A Trilogy on Discontinuous Innovation. Part I: Search

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Terry entered academia at the University of Western Sydney in 1986 as a mathematics lecturer, moving to a position lecturing in management in the 1990's and since progressing to Associate Professor. An active member of the Centre for Industry and Innovation Studies (CInIS), his teaching and research are presently centred on innovation, knowledge management and logistics in supply chains; particularly those associated with SMEs in Manufacturing. His output over recent years includes over 20 refereed publications, more than 25 conference papers, and several consulting projects in the areas of business communications and quality management systems along with numerous funded research projects.

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ABSTRACT

In this article we discuss the concept of Discontinuous Innovation (DI) and how it differs from incremental (or steady-state) innovation. We propose a model to conceptualise the different aspects of DI and discuss the complex nature of the DI process through an investigation of previous literature, and propose a sequence of articles roughly following the key components as described in the conceptual model, beginning with aspects of 'search'. We then describe an on-going multi-national action research program established to investigate DI through the development of learning networks of firms in several European nations and Australia. The research progress to date is outlined and initial results of analysis on both quantitative and qualitative data collected thus far is used to explore how companies go about searching for clues or ideas about potential discontinuous innovations, which may either create competitive advantage for, or threaten the survival of the business. Key outcomes of the research to date include the identification of the most common search strategies within the participating companies and some descriptive analysis on just how these strategies are implemented in targeted firms. Finally we describe the proposed future research program and the two papers to follow completing the planned three part series on Discontinuous Innovation.

Keywords: Discontinuous innovation; Intellectual capital, Search cycle behaviour; Inter-firm knowledge sharing; Learning networks; Business innovation.

BACKGROUND

'Change favours only the prepared mind'
Louis Pasteur

In our research program, we apply a relatively broad definition of innovation as follows: "[Innovation is]….**a renewal process**. The process unfolds as a complex interplay between renewal of product/service, market, technology, organisation, and/or business process, with the purpose of **increasing the stakeholder values"** (Gertsen et al 2006). This definition emphasizes the integrative nature of innovations. Whereas much innovation management literature has focussed on products and processes as the object of renewal, more recent literature tend to include many other objects of renewal (such as markets or business models). In particular, business model innovation appears to be a growing type of innovation.

Many innovative businesses have developed 'good practice' models for product and process innovation. A major limitation of these 'good practice' models is that they are about 'steady-state' innovation – essentially innovative developments in product and process areas that are about 'doing what we do, but better' (Tidd et al, 2005: 18). Continuous Innovation (or steady-state innovation) is very important to any organisation as it is the driver of product improvement, line extension, market development, etc., but firms also need to be aware of the challenges and opportunities of what might be termed "Discontinuous Innovation". Herein this term is considered to incorporate 'disruptive' and 'radical' innovation as discussed by others (Christensen, 1997; Leifer et al, 2000:1; Tidd et al, 2005:13).

Innovation is considerably more difficult when elements of discontinuity come into the equation. Such discontinuous challenges arise from shifts along technological, market, political and other frontiers and require new, or at least significantly adapted, approaches for effective management. Businesses need to understand the particular contexts in which different approaches might help, and what configurations of new and existing practices might enable organisations to deal with and benefit from such discontinuities. Discontinuities such as digital photography, DVDs, mp3 music, etc. can rapidly destroy a market for hugely successful products and cause large, highly respected firms to stumble and fall. The increasing pace of change in technological, regulatory, environmental and global market developments is forcing firms to consider the strong possibility that discontinuity will almost certainly change the basis of the business sooner or later.

While much research has focused on continuous incremental innovation; requiring firms to constantly seek and implement innovation in their products, services, processes and business models; the research reported in this paper considers Discontinuous Innovation (DI) and the challenges and opportunities it provides businesses of all types and sizes. Thus the objectives of our research are to better understand the differences between incremental and discontinuous innovation, and to explore the possibilities for firms to respond to, and perhaps, take competitive advantage through, DI. This paper explores the concept of DI, proposes a conceptual model for DI and explores the first stage of that model, the Search stage. We intend to complete the trilogy with a second part examining 'selection of ideas' and a final paper examining the 'implementation' phase.

DI can be differentiated from incremental or steady state innovation because it **changes the competitive basis** of a market, thus DI presents high uncertainties in terms of market, technology, organizational support and resources. DI can involve the creation of a **new line of business** – new for both the firm and the marketplace, and incorporates the concept of **radical innovation,** which Leifer et al (2000) defined as: new to the world performance features, or 5-10 times (or greater) performance improvement over existing products, or 30-50% (or greater) reduction in cost. DI can involve a new way to combine existing technologies/resources through the introduction of a **new business model**; and DI incorporates Clayton Christensen's (1997) "**disruptive technology**" concept, where a disruptive technology is one that: provides a brand new offer, or a new market; provides a surprisingly good performance for the price; and, is incompatible with existing market standards.

However, rather than consider incremental and discontinuous innovation as a dichotomy, we consider them as existing upon a continuum scale which is useful in understanding different types of innovation. Hedberg (1981) has claimed that the process of learning through which knowledge is acquired is always somewhat incremental regardless of the type of innovation involved.

We contend that companies – or at least part of them – are often aware of emergent discontinuous innovation that will have a disruptive effect on their business. The trouble is that it may not be taken seriously enough, or by the time it is taken seriously, it is too late because of the timeframe and/or the amount of change needed. Christensen (1997) points to the blindness, hesitation, and incapability of management and organizations to change. Many other authors have written about cycles of continuous improvement disrupted by major changes (Imai, 1986; Adizes, 1999; and Churchill and Lewis, 1983). Even Schumpeter (1934) spoke of periods of temporary advantage punctuated by periods of destruction. Following March's (1991) concepts we believe companies need to maintain a balance between exploitation activities (continuous improvement, steady-state innovation) and exploration activities (searching for and reacting to, or creating, discontinuous innovation). Other authors have also discussed the difficulty of balancing the exploitative and explorative actions within the one company structure (DeTienne and Koberg, 2002; Boer and Gertsen, 2003; Benner and Tushman, 2003; Andreassen et al, 2007).

Assink (2006) quotes Veryzer (1998) when describing three types (or sources) of disruptive innovation: technological discontinuities; commercial discontinuities and a combination of both. We believe there are several other identifiable sources of discontinuities, as shown in Figure 1. Contrary to the more sequential process of steady-state innovation, discontinuous or disruptive innovation is a complex interactive process of searching, probing, learning and unlearning, exploring and experimenting, involving cycles of convergent and divergent thinking (Assink, 2006). Considering the wide range of possible sources of discontinuity, and the key aspects of Discontinuous Innovation, we have developed the simple model shown in Figure 1 that tries to capture the main aspects of Discontinuous Innovation.

A simple model of a complex process

The model in Figure 1 depicts a number of triggers of discontinuity, which require companies to search and monitor for opportunities and threats. For instance, new technology is an important trigger of discontinuity. As a current example, even the very symbol of an innovative idea – the Edison/Swan glow lamp from 1879 – seems to be heading towards obsolescence due to a combination of two discontinuous triggers – technological and regulatory. Australia is set to forbid sales of glow (or

incandescent) bulbs from 2010 to reduce coal-powered electricity consumption and therefore CO_2 emissions, and the EU seems to be following that lead[1]. It is not clear which technology will substitute, fluorescent tube 'bulbs' are currently replacing glow bulbs, but the LED light may be a better candidate offering perhaps 80% more energy efficiency and 16 times longer lifetime. As the market is in considerable flux, it is difficult – as in many other cases - to predict which paths will emerge when social and cultural forces select, combine, use and reshape technology. Other examples of discontinuity sources include political regime change (the transformation of China), sea changes in social and cultural mores, the emergence of new business models (for example Dell Computers and Ryan Air), and 'unthinkable' events, such as 9/11, SARS, global warming, and large-scale earthquakes and tsunamis. The consequences (and opportunities) for industries arising from these sources of discontinuities are many and can be widely scattered in time and space.

Firms and industries need to develop *search* routines for such discontinuous conditions, including finding, recognizing and processing information (e.g., gather, store, analyse, filter, transfer, communicate) from possible sources, and then *selection* routines to assist in deciding which particular ideas or sources of discontinuity the firm should investigate by probing against internal and external evaluators. Finally firms need to develop routines for *implementation* of evaluated concepts, eventually leading to effective response to the market in terms of reaction to or creation of discontinuous innovation. Indeed these steps are not trivial. In particular, the creation and transfer of knowledge across deliberately diverse entities may introduce high levels of knowledge stickiness.

In steady state innovation these process steps may be rather separated and internal to the firm, whereas in discontinuous innovation they become significantly more complex, intertwined and interactive with a range of contacts and collaborators outside the firm and outside the industry. Thus the firm's social capital becomes a telling factor in the success or otherwise of the firm's ability to respond to, or create discontinuous innovation.

{Take in Figure 1 here.}

Understanding the complex nature of the process

Although created to understand systems in natural science, complexity theory offers an interesting metaphor for understanding the nature of processes at the front-end of innovation, and particularly for discontinuous innovation. Complexity theory suggests that the future emerges unpredictably from interactions under conditions of flux. Key aspects emphasized are 'emergence', 'self-constructed evolution', and 'order-generating rules'. The idea of 'emergence' suggests avoiding path-dependency and focusing on new emergent paths instead. 'Self-constructed evolution' suggests that it is important to keep 'stirring the pot' by making actors interact, yet keeping a balance of change not over stressed and not settled. 'Order-generating rules' emphasize that relative order is established through self organizing and simple rules (Lassen, 2007; Stacey, 1996).

Applying this perspective to our study of discontinuous innovation has important implications. Innovation must evolve through a process of learning, unlearning, experimentation, interactions, openness, and improvisation. Companies interacting under discontinuous conditions need to recognize and accept uncertainty, if they seek constant stability they are bound to fall short of competitors. They need to be open to 'accidents', serendipity and coincidence as triggers of emergent strategies and possible futures, and be ready to seize such opportunities whenever and wherever they might arise. This limits the control and influence of managers, but managers can set the stage for increased interaction, learning, trust and openness, be part of such interaction, and influence the meaning constructed through such interaction. The aim is to encourage and support effective, on-going interaction, and not some one-off choice of specific solutions such as any one particular search strategy or way of organising the innovation. It is about maintaining the dialog about these things alive and ever changing (Möller and Svahn, 2005).

In this paper we will be reporting on our research to date which has focused on search strategies involving learning networks of firms in 3 European nations and Australia. Empirical data collection and analysis from firms involved in the learning networks in 6 countries is on-going and the results

presented herein represent an initial view only. Quantitative data from around 30 firms in Europe and Australia have been supplemented with qualitative data from interviews in 4 Australian firms. Research is on-going and will be extended as the data collection and analysis activities continue throughout 2007 and 2008.

IN SEARCH OF SEARCH THEORY

It takes a difference to make a difference (Bateson, 1972). Ideas for (discontinuous) innovation come about in a variety of different ways. They may stem from information acquired from the outside of a focal organization or generated internally – or (more likely) in a boundary spanning network/relationship. We are concerned with the specific ways ideas related to discontinuous innovation come along, specifically how companies search for, scan for, generate, or acquire information or ideas. Ahuja and Katila (2004) found that new path-creating search established by crossing additional scientific and geographic boundaries contributes to increasing innovative output.

'Search' especially resides at the fuzzy front-end, where authors speak of problem/opportunity structuring and/or identification/recognition (Leifer et al. 2000). It is concerned with knowledge collection/exploration (March, 1991) and the nature of the activities – creative, experiential, explorative and hard to assess - tends to produce looser, perhaps less visible organizational structures, especially at the 'early' front-end. The 'later' front-end involves aspects of idea generation and concept development (implying selection activities, cf. our framework, Figure 1), continued information collection, and informal or pre-screening with possibly some initial fund allocation for exploring a new idea (Reid and de Brentani, 2004).

In a paper also based on the DI Lab research, (the same common empirical foundation as this project) von Stamm and Bessant (2007) identify 12 search strategies, ranging from well known methods to newer approaches with potential for innovating under discontinuous conditions (Table 1).

{Take in Table 1 here.}

Some of these search strategies may be considered mostly as techniques with a main focus on the actual search activity (idea generators, exploring multiple futures, using the web) whereas others are a bit wider in their scope as regards process steps in an innovation process, time frame and organization. For example, probe and learn can be helpful in selecting ideas by trial and error against the market, mobilizing the mainstream and corporate venturing is likely to involve more process steps, organizing and a longer time frame than the technique-like strategies.

Based on experience from Hewlett Packard, Kaplan (1999) proposes four different strategies to help identify opportunities for discontinuous innovations. These strategies primarily seem to facilitate 'pattern breaking' thinking. The first 'radical cannibalism' suggests to hypothesize obsolescence and to scan start-ups; the second 'competitive displacement' suggests to expand business from the root end-user needs and explore how the core value provided can be used outside the industry; the third 'market invention' involves expanding the firm's understanding of the market and of the total value system relevant to the product; and the fourth 'industry genesis' suggests to imagine miniaturization – what if your product was 10-20 times smaller and to combine technology/functionality to provide new value.

Who is involved in search activity?

Reid and de Brentani (2004) argue that individuals play an important role at the front-end: "As a result, the fuzzy front end for firms involved with discontinuous innovation is often a period where individuals within the firm are marrying new information with previous knowledge, and it is this process within the fuzzy front end that has not been understood well—that is, the process where individuals link corporate-level and individual-level knowledge with new information from their environment." These authors also state "Such individuals perform a boundary spanning function by identifying and by understanding emerging patterns in the environment, with little or no direction from the organization". They take a decision process approach and argue that the nature of the information pursued (as 'non-directed') points to the individual as the key actor in the early front-end (boundary

and gatekeeping), and then the decisions become gradually more institutionalized at the project-interface (Reid and de Brentani, 2004).

There is ample evidence that users are an important source of ideas for innovation. Von Hippel (1988) has found that user involvement varies greatly across industries, thus in some particular industries users are the source of up to 90% of all innovations. For example, in scientific instruments and the pultrusion process (the continuous semi-autonomous production of composites materials) innovation, customers provide between 70% and 90% of all innovation sources. He provides compelling arguments for replacing a 'manufacturer-as-innovator' assumption with a view of the innovation process as predictably distributed across users, manufacturers, suppliers, and others' (von Hippel, 1988; 2005). Of course this has some prerequisites regarding the costs and 'rents' of innovation.

It is generally accepted that most user-sourced ideas are of an incremental nature (as per the Henry Ford quote: 'If I had asked my customers what they wanted, they'd have asked for a faster horse'). Arguably, this is the case for most innovation ideas in general - user-driven as well as internal, however the lead-user concept and more 'advanced' search methods have shown that more radical innovations can also emerge from the natural insights and inventiveness of users.

The shift from 'manufacturing-centred' innovation to 'user-centred' (op. cit.) innovation is not easy for all manufacturers but offers some great advantages for the users. Empirical studies show that between 10% and 40% of all users engage in developing or modifying products (von Hippel, 2005)[2]. Since needs tend to be heterogeneous just as users, the potential here seems huge. Besides getting what they want, users seem to enjoy and be motivated by the problem-solving process, which manufacturers usually pay developers to undertake. Users also tend to freely give away IP rights because they consider it as the best or only practical option, protection may be of limited value, whereas return contributions from other such as improvements and reputation (in communities) may be more valued (von Hippel, 2005).

As the resources needed to facilitate design work decreases, (computers and software) and perhaps to produce prototypes (3D printers), von Hippel (op cit) predicts that the design will become (more) democratized. One implication may be that (manufacturing) companies should increasingly look for lead user innovations and commercialize them. Perhaps we will see a trend towards 'mass-design' just as we have seen 'mass-customization' in manufacturing. Similarly, just as manufacturers used to have a make-buy decision, the users now have an innovate-or-buy decision (von Hippel, 2005). Thus users can be a key source of discontinuous possibilities as well as incremental innovations, and become part of wider groups including suppliers, industry and regulatory associations, University and professional associations, etc. that can be tapped for possible discontinuous search possibilities.

How to search?

There is a rather wide consensus that variety and diversity are needed to create different ideas and that ideas are often sparked at the intersection of divergent areas of expertise. That is, using diverse backgrounds and expertise to create ideas 'out of left field' or 'outside the box'. This diversity can be created in many ways via temporary scene shifts and organizing people in non-standard arrangements.

Theories of innovative roles suggest how some roles may be of importance to search. Trott (2001) proposes a range of possible roles applicable to front-end innovation processes including *champion* (entrepreneur), *gatekeeper, scout*, *idea generator* and *technical innovator*. The individual drivers of discontinuous innovation may have either a technological or market visioning role (O'Connor and Veryzer, 2001; Reid and de Brentani, 2004). Often the discontinuous innovation will grow and spread in the organization from these people.

From a power perspective discontinuous innovation and its early proponents may work against the stream of power. A strategically balanced, top-down/bottom-up approach is presented by Burgelman (1990) and also, in his corporate venturing approach Burgelman (1984) describes how ideas often emerge from lower level core functions and gradually move to corporate level, overarching systems through a 'negotiating process'. Lassen (2007) hypothesized three types of radical innovation processes with respect to strategy; 'the pre-defined journey' which roughly falls within the bounds corporate strategy; 'the personal quest' comes at odd with current strategy; and 'the infinite journey of

opportunity creation' that reshapes strategy through a learning process. Also previously presented Table 1 holds a number of suggestions as to 'how to search'.

Where to search?

According to a recent McKinsey global survey of 3,693 executives[3], two out of three executives say internal development (formal or informal) by an R&D (or similar) department or organization, is their companies' most important source of knowledge. Following this, partnerships with other businesses and cooperation with academic institutions is seen as less important. The 'movement towards open innovation' is therefore not clearly evident from this study, although there is a suggestion that 'internal development' as considered by the executives, has been enriched or tapped from external sources.

A comprehensive repeated study of product innovation in Denmark (1988-2000) almost consistently over the years ranked sources of innovation in the following order of importance: customers; internal sources; suppliers; tradeshows etc.; universities; other research institutions; technological service centres; and consultants (Christensen et al, 2006). However, these results specifically concern product innovation and primarily involve incremental innovation. Based on data from the 2001 UK innovation study (a representative study across several industries with 18,602 distributed questionnaires and a response rate of 41.7%) Laursen and Salter (2006) found that general innovation sources are dominated by suppliers (equipment, materials, and components) and customers/clients. Specialised sources such as technical and environmental standards were the next most common source cited by respondents.

Blair (2002) has studied the sources of radical innovation and found that 67% came from dominant firms in a given industry, while Sorescu et al (2003) found in a study of the pharmaceutical industry that a large majority of radical innovations come from a minority of firms. Herstatt (2002) found that current market research methods for the discovery of radical innovations in the form of new market/technology combinations possess only limited suitability, whereas better ways were needed to involve sources of specifically qualified, innovative knowledge carriers early-on in the process such as lead users or external experts with relevant knowledge from analogous markets. Von Hippel (2005) discussed identification of lead users, for instance using 'pyramiding' – looking at more advanced users, maybe in other fields (for example ABS braking for cars was developed from looking at aero space developments). It seems as if radical innovations require companies to push out the boundaries of knowledge and competencies and are for that reason predisposed toward utilizing external knowledge (Deverell and Lassen, 2006)

There is a rather wide recognition that the environment external to the firm is the primary source of new ideas for discontinuous innovations and that even in-house ideas ultimately have some input from external sources (March, 1991; Reid and de Brentani, 2004). The latter may explain some persistency in surveys reporting that ideas come from the corporate R&D department (ranked number 1-3 in the surveys quoted above). Since ideas are made of 'elusive stuff' the ownership can be hard to untangle and the first shapes of ideas in companies may be a patchwork of many ideas, some used in different ways or slightly changed from the original spark. "In the case of discontinuous innovation, old elements usually come initially from an individual in the firm who has the idea to combine one or more technologies, which previously were unrelated in an important way. In other words, new-to-the-world products that expand the market tend to be initiated from outside the current industry but through individual and firm-level processes" (Utterback, 1994). Although not being in focus here, issues of tacit, non-codifiable and sticky knowledge are acknowledged to have great impact on knowledge creation and transfer processes (Nonaka and Takeuchi, 1995; Polanyi, 1966; von Hippel, 2005).

Search scope and implications for outcome

Many studies of innovation search conclude that local (internal) innovation search is prevalent in organisations but the consequences of this choice for the output including its 'radicality' is rather unclear (Katila, 2000). This author then examined the impact of innovation search on new product outcome in the robot industry and found that: 1) search scope (the proportion of new knowledge 'sources') is positively related to the radicality of new products (e.g. due to more variety and possible re-combinations of knowledge); and, 2) search depth (familiarity with knowledge elements being

searched) is *negatively* related to radicality of new products. Findings regarding radicality when combining the two (interaction of depth and scope) were not significant, but all three had positive impact on the number of products developed. Some constraints were also investigated and it was found that prior experience with broad scope search also had a positive influence on radicality of new products (Katila, 2000).

However, Laursen and Salter (2006) found counter-evidence: "We found that external search *depth* is associated with radical innovation" and explain that "In early stages of the product life cycle when the state of technology is in flux, innovative firms need to draw deeply from a small number of key sources of innovation, such as lead users, component suppliers, or universities. In these early stages, only a few actors may have knowledge of the key technologies underlying the evolution of the product. Innovators need to cling to these sources, drawing deeply from their knowledge and experience". They imply that companies should thus be aware of over-search, due to e.g., search costs. Case examples from Deverell and Lassen (2006) may indicate the need for a wide scanning to detect sources for ensuing deep draw investigation, which is considered necessary since 'knowledge that needs to be created for a radical innovation is often highly research intensive'.

Laursen and Salter (2006) also found that for all innovations (various levels of innovativeness) innovation performance takes an inverted U-shape related to both the breadth and depth of search. In other words, too little and too much search is not beneficial for the outcome. On average firms only draw deeply from one knowledge source. In addition they argue that as the technology and market mature and the network-supported innovation expands (thus knowledge becomes more widely spread and developed) innovative firms need to expand the search scope and scan across a wider number of search channels to find new combinations of existing technologies having emerged in a variety of places. They also found that breadth and depth of search varies across industries.

METHODOLOGY

In trying to address the challenges of discontinuous innovation, research has been conducted along with the simultaneous facilitation of networks of firms acting as a community of practice, a 'co laboratory' (Philips, et al, 2006) for learning and sharing experience with DI. Empirical evidence has been obtained from the Discontinuous Innovation (DI) Lab Project currently operating in 6 European nations and Australia. The DI Lab project was initiated by Professor John Bessant in the UK and expanded via a network of researchers in several countries facilitating and researching interactively with learning networks of firms interested in a deeper understanding of, and sharing knowledge and experience with the challenges of Discontinuous Innovation.

We draw particularly in this paper on the experiences of two parallel networks in Australia and Denmark, and on data from the initiating network in the UK and the network in Germany. Within and across these networks we are trying to develop a systematic structure for comparing and sharing experiences and articulating research issues – a 'benchmarking framework' which will allow firms to identify potential sites for learning from and with each other around the development of discontinuous innovation (DI) capabilities (von Stamm and Bessant, 2007).

The co-laboratory combines elements of action research with case-studies of individual firms, quantitative questionnaire data, and data collected via a series of experience-sharing workshops focusing on core themes in an emerging analytical framework for the DI process. The process may be conceived as an interactive co-evolving relationship between the researchers and the corporate network members. In action research the researcher takes an active role by participating in and being responsible for formulating and achieving the objectives of the field (the objectives of the network and the benefit for participating companies) (Kotnour, 2001). Westbrook (1995) says concisely that a researcher *"…performs research in action, rather than about action"*.

Phrased in the terms of complexity theory, the researchers try to facilitate and stir the on-going interaction, acknowledging participants need to thrive on emotionally positive processes as many actors have not had enough time to develop trust (or distrust). Initially setting the stage and climate of the network is a fragile and important process for the prospects and outcomes. The researchers organize and facilitate during the workshops with some intervention impact, through theory and

empirical knowledge transfer, and share knowledge through company presentations and discussions during the workshops. Furthermore, some impact has happened via interviews undertaken for the purpose of writing cases, through the delivery of company feedback via 'corporate reports', and DI lab international conferences have been organized. A few 'spin-offs' have been observed in terms of bilateral exchange relationships between network members, and consultancy work involving some academics. In order to fuel the interaction with firms and the impact of the process there is a deliberate focus on successful case examples in order to inspire and motivate the overall action process and progress of the DI lab.

A more balanced assessment is undertaken by the questionnaire and somewhat through the case interviews. Due to the infrequent appearance, concealment, emergent nature and (perhaps only) post-recognition of the phenomenon of discontinuous innovation it is very difficult to find companies for real-time case studies. The approach taken is therefore to collect 'bits and pieces' building on a large variety of companies, which are largely recognised as being innovative. In this article we draw particularly on selected data items from the DI Lab questionnaire (appendix 1) related to search issues. Results from the 'Search' aspects of the questionnaire from 25 companies from 3 European nations (Germany, Denmark and the UK) and Australia have been examined. The companies range from small to large and include both service based firms and traditional manufacturing sector firms. We also use qualitative data from mini-case studies, typically interviews with R&D managers, mostly in Australia and Denmark but including some examples shared in the DI Lab.

FINDINGS AND DISCUSSION

Using feedback from the 'Search' related questions in the DI questionnaire (see Appendix 1) the chart shown in Figure 2 maps the importance and usage medians for search strategies within the 25 companies surveyed thus far. Company responses to questions concerning search strategies and activities were mapped onto the 12 search strategies as listed in Table 1 and discussed more fully in von Stamm and Bessant (2007).

{Take in Figure 2 here.}

It is clear from Figure 2 that that the two search strategies that are most widely regarded as important (and most widely adopted) by the firms are Idea Scouts and Mobilising the Mainstream, as shown in Table 1. While extensive discussion can be made on all the identified strategies, we will limit our considerations to those strategies that have been found to show the greatest difference between importance and usage.

Using the web

This search strategy tries to harness the power of the web, through online communities, and virtual worlds to, for example, detect new trends. Our measurement addresses specifically the use of the web to open the innovation process in terms of using a community of scientists for problem-solving. The data indicate that companies have made little use of this, but do recognize that it has importance beyond its current level of use.

The questionnaire does not allow in-depth analysis of the search strategy. With new generations of web 2.0 tools (web 3.0 etc.) this strategy may be expected to hold greater potential. Cases in several European companies display interesting and novel solutions. e.g. the Lego Factory website allows users to build their own models online and then buy and receive a parcel with the ready to assemble set of items (http://factory.lego.com/). In terms of search, the site facilitates direct communication with users and helps to identify potential lead users and ideas for wider use, e.g., 4 lead users were involved in the development of the second version of the Lego Mindstorm product. Case study research in Australia has found that a major telecommunications firm makes extensive use of web-sourced information for in-depth data mining and statistics to better understand users and customers.

Corporate venture units

Creating and deploying such venture units was used sparsely by the companies examined, and there is a large gap between its use and its claimed importance. An Australian construction firm noted the use of spin-off units in its recent history to take advantage of market discontinuities that would have disrupted the functioning of their business had they been incorporated in the main company unit. In trying to open up new markets and technology spaces to move beyond its current product range Coloplast established a small group (Nebula – New Business Lab) with the remit to explore and bring back new options. These could be acquisitions, licences for new technologies, new alliances and partnerships or established product ideas. The group also had a mandate to explore licensing and spinning out business units. Similarly Novozymes is developing a 'Radical Innovation Hub' with a similar remit – to experiment and challenge with new business models and directions. They include in sourcing, acquisitions, and idea scouting as part of this mandate. The team currently involves around 30 people worldwide and they are trying to grow this by recruiting entrepreneurs into the company.

As an alternative approach an Australian toolmaker has established networks of Australian firms to enable their joint access to larger international markets (e.g, aero industries) that were beyond the reach of the company acting alone.

Deep dive

The Danish medical company AMBU has felt a need to generate better concepts. In support of this a '*preject'* process has been initiated. This 'preject' process, implemented in the early stages of product consideration and development, is supposed to generate a more comprehensive picture of the area of interest. The current version of the 'preject' process has strong inspiration from the deep dive approach.

Coloplast has been experimenting with this on the back of its successful use of health professionals as active 'lead users'. Their approach has been to find new communities, or those less well-served – for example, in developing country contexts, where the nature of the context differs radically but where a deep understanding of how their devices might be used in such a context will be critical for entry to those markets. However in building this understanding there may be important lessons to transfer back to the mainstream. For example, how to make products which are 'good enough' in quality but available at a fraction of the current developed market prices.

An Australian pharmaceutical company assimilates deep knowledge through close interaction with users through sales, marketing, and field tests. This is supplemented by close examination and analysis of information from customer complaints.

Von Hippel's (1988, 2005) extensive work on user involvement indicate a potentially huge impact from using this search strategy and also point to implications and issues of ownership and benefit sharing.

Other findings: Expanding the search concept?

If we think of 'search and find' as a matching process rather than 'search' alone, it allows for the inclusion of viable strategies within this framework. Thus a focal company can be good at searching or good at being found. In case of the latter it need not be so good at searching *per se*, it can rely on being found by others that are good at searching. We will call this 'search and find' strategy 'visibility'. To pursue visibility as a search strategy, an organisation needs to be easy to find by being generally well-known, having a strong brand image, being exposed in the news media or other widely spread information carrier. (To draw an analogy, this strategy is one that has been widely employed during the course of natural evolution. Flowers make it easy for bees to find them; sea anemones attract small fish prey probably by its movement and colours).

One of the Australian case companies started with branding the company in part to strengthen its identity. Before this the approach to the market was more like 'Tell me what do you need, and I'll tell you if I can do it'. An important effect of this is that the company became visible to the customers and government negotiators of contracts.

Many of the 12 search strategies identified in Table 1 are linked and overlapping. We have made a cross-comparison between all search strategies, which clearly indicates that most search strategies may combine and/or complement each other. Generally search seems to be an integrated part of business activities, especially in small and medium size companies. They rarely have a range of explicit 'search strategies', but they rather give examples of how the organizations search through their interactions, e.g. with customers, suppliers, knowledge centres and other agencies. It is not unusual to hear people in companies express that they have enough ideas (Lassen, 2007), the problem being how to select and implement the *right* ones. We have heard this many times during the DI Lab workshops, although frequently the firms are still limiting their frame of reference to incremental innovation. Greater challenges become evident once they shift to a discontinuous search perspective.

One might speculate that getting ideas is more fun and the easy part of innovation. The real challenge exists in the selection phase - which ideas could lead to valuable outcomes - and development and implementation, where it becomes really difficult. Muller and Valikangas (2002) suggest that mature companies engage in alliances to explore white spots. They also suggest engaging in multiple search parties to explore different locations of the knowledge landscape. For emergent spaces, they suggest companies pursue search strategies (explorative collaboration) that emphasize low—cost of probing and learning to effectively and efficiently cover the space of interest. We have seen a variation of this in one of our case-companies. The Australian toolmaking company was working to explore how the pool of competences held by the firm and its recently acquired businesses could be re-packaged to address (potential) needs of customers.

'Search' intertwined with 'selection'.

Often it is not expedient to distinguish between search and selection as two separate activities. Search and selection are often intertwined as the innovative idea is gradually qualified. It seems as if conditioned and temporary decisions are prevailing at the front end. In one of the Australian cases representative management meetings serve (to some extent) as a place for generating ideas in the space between market knowledge and possibilities, selecting ideas to take on for further probing. However the priorities made in these meetings leave some ambiguity for the development department to interpret. 'I have this worry that we can be working on something, and they think we are working on something else or…'(development manager, Australian case). One of the Danish cases have coined the term 'half-decisions' (Lassen, 2007), which is a similar conditioned and temporary decision. Also prototypes are by definition a temporary 'expression' - a suggestion. At Bang & Olufsen part of the search resembles an artistic process of finding the right 'expression' and functional 'feel' of the product or component. In this tightly linked sequence of ideas and (physical) prototypes to test and share, learning about 'expression' and 'feel' has improved the process considerably (quicker and better designs). Decision models appropriate for this type of intertwined search and selection may be those such as the 'garbage can' model and the 'muddling through' approach (Simon and March, 1958; Lindblom, 1959). Also theories of knowledge creation and transfer have made an important contribution to the understanding of these processes.

CONCLUSIONS

We have proposed an extended conceptual model for Discontinuous Innovation and examined some of the key aspects of the front end of the model, involving search strategies. An initial analysis of empirical data collected as part of a DI Lab project in several European nations and Australia has allowed a discussion of the search strategies adopted by firms involved in the learning networks, with particular emphasis on those strategies showing the largest importance to usage gap. From the data analysed to date, the greatest opportunities for firms to improve their DI Search capabilities exist in using the web, create and deploy venture units, and deeper understanding of users/customers ('deep dive'). The quantitative data indicate that the two currently most extensive used search strategies are acquiring knowledge and ideas by 'sending out scouts' (idea hunters) and by 'mobilising the mainstream'. Although the qualitative analysis shows that the twelve search strategies can comprise most search activities identified, 'visibility' as search strategy may be considered as an additional aspect of the 'Search' phase.

For those companies actively involved in DI, search is a very integrated part of business activities. For example, information from Danish companies Lego and Coloplast show that search is an accepted part of Sales responsibilities. While smaller companies are often unaware of potential DI threats, larger companies are normally well informed of such threats; the problem mostly occurs in taking action, either proactively or reactively. The following (somewhat overlapping) issues have been identified around this problem:

- Inability to recognize the opportunity. "The technical and market uncertainties associated with radical innovations, however, often make this difficult. In 10 of our 12 cases, the individuals who generated the ideas did not recognize the opportunities." (Leifer et al, 2001). "..they [the firms] just need to recognize that they are in the right place at the right time (that is, to recognize an idiosyncratic problem or an opportunity) to start a new search" (Ahuja and Katila, 2004).
- Avoiding: hope it will disappear. Suppress the explicitly/recognition of the problem till it disappears or until it is undeniable, If the information is available (and in some cases there was not a lack of information about the DI). 'we used to think it would blow over… now we act on it…' (Australian case). Francis et al. (2003) calls this 'avoidance', one of 5 'pre-action' barriers (indecision, poverty, insularity, inability).
- The weak signals may be caught early, but there is so many of them with little propensity of becoming a threat or opportunity, so they may not seem to have been taken seriously enough, early enough – this only becomes clear when the company has the time to reflect upon it.
- Lack of capability to act: If response to a threat requires mobilizing/building a whole set of new competences (e.g., the case in many examples of disruptive technology (Christensen, 1997).

There are a number of triggers of DI (as shown in Figure 1) which will also tend to trigger new search paths in companies. We have integrated results from the quantitative and qualitative data set and identified a set of questionnaire items complementing findings from the case studies. In doing so, we also found some shortcoming in the questionnaire. For example, the questionnaire only allows for measuring a (narrow) specific part of the 'using the web' search strategy. If the quantitative data are to support the search strategies identified from the qualitative data, we contend that – as the number of responses increases - there is a need to expand the questionnaire. For example, a section on innovative performance would open new possibilities.

What is the value and limitations of learning from experience in Discontinuous Innovation? If the outcome – the Discontinuous Innovation itself – is imitated, it is by definition not anymore a Discontinuous Innovation, but the question is, to what extent can *the process* of creating new-to-the-world outcomes be reused by others?

We have also considered the possible interactions between the Search and Selection aspects of the conceptual model developed and described above. We have pointed to a number of theoretical areas that may help understanding this interaction as well as the selection process, including complexity theory, knowledge transfer theories, and decision models. This will be further expanded in Part II of the trilogy which will concentrate on the selection strategies used by firms. Finally we will complete our trilogy in Part III by examining the strategies employed by firms to successfully (or unsuccessfully) implement the discontinuous innovations that have been selected, to lead to an effective response to the market in terms of reaction to, or creation of, discontinuous innovation.

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APPENDIX 1 Search- Related Questions from DI Survey

For all items respondents were asked to answer two questions:

"We currently practice this in OUR COMPANY"

"This practice is important for DI in OUR COMPANY"

A. Learning about markets for Discontinuous Innovation	A.1. **Multiple market experiments**
	When we have a very new and different technology, we search for multiple applications and conduct several market experiments to discover promising markets.
	A.2. **Market diagnostic tools**
	To learn about unfamiliar markets, we rely on a set of unconventional market research tools to identify latent, yet unarticulated needs among different customer groups.
	A.3. **Applying existing technologies in new markets**
	We have a dedicated group of people (e.g. from marketing, sales, R&D) that explores new ways to apply our existing technology to new industries and new customers.
	A.4. **Co-developing products with lead users**
	We actively try to find those lead users who are actively innovating to solve problems present at the leading edge of a trend and seek to "co-evolve" new products and services together with them.
	A.5. **Look beyond the customer to the consumer**
	We make an effort to connect to our customers' consumers (end users) and obtain regular feedback on their demands, as we recognise that they drive what our customers need.
	A.6. **Learning from outside industry boundaries**
	We systematically seek out and learn from firms - within and in particular outside our industry - that are known to have well-functioning innovation practices in order to improve our own innovation system.
B. Managing discontinuous idea generation	B.1. Idea hunters
	We have technical people with business development skills tasked with finding new sources of potential discontinuous ideas within our firm.
	B.2. Using themed projects to stimulate discontinuous idea generation of high strategic relevance
	In our organization, we try to stimulate discontinuous innovation by periodically commissioning teams to generate ideas around major platforms or themes that are strategically relevant to us.
	B.4. Idea management team
	We have a team of people with responsibility for our idea management system.
	B.5. All ideas are welcome
	We encourage people to come forward with ideas, even if they have only a vague idea of the potential market applications for the idea.
C. The existence of an entrepreneurial environment	C.1. Heroes
	Successful innovators of breakthrough ideas are well-known and respected within the organization serving as inspiration for others.
	C.2. Entrepreneurial environment
	There is an atmosphere in our organisation which encourages everyone to take part in innovation.
	C.3 Risk-taking environment
	We have an environment where risk-taking is encouraged, e.g. to initiate discontinuous innovation projects and become entrepreneurs.
	C.4. Accepting failure in discontinuous innovation projects
	In our organisation failure is accepted in regard to discontinuous innovation projects and considered a natural part of the learning process.
D. Culture support system for discontinuous innovation	D.3 **Skunk works**
	Our organization allows some space and time for people to explore 'wild' ideas.

E. Helping employees solve their problems with discontinuous innovation	E.3. Corporate innovation consultants
	In our organization, we have individuals who have received special training in discontinuous innovation with the purpose of breeding "discontinuous innovation black-belts" who act as consultants on discontinuous innovation projects.
F. Project management for discontinuous innovation	F.2. Multidisciplinary and international diversity in discontinuous innovation teams
	When selecting our teams for discontinuous innovation projects, we aim to include members that are multidisciplinary (different functions) and when possible of different nationalities to achieve the greatest diversity.
G. Network management system for discontinuous innovation	G.1. Network brokers
	In our organization, we have "network ambassadors" who can help discontinuous innovation teams connect with other people company-wide when new knowledge or insight is needed
	G.2. A company wide network system that gives access to locating experts on discontinuous innovation
	In our organization, teams engaged in discontinuous innovation projects can locate experts on various disciplines in discontinuous innovation when needed through accessing a database on our intranet.
I. Openness to external sources for discontinuous innovation	I.1. **Online portal for problems and solutions**
	We use an open innovation system in which technology-related challenges are posted online by our R&D staff so that a community of registered scientists anywhere in the world can propose their solutions.
	I.2. **Licensing**
	We openly share many of our patented technologies with a network of research partners in order to license-in and license-out new technology.
	I.3. **Increasing reliance on external sources in R&D**
	Instead of doing all R&D ourselves we are moving towards open innovation by increasingly using external sources as input to our innovation process.
	I.4. **Collaborative research with external research institutions**
	We have implemented an open and collaborative research environment with e.g. universities, research centres and specialized agencies.
	I.5. **Discontinuous Short-term Flexible Alliances**
	Alongside our usual long-term strategic alliances, we develop short term technology-focused partnerships with other companies.
L. A venture capital system for discontinuous innovation	L.1. Direct external investment in small start-ups
	We have in our organisation an external venture capital program where we invest directly in promising start-up firms that operate at the edge of our own technologies.
	L.2. Investment in external venture capital funds
	We invest capital in external venture funds that specialize in managing a portfolio of firms that are related to our technological core competencies.
	L.3. Taking options in investments
	The team that manages the portfolio of internal and external investments exhibits an "options" mentality as it pertains to individual project selection.
M. Acquiring funding for discontinuous innovation	M.5. **Managerial budgets for small scale experiments**
	In our organization, all managers have been allocated a small financial budget, which they can use for small scale experiments on discontinuous innovation projects.

FIGURES

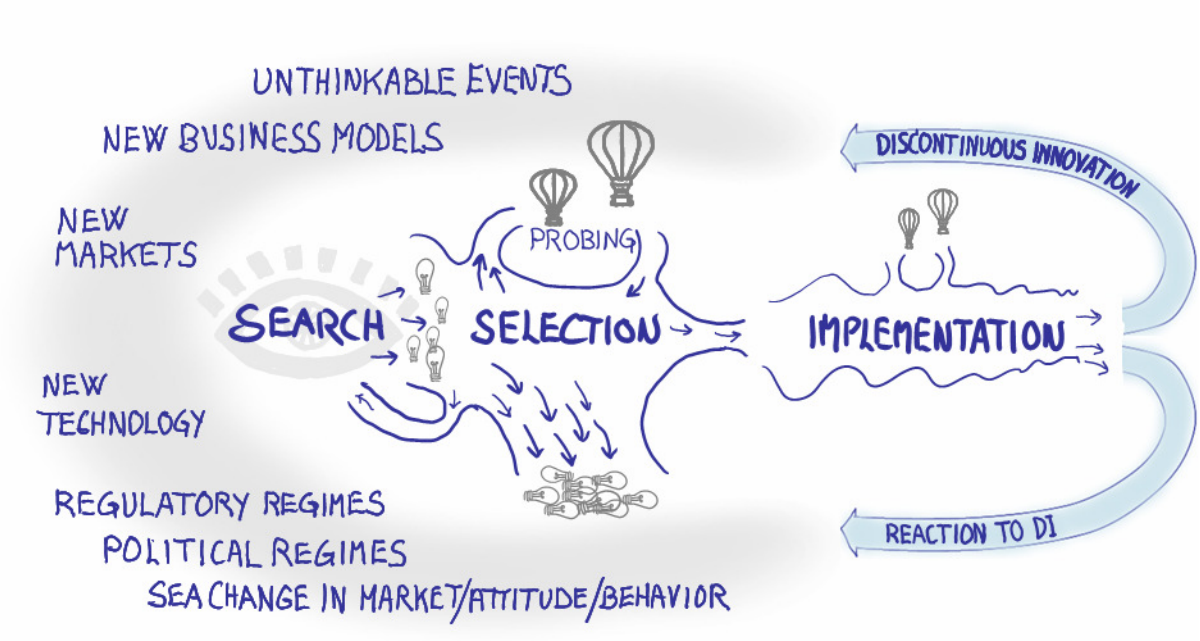
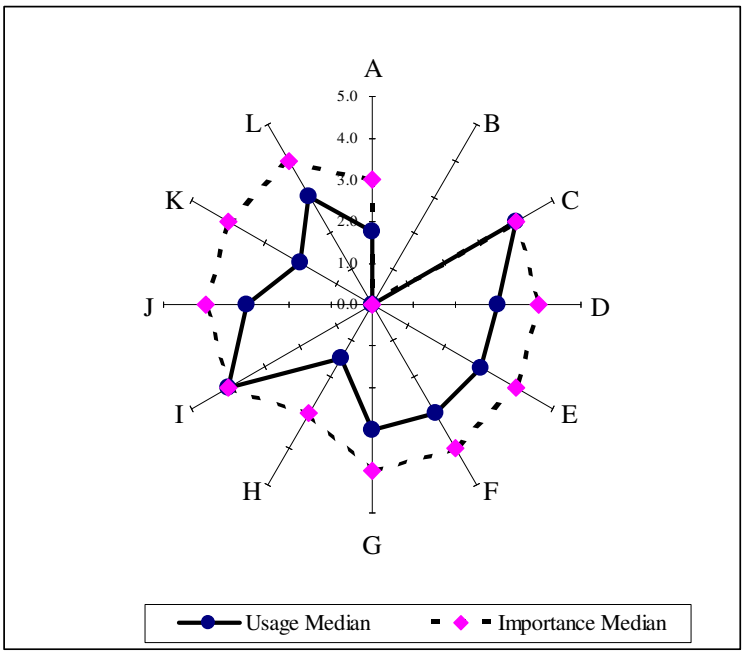


Figure 1 – A Model for the Key Components of Discontinuous Innovation



A	Use the Web
B	Futures
C	Idea Scouts
D	Idea Creation
E	Deliberate Diversity
F	Brokers
G	Intrapreneurs
H	CV Units
I	Mobilise Mainstream
J	Probe and Learn
K	Deep Dive
L	Active Users

Figure 2 Results from Search Components of DI Questionnaire

TABLES

	Search Strategy	*Mode of operation*
A	***Using the web***	Harness the power of the web, through online communities, and virtual worlds, for example, to detect new trends.
B	***Exploring multiple futures***	Use futures techniques to explore alternative possible futures; and develop innovation options from that
C	***Sending out scouts***	Dispatch idea hunters to track down new innovation triggers.
D	***Idea generators***	Use creativity tools
E	***Deliberate diversity***	Create diverse teams and a diverse workforce.
F	***Use brokers and bridges***	Cast the ideas net far and wide and connect with other industries.
G	***Corporate entrepreneurship and intrapreneuring***	Stimulate and nurture the entrepreneurial talent inside the organisation.
H	***Corporate venturing***	Create and deploy venture units
I	***Mobilise the mainstream***	Bring mainstream actors into the product and service development process.
J	***Probe and learn***	Use prototyping as mechanism to explore emergent phenomena and act as boundary object to bring key stakeholders into the innovation process
K	***Deep diving***	Study what people actually do, rather than what they say they do.
L	***Working with active users***	Team up with product and service users to see the ways in which they change and develop existing offerings.

Table 1: Twelve search strategies derived from DI Lab research (from von Stamm and Bessant, 2007).

[1] 'Household light bulbs get the flick' by Mark Kenny and staff writers, February 20, 2007 12:18pm. URL accessed 7th of June 2007 HTTP://WWW.NEWS.COM.AU/STORY/0,23599,21255435-2,00.HTML. EU follow by a restriction on maximum effect used (source: HTTP://ING.DK/APPS/PBCS.DLL/ARTICLE?AID=200770312008&NL=1&CATEGORY=MILJO (in Danish).

[2] Note that von Hippel consider 'users' the ones who benefit from using a product (companies as well as private consumers), and 'manufactures' as the ones who expect to benefit from selling a product or service (von Hippel, 2005).

[3] *The McKinsey Quarterly (March, 2007)* conducted the survey in March 2007 and received 3,693 responses from a worldwide representative sample of business executives— 37 percent of whom are CEOs, other C-level executives, or board directors. All data are weighted by GDP of constituent countries to adjust for differences in response rates.