias into our study, but were well aware of this limitation.

As mentioned before, some cases in our sample were joint developments of two or more partners from different industries. Investigating these cases showed us that what one partner finds disruptive might only be incremental for another. Consequently, we call for more studies in the field of co-creation in cross-industry innovation.

Our sample is, moreover, limited to 25 cases and biased by large companies' marketing efforts to promote their latest innovation as a cross-industry one. Therefore, larger scale studies focusing on SME and including failed cross-industry efforts could shed light on when and how the highest innovation performance can be achieved and at what costs. As mentioned, a longitudinal study could also show whether the market value is larger if the cognitive distance is higher in cross-industry innovation.

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