City Research Online

City St George's, University of London

Citation: Verona, G. & Ravasi, D. (2003). Unbundling dynamic capabilities: An exploratory study of continuous product innovation. Industrial and Corporate Change, 12(3), pp. 577-606. doi: 10.1093/icc/12.3.577

This is the accepted version of the paper.

This version of the publication may differ from the final published version. To cite this item please consult the publisher's version.

Permanent repository link: https://openaccess.city.ac.uk/id/eprint/4612/

Link to published version: https://doi.org/10.1093/icc/12.3.577

Copyright and Reuse: Copyright and Moral Rights remain with the author(s) and/or copyright holders. Copies of full items can be used for personal research or study, educational, or not-for-profit purposes without prior permission or charge, unless otherwise indicated, provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way. For full details of reuse please refer to City Research Online policy.

City Research Online: http://openaccess.city.ac.uk/ publications@citystgeorges.ac.uk

Unbundling Dynamic Capabilities: An Exploratory Study of Continuous Product Innovation*

Gianmario Verona
SDA Bocconi – Bocconi University School of Management
Via Bocconi 8, Milano, Italy
Tel. (39) 02.5836.6522
E-mail: gianmario.verona@sdabocconi.it

Davide Ravasi
SDA Bocconi – Bocconi University School of Management
Via Bocconi 8, Milano, Italy
Tel. (39) 02.5836.2540
E-mail: davide.ravasi@uni-bocconi.it

October, 2002
Second revision

Paper submitted to Industrial and Corporate Change (February, 2002) and accepted for publication, subject to the revisions (July, 2002)

Unbundling Dynamic Capabilities:
An exploratory study of Continuous Product Innovation

In order to better understand the organizational sources of continuous innovation, the article provides an in–depth analysis of Oticon A/S, a leading company in the hearing-aid industry which showed an impressive ability to develop new products in the Nineties. Findings highlight that dynamic capabilities are made up of: knowledge creation and absorption, knowledge integration, and knowledge reconfiguration. Discussion links the findings to previous literature and shows how these knowledge-based processes are all based on a coherent mix of organizational resources.

Introduction

In recent years, the debate regarding organizational theory and strategy has shifted from the sustainability of competitive advantage to the capacity to manage innovation and change (Brown and Eisenhardt, 1997; Tushman and O'Really, 1997; Christensen, 1998). Management scholars have emphasized the virtues of product development in driving continuous change. New products have been indicated as the most natural driving force behind change and renewal at the corporate level (Dougherty, 1992; Nonaka, 1994; Daneels, 2002). Introducing new products in the market on a regular basis has been considered the most effective way of turning change into an endemic and continuous process (Eisenhardt and Tabrizi, 1996). It has also been maintained that it is mainly through the product development process that organizations perform their critical role of integrating dispersed knowledge of a different nature – mainly, scientific, technological, marketing - in an innovative way (Henderson and Cockburn, 1994; Kogut and Zander, 1996; Grant, 1996), and thus generate effective, new knowledge (Iansiti and Clark, 1994; Helfat and Raubitschak, 2000). For this reason, a growing number of studies has been investigating and theorizing about the strategies and structures that might help firms acquire the capacity to continuously innovate by introducing new products.

Many of these studies point to company resources and competencies as key factors in understanding continuous innovation (Verona, 1999). In this connection, the "dynamic" resource-based view of the firm identifies dynamic capabilities as the main source of sustainable competitive advantage in a changing competitive landscape (Teece and Pisano, 1994; Teece, Pisano, Shuen, 1997).[1] Dynamic capabilities are defined as "the subset of competence/capabilities which allow the firm to create new products and processes, and respond to changing market circumstances" (Teece, Pisano, Shuen, 1997, p. 510). These processes "specifically the processes to integrate, reconfigure, gain and release resources, use resources to match and even create market change" (Eisenhardt and Martin, 2000, p. 1107), and they are vital to gaining and sustaining competitive advantage in industries where technology and the market change.

Despite their increasing relevance in several settings, in recent years dynamic capabilities have been predominantly subject to theoretical debate (Teece, Pisano, Shuen, 1997; Eisenhardt and Martin, 2000; Zollo and Winter, 2002). Empirical evidence that links these firm-based processes to market and technology adaptation is still at an early stage[2]. Consequently, although we now do have a clear understanding of the microeconomic evolution of industries in periods of technological change and its impact on the dynamics of firms (e.g., Abernathy and Utterback, 1978; Nelson and Winter, 1982; Malerba and Orsenigo, 1996), it is less clear how firms actively leverage their resources to shape the market and technological trajectories of their industries through continuous innovation. Therefore, how firms can actually develop and nurture these "second order" capabilities (Collis, 1994; Daneels, 2002) has not really been explained. For this reason, the aim of this paper is to unbundle the very concept of dynamic capabilities and help clarify the nature of the processes that really foster continuous innovation at the organizational level in order to unravel the roots of product innovation sequencing.

In order to do this, we investigate an excellent performer and outstanding product innovator in the hearing-aid industry, Oticon A/S. The considerable number of new, high-quality products introduced by the multinational Danish company during the '90s clearly demonstrates its capacity to develop and launch new products, thus providing instructive insights to better understand the organizational basis of dynamic capabilities. The company has been widely studied in the nineties, although previous accounts its success focused mainly on innovative

organizational features (Peters, 1992) and the strategy-making process (Lovas and Goshal, 2000). However, in-depth investigation of the roots of Oticon's capacity to continuously innovate directed us beyond traditional explanations and highlighted the central role of knowledge integration and the related organizational processes.

Several studies have highlighted the knowledge-related processes that underlie continuous innovation. Indeed, new products rely on new concepts or new technologies that embody knowledge of a different nature (Dougherty, 1992; Iansiti and Clark, 1994). Most of these studies, however, tend to focus on one specific knowledge-related process. For instance, some have observed the importance of combining different kinds of specialised knowledge into product development projects (e.g., Burgelman, 1991; Henderson, 1994; Iansiti and Clark, 1994; Grant, 1996). Others have highlighted the importance of a periodic reconfiguration of the patterns of combined knowledge that form the essence of products and strategies (e.g., Brown and Eisenhardt, 1997; Hargadon and Sutton, 1997; Galunic and Rodan, 1998). In addition to demonstrating the fundamental knowledge-based nature of dynamic capabilities, the findings of our study indicate how continuous innovation requires the simultaneous presence of three fundamental processes at the organizational level: knowledge creation and absorption, knowledge integration and knowledge reconfiguration (Figure 1). More specifically, at Oticon:

- *knowledge creation and absorption* reflects a long-term commitment to the investment in basic science, its potential technological and market applications and the creation of a worldwide reputation in the scientific field in order to also absorb knowledge from the outside;
- *knowledge integration* refers to the capacity to shape and manage a context that stimulates latent and dispersed knowledge-resources, so that they can jointly contribute to developing and launching new products;
- *knowledge reconfiguration* regards the creation of an "open" structure that makes it possible to redefine role systems and relational patterns in a flexible way in order to make it easier to continuously recombine resources; this process of recombination allows the company to keep the new product pipeline filled.

These three capabilities are the driving force behind the creation of new products which revitalize the company through continuous innovation. The findings of the empirical research also show that dynamic capabilities tend to leverage actors, physical resources, structure and systems, and company culture. These four groups of resources are those that dynamic capabilities must use and leverage in order to generate continuous product innovation. Resources must be coherent internally in order to allow the capability to fulfill its function.

In presenting our findings, we first describe the research methodology and discuss the environmental and competitive context in which the organizational changes at Oticon took place and displayed their effects. We subsequently provide and discuss evidence of the three dynamic capabilities that fuel continuous innovation. The concluding section is devoted to a discussion of our findings where we point out the managerial implications of the model we propose and discuss its potential impact on academic research in the field of continuous innovation and dynamic capabilities.

Research method

GIVEN THE EARLY STAGE OF EMPIRICAL RESEARCH ON DYNAMIC CAPABILITIES, WE FOLLOWED THE LOGIC OF GROUNDED THEORY BY BUILDING OUR ANALYSIS ON AN EXPLORATORY CASE STUDY (GLASER AND STRAUSS, 1967; MILES AND HUBERMAN, 1994). THIS METHOD HAS ALREADY

BEEN SUCCESSFULLY ADOPTED IN THE FIELD OF CONTINUOUS INNOVATION (BURGELMAN, 1991; LEONARD BARTON, 1995; BROWN AND EISENHARDT, 1997; DANEELS, 2002) AND IS CONSISTENT WITH THE ISSUES OF THEORY DEVELOPMENT IN THE FIELD OF DYNAMIC CAPABILITIES. THE ADOPTION OF A QUALITATIVE METHODOLOGY IS ALSO CONSISTENT WITH THE FACT THAT CAPABILITIES ARE PROCESSES AND PRESENTS AN EMBEDDED NATURE (LEE, 1999). FOR EXAMPLE, HENDERSON (1994) OBSERVES HOW CAPABILITIES ARE TYPICALLY THE RESULT OF COMPLEX PROCESSES COMPRISING THE ACCUMULATION OF MINOR DECISIONS AND ACTIONS UNDERTAKEN OVER MANY YEARS IN A SITUATION OF GREAT UNCERTAINTY. THEREFORE, THEY ARE VERY DIFFICULT TO IDENTIFY THROUGH QUANTITATIVE RESEARCH. MOREOVER, EISENHARDT AND MARTIN (2000) OBSERVE THAT THE EMBEDDED NATURE OF CAPABILITIES MAKES QUALITATIVE RESEARCH MORE SUITABLE THAN ECONOMIC AND FORMAL MODELING. FINALLY, ROUSE AND DAELLENBACH (1999) CONTEND THAT IT WOULD BE BETTER FOR EMPIRICAL STUDIES ADOPTING A RESOURCE-BASED APPROACH TO IDENTIFY SIGNIFICANT AND HIGH PERFORMING STRATEGIC GROUPS IN A GIVEN INDUSTRY AND ANALYZE THE SPECIFIC SUCCESS FACTORS OF LEADING FIRMS THROUGH IN-DEPTH FIELD WORK, RATHER THAN RELYING ON CROSS-SECTIONAL STUDIES THAT SEEM LESS SUITED TO STUDYING ABOVE-AVERAGE PERFORMANCES IN AN INDUSTRY. ALTHOUGH WE ADMIT THAT FOCUSING ON ONE CASE MIGHT PREVENT US FROM APPLYING OUR FINDINGS ON A WIDER BASIS, WE BELIEVE THAT THE CONTRIBUTION OF OUR STUDY RESTS MORE ON THE ATTEMPT TO CONCRETELY ANALYZE A CONCEPT – SUCH AS DYNAMIC CAPABILITY – THAT HAS BEEN THE SUBJECT OF CONSIDERABLE THEORETICAL SPECULATION BUT SCANT EMPIRICAL RESEARCH, AND TO PROVIDE INSIGHTS ON THE DYNAMICS OF CONTINUOUS INNOVATION.

Our research setting, Oticon A/S, is a leading producer of hearing aids. Following Pettigrew (1990), Oticon was selected because of the high visibility of the object investigated – i.e. the capacity to sustain impressive continuous innovation. This does not mean that Oticon showed "unique" capabilities. As Eisenhardt and Martin (2000) state, dynamic capabilities often present commonalties among companies within the same industry. What is relevant is that these capabilities definitely contributed to changing Oticon's capacity to innovate and gain competitive advantage through innovation. As a matter of fact, in the '90s Oticon changed its performance and can be cited as an outstanding innovator in the hearing aid industry (Lovas and Goshal, 2000).

In the early '90s, following the radical reorganization of headquarter activities, the company's innovative capacity considerably improved and Oticon became an exemplary and widely studied case in turnaround management (Peters, 1992). Although for decades the company had played a leading role in the industry, at the end of the '80s its products largely depended on a mature and declining technology and the company was losing ground to its major competitors, Starkey and Siemens. Oticon's market share plummeted from 14% to 9% in an 18-month period, causing the company to rank third on the market with balance sheets showing substantial losses. However, in 1990 the company began to radically reorganize its structure and systems and subsequently underwent a period of considerable growth also due to its outstanding capacity to innovate in products, technologies and services. The changes in the organizational structure aimed

to develop a faster, more creative and efficient company that could benefit from the new technological changes affecting the industry with the advent of digital technology.

In the following years, the new product development schedule was cut by almost 50%. The innovation rate, expressed in terms of proportion of sales due to new products, more than doubled, and by 1993 half of Oticon's sales were already accounted for by products introduced in the previous two years (just before the change the corresponding figure was only 20%). The renewed innovative capacity is reflected in the considerable, sustained improvement in financial performance (see Table 1) obtained while structural dynamics in the hearing-aid industry became increasingly consolidated and concentrated.[3] As further evidence of the renewed competitiveness of the company, at the end of the '90s, Oticon's market share rose once again to about 15% of the global market and the company led the development of a new generation of products based on digital technology. Since prior events are generally assumed to have some connection with those that follow, even though this connection may not be "neat and clear" (Miles and Huberman, 1994, p. 145), we set out to explore to what extent the sweeping reorganization of the company might be plausibly related to the capacity for continuous innovation that the company displayed soon after.

Our study encompassed in-depth individual, semi-structured interviews with the CEO, members of the top management team, and other managers of the Copenhagen headquarters and the Italian subsidiary. Those interviewed included the head of the research center, most of the senior management positions, and other researchers and managers directly involved in the projects leading to the development of MultiFocus, MicroFocus, and DigiFocus – three of the most successful innovations launched by the company in the mid-'90s. We selected our informants, trying to balance the different professional areas, and different levels of responsibility and seniority in order to gather and integrate a variety of perspectives. We also relied on an extensive archival search that included financial statements, annual reports, internal documents, industry publications, and other written material on the company.

The interviews began by asking about the respondents' background and the role they played in the organization. We also asked them about changes made in the organization at the end of the '80s and how this affected their activities. We subsequently focused on the process of product development in order to identify the different activities required to manage continuous innovation. The respondents were first asked to describe the structure of the process and their specific roles and were then asked to provide detailed examples, charts, and documents and to elaborate further on their statements. They were asked to furnish their own explanation regarding the overall improvement in the product development rate and why it was so effective. We tried to leave the questions as open as possible. Since we did not want to impose our own theoretical frame of reference on our informants' interpretations, we carefully avoided referring explicitly to concepts like "dynamic capabilities" or "continuous innovation". We stopped interviewing when the saturation point was reached, that is, when additional questions would not have added much to our understanding of the phenomenon (Glaser and Strauss, 1967). The first set of interviews took place in July 1997. Two subsequent follow-up interviews were held to collect further data, solve minor discrepancies and submit our tentative interpretations to our informants. The first one took place a few months after the first set of interviews and the second in January 2000.

Data analysis followed the general guidelines for grounded theory (Miles and Huberman, 1994; Lee, 1999). The analysis was initially conducted independently by the two authors and combined with the results of the archival collection. Our aim was to build on and move beyond our informants' descriptions in an attempt to interpret facts and information and integrate them in

an emerging theoretical framework. Although the process followed a sequential path, results from each stage were adjusted and further developed as additional sets of data made us reconsider and revise our interpretations in order to improve the fit between the tentative framework and the data. This iterative approach is consistent with the general prescription for grounded theory building to interpret data on a continual and evolving basis (Lee, 1999).

We began our analysis by looking for core categories that could explain the observed phenomenon – i.e. the substantial increase in the company's innovative capacity. By building on insightful remarks from some of our informants, we selected knowledge integration as an effective general framework to guide our interpretation. The concept of knowledge integration appropriately describes the essential feature of innovation in the hearing-aid industry. A hearing aid is basically made up of simple components (a transducer, an amplifier, etc.) developed and produced by external suppliers. Therefore, a new hearing aid requires the innovative redesign of the architecture that combines these standard components.[4] Our attention then turned to the capabilities that underpinned the company's increased capacity to integrate distributed knowledge. Following the above-mentioned definition of capabilities, we focused on organizational processes, starting with those that were more directly affected by the reorganization that preceded the considerable improvements in the effectiveness and efficiency of the new product development process. Our search initially focused on the features of the new organizational structure and systems to investigate how they affected the process of knowledge integration.[5] However, following our informants' accounts, we soon realized that the new organizational context alone could not completely explain the renewed ability to innovate. What the new structure had also accomplished was to facilitate the refinement and exploitation of the scientific and technological innovation that was taking place in the research center. In addition to focusing on the major processes affected by the reorganization, we also had to study the research process in order to better study the company's innovative capacity. Furthermore, there seemed to be something more than simple knowledge integration in the renewed capacity to continuously innovate. Constantly producing new knowledge of a scientific and technical nature while at the same time preserving the capacity to periodically change the dominant patterns of knowledge combination – i.e. the architecture of the products – seemed to be just as important in supporting continuous innovation.

After having identified the fundamental processes/capabilities that underpinned continuous innovation, we tracked the activities, decision and structural features considered to be fundamental. We drew detailed causal network maps (Miles and Huberman, 1994) of the events, activities and environmental conditions that our informants explicitly or implicitly associated with the three fundamental capabilities identified in the previous phase. Further sets of collected data helped us identify the changes that had made the transition to the new organization easier, that became essential blocks of the displayed capacity to continuously innovate. These fundamental elements were later grouped into four categories – actors, physical resources, structures and systems, and culture – linked, although in different ways, to the knowledge-related activities that represents the essence of dynamic capabilities. This grouping did not only emerge from the data but was consistent with the idea that capabilities are processes that leverage specific resources (Leonard Barton, 1994; Grant, 1996; Eisenhardt and Martin, 2000). While the actors bring individual specialized knowledge embedded in skills and expertise, the physical resources and infrastructures, such as a comprehensive library on acoustics and audiology or the corporate electronic archive containing virtually all the codified information of the company, represent collective repositories of codified knowledge. Structures and systems (roles, incentives, etc.) on the one hand, and the organizational culture (values, norms – in other words, the set of

collectively shared knowledge structures) on the other, contribute to defining the organizational context that guides people's behavior and affect knowledge flows in the company.

In the next paragraph, we will first briefly describe the environmental context in which Oticon's strategic changes occurred and then give an account of how the company was able to pioneer the development of technology in the industry. We will subsequently describe and discuss the fundamental building blocks of the dynamic capability that underpin Oticon's ability to continuously innovate and upgrade its product range.

Technology development and product innovations in the hearing aid industry

A hearing aid is an instrument that filters and amplifies sounds so that a person can hear better. The most common types of hearing aids are behind-the-ear (BTE) - external devices connected to a soft plastic ear-mold which fits inside the ear -, in-the-ear (ITE) -fitted completely in the outer ear-, and in-the-canal (ITC) - similar to in-the-ear hearing aids except that they are smaller and fit mainly in the ear canal -. No matter what the size or style, all hearing aids have the same basic components: a microphone, an amplifier, a receiver, and a battery for power. The microphone transforms sound into an electrical signal and sends it to the amplifier. The amplifier increases the amplitude of the electrical signal; filters and volume or tone controls may further modify the signal. The amplified signal is transmitted to the receiver where it is transformed into sound.

Until the early '90s, all hearing aids were based on an analog/adjustable circuitry where all the amplification parameters (such as gain, frequency response and maximum output) were controlled by fixed or variable components in the hearing aid. Based on a comprehensive audiological evaluation of hearing, the basic features of analog/adjustable hearing aid operation were specified by the audiologist and installed in the laboratory. In recent years, analog/programmable hearing aid circuits have become extremely popular; they differ from analog/adjustable hearing aids in the way audiologists can modify both basic and fine parameters of instrument performance. At the time of fitting, analog/programmable hearing aids are connected to a computer, which is used to set the various basic and fine parameters. The latest generation, however, is the digitally programmable hearing aids, introduced in the market in 1996. These devices represent a substantial improvement over previous technology in that they are extremely flexible, can be fine-tuned, and have advanced compression (loudness limiting) capabilities. Digitization means that incoming sounds are converted into numbers, which are then analyzed and manipulated through a set of algorithms programmed into the chip which controls the hearing aid. The computerized digital aid analyzes incoming sound, makes a determination regarding speech versus noise content and then converts this information into numbers. The resultant digitized numbers are subsequently manipulated according to the algorithm instructions, reconverted to an analog form (sound waves) and delivered to the ears without producing the types of distortion commonly associated with analog technology hearing aids.

Recent developments in the basic technology of hearing aids are punctuated by Oticon's products (Table 2). MultiFocus in 1992, MicroFocus in 1995 and DigiFocus in 1996 marked substantial advances in the technology and design of hearing aids. MultiFocus introduced a fully automatic system for adjusting amplification and tonal balance according to the frequency of sounds (whereas traditional hearing aids used to amplify weak sounds as much as loud sounds, high-frequencies as much as low frequencies so that people had to keep adjusting the volume control). Although relying on electronic circuitry for sound processing, MultiFocus technology was still based on analog amplification. In 1995, MicroFocus applied the knowledge gained from

MultiFocus to a cosmetically attractive ITC instrument that marked the transition to analog/programmable hearing aids. MicroFocus, in fact, incorporated some of the digital technology that would later be fully applied to DigiFocus since it could be programmed to filter sounds according to the patients' specific impairment as well as their preference for sound quality factors and specific communicative contexts. In 1996, the introduction of DigiFocus redesigned the basic architecture of the product and opened up a fast-growing and highly-profitable market segment. Digital hearing aids already account for a considerable share of the worldwide market and are bound to replace analog ITE hearing aids as the dominant design (*Business Week*, 1999). DigiFocus was programmed to reproduce sounds in an entirely new way: sounds of different frequency could be processed separately and the amplification could be constantly adjusted according to changes in the external environment. DigiFocus could therefore improve speech understanding in a wider variety of situations, including noisy environments. As Oticon pioneered the new digital technology, it further eroded the market shares of its larger competitors, Starkey and Siemens. In the meantime, in fact, the two companies were still exploring the possibilities of the new technologies: their first digital products were released only two years later.

During these years, the company paced the rate of innovation by also introducing products that, without altering the basic technological architecture, incorporated incremental changes regarding aesthetic appeal, size and ease of handling. All this exploited the potential of current design and made the hearing aids appeal more to specific target groups. The Personic line, for instance, was offered in a variety of colors similar to those of electronic devices so that hearing aids were no longer regarded as a mark of a physical handicap but as, in the Ceo's words, "modern communication systems that reflect the user's personality, hair-style and life-style." The company even designed a special line for hearing-impaired children called Oticon 4 Kids. The device had a colorful and original look and presented in a specially designed package which contained information material meant to reduce the psychological burden of having to wear a hearing aid at a young age.

As we anticipated in the methodology section, the impressive flow of product innovations introduced in the '90s is in sharp contrast with the substantial lack of new products in the previous decade when the company was exploiting on a mature and declining technology, BTE, and was lagging behind in the development of more modern and appealing ITE devices. The turning point can be traced back to the organizational transformation, which affected the corporate headquarters in 1990 and soon after the rest of the global organization. Dismantling the formal structures regulating the hierarchical relations and the task-system was the essence of the transformation. Departments, positions, titles, and job descriptions were abolished and the previous functional structure was replaced with a project-based organization. Functional activities were re-grouped across projects and processes, which substituted departments as centers of coordination. These radical changes seem to have created a favorable context for the development of dynamic capabilities that were reflected in the continuous flow of new products. Evidence from our study suggests that these capabilities rest on the simultaneous presence of three processes regarding knowledge creation and absorption, knowledge integration, and knowledge reconfiguration. In the following sections, these three essential processes will be presented and discussed by showing the set of structures and resources they build upon and their relations with Oticon's capacity to continuously innovate.

Knowledge creation and absorption

The creation of a hearing instrument draws upon two scientific fields, namely, audiology and acoustics. The two sciences provide the basic knowledge of the way hearing instruments work. The excellence of the Danish competitors in the hearing-aid industry – together with Oticon, the Copenhagen-based Widex and Danavox account for about one-fourth of world sales (Lee and Lotz, 1998)– is often ascribed to the development of the Danish educational system in these two scientific fields. Denmark's long tradition of research and education in acoustics and audiology was, in fact, boosted in 1953 by the Danish government's decision to provide a free hearing aid to anyone who needed it. In this connection, just as US based computer firms strongly benefited from hiring Ph.D.s from American graduate schools (Iansiti, 1997), Danish hearing-aid producers strengthened their global competitive position by employing well-trained Danish university graduates. However, developing a hearing aid is not solely based on these two basic sciences. Helping impaired people hear, in fact, is not simply a matter of amplification. What is crucially important is the way a person perceives sounds, something which is, in turn, strongly influenced by a person's lifestyle and surrounding environment. In this regard, the aid of psycho-acoustics is fundamental in guiding research about the architecture of the product. Since it is based on considerable fieldwork, psycho-acoustic research differs from research undertaken in the related areas of audiology and acoustics, in that it requires constant interaction with hearing impaired people in order to identify and measure their specific reactions to various sound stimuli.

Until the late '70s, Oticon followed the usual pattern commonly adopted in the hearing aid industry of integrating basic research with technology development in a specific Research and Development department. Researchers employed by hearing aid firms, in fact, usually have an engineering background that enables them to deal with the acoustic or electro-acoustic aspects of product development. At Oticon, such a model became a source of major problems since the development activities were so time consuming that the R&D people spent most of their time solving minor technological problems; this was especially true in cases when there was little time left before the product was to be put on the market. Therefore, the creation of new scientific knowledge did not receive due attention. As the Director of the Oticon Research Center remarked:

> This habit took over more and more and, in the end, it was always long-term research which was neglected. So, it was decided that if we really wanted to have long-term research it had to be established away from the rest of the company.

This problem, together with the promising discoveries made in the emerging field of psycho-acoustics, led Oticon executives to consider establishing an in-house research center as a strategic opportunity for the development of new products. Therefore, in 1975, a research center located in Eriksholm (about 50 miles from the Copenhagen headquarters) was opened and equipped with the most advanced technologies and infrastructures including one of the world's most comprehensive libraries on audiology and acoustics and hearing instruments. Since that time twelve researchers work full-time with hearing-impaired patients in order to carry out research on ways to develop new scientific knowledge.

There are nine hundred and fifty hearing impaired people involved in a long-term relationship. The very decision to locate the research facility in a pleasant resort in the countryside outside Copenhagen was designed to encourage these patients (who come to the laboratory at least three times a year) to participate in the field experiment. Moreover, in order to further reinforce this commitment to basic research, a unique museum focusing on the history of hearing instruments has been recently built. The Eriksholm Collection includes over five hundred hundred

hearing instruments which trace the technological history of the industry.

The fact that the researchers dedicated their time, attention and effort exclusively to basic research created a favorable environment for the development of scientific knowledge which often led to development projects. The scientific knowledge developed at Eriksholm often provides a fundamental input to the conception and design of innovative products. As a senior researcher said:

> What we do here is psychoacoustic research with hearing impaired subjects. We are not making major discoveries with new technologies or new production methods. We are more interested in creating the knowledge on how a new hearing aid should function: what should be the functionality of it – not how that functionality should come about, nor which technology should be used. That is in the sole hands of the development units at the headquarters. (…) Our responsibility is to ascertain that we can come up with new principles of what a new hearing aid should do: not how it is constructed, but its function, what it does when the sound passes through it.

The establishment of a separate research facility also increased the capacity to absorb knowledge from external sources. In fact, a distinctive characteristic of the research site is the broad autonomy researchers enjoy in terms of fields and line of inquiry. Unless specifically related to new product development, scientific knowledge produced at Eriksholm is shared with the rest of the scientific and academic community: Oticon's researchers are encouraged to publish in academic journals as well as participate in the major international scientific conferences. As a consequence, Eriksholm gradually came to be widely regarded as a scientific research center, operating in the field of audiology, acoustics and psycho-acoustic. As the Director of the center said:

> In some way, Oticon has succeeded in turning this place in many people's mind into a research center, not an industrial related facility. They do not see the industrial company when they come here - they see a research center like the one they have at home. (…) When we go out talking in some scientific meetings, we never ever talk about products. We talk about measurement principles, evaluation principles, how to construct a questionnaire for hearing impaired etc. - not about the outcome or evaluation of a specific product. People are sure that we are not going to give a business talk. So, over the last five years people have stopped to be picky about the fact that we are related to a business. Researchers at the University do not mind doing research with us any more. Ten years ago it was impossible - they did not want to be 'entangled with a greedy industrial company'!

This reputation is good for Oticon since it helps the company to acquire knowledge in several ways. First, in conjunction with the Danish government, the company co-sponsors Ph.D. students in a specific program- called the Industrial Ph.D. Educational Scheme. According to the Scheme, a group of about three students is employed in the company for the entire period of the Ph.D. program. Students are required to take courses related to their business or activity, such as project management or product development. The ideas they develop for their thesis are often tested and developed and might lead to improvements in existing product lines.

The firm also works closely with university centers. For example, a Swedish university carried out two Ph.D. projects that were an integral part of the work that led to the functionality at the basis of DigiFocus. Other formal cooperation agreements have been stipulated with schools in the UK and the US. Moreover, in 1997, the research department introduced an annual series of

seminars, chaired by outstanding scholars in the field of psycho-acoustic. The seminars bring together scientists from all over the world who carry out research on psycho-acoustics.

More unconventional collaborations may be established for individual projects. For example, the development of the DigiFocus line was based on a device called Jump-1, initially developed for field research. The basic feature of this device was that it could access all the parameters that were usually fixed in analog instruments. The firm involved fifteen laboratories located around the world and gave them the experimental hearing aid for their own research. They were invited to come over and attend a seminar on the use and potentialities of the new device. The only thing they were asked to do was to keep the company informed on how the research and experimentation progressed. If the company subsequently thought that the research project could turn into something that could in some way be patented or marketed, Oticon would be offered the first right of refusal.

The long-term focus on basic research makes Eriksholm an important center for the advancement of scientific knowledge in the fields of audiology and psycho-acoustics. At times, however, scientific research also leads to technological development. Specific technologies designed to investigate hearing disorders do not exist and scientists need to produce these devices by themselves. For instance, both MultiFocus and DigiFocus were not initially conceived as products but as experimental devices for specific field tests on noise reduction that could not be done with the traditional analog technology. In these cases, the need to obtain the data for the field test led to creating systems that eventually led to new generations of products.

To sum up, evidence from our study emphasizes the impact of long-term commitment to scientific research (conducted in a separate entity loosely connected to the rest of the organization), which makes it possible to develop and acquire specialized knowledge. By exclusively devoting its efforts to reaserch in the scientifc field with no specific limitations and gaining acess to external networks of knowledge production enhanced Oticon's capacity to pioneer technology evolution in the industry. Figure 2 maps the resources and structures that underpin this capability, such as unique repositories of knowledge like the Eriksholm library, and a staff of high-skilled researchers and long-term relationships with a pool of loyal patients that constantly take part to field-testing. Also, the structural separation of the research center facilitated the establishment of an organizational culture that valued academic recognition, encouraged autonomous pursue of research paths, and promoted participation to scientific international meetings. Eventually, the physical and substantial autonomy of Eriksholm helped Oticon to develop a worldwide reputation as an outstanding producer of scientific knowledge, facilitating cooperation both at the individual level – by attracting students and scientists from all over the world – and at the institutional one – establishing ongoing collaborations with other universities and research centers. As the Director of the center put it:

> If you open up and trust you will be trusted and information will be shared with you. If you do not you will not get anything.

At the same time, as we will discuss in more details in the following sections, the center maintained a loose connection with the development units ensuring that scientific and technological breakthroughs could be quickly applied to the development of new products. While, in fact, experimentation and field testing at the Eriksholm research center had produced important insights in the perception of hearing impairments and innovative devices in the elaboration and amplification of sounds, most of this knowledge lay underutilized in the research labs. It was only after the establishment of the new project-based organization that market application of this accumulated knowledge were quickly identified leading to commercial successes like MultiFocus.

Knowledge integration

Some of the new product lines introduced by Oticon during the ‘90s were based on incremental innovations developed on the spontaneous initiative of engineers and marketers at the company headquarters. For instance, the MultiFocus product line was initially developed by a group of engineers who had worked on the original project. Thanks to their research, the hearing aid was made smaller, the design improved and the original BTE product transformed into an ITE version. They also contributed to the development of a miniature-size canal hearing aid, the MicroFocus, that benefited from the state-of-the-art technology without substantially altering the core concept and hearing-aid functions.

Up until the end of the ‘80s, however, product development at Oticon had adopted a rather different, sequential approach. Researchers provided the basic inputs, engineers developed the actual product and then handed it over to the marketing department. The increasingly complex technology used to create the product made the sequential process unable to meet the competitive requirements introduced by the emergent digital technology and the increasing competition. For these reasons, a more organic architecture was implemented in order to increase the speed and efficiency of transferring ideas and concepts across the organization. The new architecture, called Integrated Product Development, is organized around a series of cross-functional project teams in charge of single development projects.

Interdepartmental barriers have been removed so that departments and positions no longer exist. Most employees are now grouped together in so-called “professional areas” and “competence centers”, which have replaced the old functional organization. Most professional areas do not correspond to the old departments and their boundaries are loosely defined. Competence centers, such as Integrated Circuit or Mechanical Engineering, are groups of people sharing specific technological skills. A basic principle underlying the new structure is that if the company is to take full advantage of the potential contribution of each group member, jobs would be designed to fit each person, and not the other way around. As one member of the development group remarked:

> One of the reasons why we have abolished the concept of departments is that departments tend to close you in: good engineers, for example, may also possess very good skills in some particular aspects of marketing. Project groups provide an opportunity for people to exercise skills of different kinds: people may not use their skills to one hundred per cent, but they surely use them more than in a traditional structure where they are discouraged to use them outside their department.

Coordination within professional areas and competence centers are achieved through “professional managers” who are in charge of obtaining physical, technological and human resources for the product development process. They are responsible for selecting, hiring and training people and coordinating the development of internal skills in order to maintain sources of competencies for the different projects. They are also responsible for the acquisition and in-house development of technology in their specific area. Technical knowledge developed within competence centers is then applied to a continuous activity of technical problem-solving and product upgrading that goes on within projects. As the coordinator of the Integrated Circuit Component Center said:

> Projects have their own “domain” of innovation - innovation in the integrated circuit component takes place in the integrated circuit -competence center. We develop and provide building blocks for the integrated circuits so that innovation in the projects does not have to take care of it. If you look at the commonalties between the needs of the different projects

you realize that 50% to 90% of the content is really the same, just put together in a different fashion; therefore, it really pays to devote some effort to optimizing component design.

Professional managers are also responsible for making sure that specialized knowledge circulates and is transferred across projects. People belonging to competence centers and professional areas meet weekly to discuss issues of general interest in order to make sure that all the members can benefit and learn from the experience acquired in individual projects.

While competence centers and professional groups represent sources of specialized knowledge, the integration of this knowledge actually takes place in development projects. At the start of any project, a team is formed and the members work together until the project is completed. For example, all project groups dealing with new product development have to include at least one person from the research center, one or more engineers from the technology development units as well as persons with a background in audiology, marketing, and so on. Team members are relatively free to decide whether to take part in a project or not and how to allocate their time among different projects. In this sense, people are not assigned on a hierarchical basis but are encouraged to participate according to their skills and interests. Everyone is responsible for developing a job portfolio - corresponding to the activities performed in the different projects - according to the person's attitudes, skills, and personal aspirations. As the CEO remarked:

> In this organization you can't do central planning: you need to create a framework in which it takes place (...). We create this framework by stimulating open communication as much as possible. Usually the resource conflicts are very clear to the people involved and if they have all the information, then they are the ones who can best solve them. They may occasionally make the wrong decision, but I'm sure that a central manager would make more wrong decisions.

People are also encouraged to feel responsible for the entire project not only by applying their specific skills but also by contributing to solving the problems arising during the various phases of the project. Our informants agreed that the new project-based organization has led to increased interaction across levels and professional groups so that it is easier to exchange ideas and integrate specialized skills. Even communication problems and traditional bickering between departments have gradually disappeared.

The new structure requires most employees to perform different activities in different projects some of which lie outside their formal competence or education. Such an unconventional job system has a considerable impact on how jobs are perceived. On the one hand, people have to value professional growth and personal challenge more than career advancement since there are no formal career plans and paths. Indeed, the absence of a hierarchy makes a traditional career impossible; people see a salary increase based on individual contributions and results and a potential redefinition of their role according to the skills they develop and the opportunities the organization provides. On the other hand, the absence of a clear structure requires a willingness to work in a fundamentally ambiguous environment. In order to ensure that employees possess the flexibility such a system requires, recruiting is based not only on professional skills but also on attitudes and life experience. Oticon tries to hire people with different backgrounds and gives them a great deal of freedom in the company. A candidate with an "unconventional" resume is considered more likely to adapt to the new structure than a candidate with a traditional MBA education. As a senior manager involved in global policies told us:

> Usually, companies have specific problems and hire people trained to solve those problems. On the contrary, at Oticon, we like to hire people with different skills. If I need to hire

somebody that helps me deal with accounting, I also want him to know something about marketing, because sooner or later he may be involved in that. That is the reason why we'd rather hire people with heterogeneous experience.

The integration of specialized individual knowledge is also facilitated by the absence of physical barriers. The new working environment consists of an open space filled with similar workstations based on a drawer-less desk equipped with computer, telephone and fax. Everyone has a "trolley" - a personal file-cabinet on wheels - and is encouraged to freely move around the common workstations, changing location according to the specific project work. For instance, when we interviewed the CEO, he said that at that time he was working almost full-time on a marketing project. We could actually see his trolley parked around a group of desks where people were discussing how to price a new product. Moreover, the cafeteria and tea-and-coffee buffets on every floor are common meeting-places where employees exchange new ideas. .

Knowledge integration is further facilitated by easy access to the stock of organizational, codified knowledge. A new electronic archive gives every employee easy and direct access to virtually any available company information including market reports, quality assurance results, technical documentation, and so on. Only the minutes of the Board and salary information are kept confidential. All the physical documents were initially scanned in the corporate data base so that they could be easily retrieved. In this connection, the CEO said:

> We use paper a lot but we try to avoid filing paper: filing is all made in the computer system either scanned in or directly typed in. Having all the information accessible in an electronic archive is important because if the information is kept in physical files in closed office, it is accessible only in theory, not in practice. In our case, no matter were you sit, it is accessible. You can flexibly move around.

To sum up, even though knowledge creation and absorption represent the pre-requisite for innovation, what triggers the dynamic process of continuous innovation is the capability of integrating the specialized knowledge dispersed in company. At Oticon, this capability rests on a fluid project-based organization that fosters the development of individual potential, improves the capacity to tap individual knowledge and ideas, and institutionalize the spontaneous and collective contribution to product innovation. The resources and structures that underpin the process of knowledge integration and that are above-mentioned in our description are shown in Figure 3. The increased interaction and exchanges between experts from different professional areas, the establishment of an integrated product development process combined with the absence of physical and structural barriers all stem from a corporate policy that strives to integrate different skills and expertise into new product development initiatives.

Knowledge reconfiguration

Retrospective descriptions of company operations in the '70s and '80s indicate the existence of a marked informal professional hierarchy with technicians and development engineers well above the marketing and sales personnel. Engineers were regarded as crucial to maintaining Oticon's leading market share especially considering their expertise in advanced BTE technology. However, as the market changed, that technology gradually became less appropriate to the emerging needs. It was not long before the very same core technological competence that had led Oticon to reach its dominant position in the market proved to be a major impediment to

the development of a new product architecture. The technician-dominated management offered little support to the development of the new technology. Instead, Oticon decided to reinforce its core technologies and continued to invest its resources in analogue BTE products: as a consequence, the development of ITEs came to a halt. As the ITE segment grew during the '80s, the company found itself tied to an old system while the development of the technologies needed to satisfy market demand lagged behind. In other words, its core competence had become very rigid. This made it impossible to develop and establish new capabilities and reorganize a product architecture based on different functional and technological premises. The presence of a rigidly defined hierarchy of jobs and positions based on tradition and professional prestige ultimately inhibited the development of knowledge outside the established domains.

However, in the first few years after the change, Oticon rapidly introduced major changes in the architecture of the product, none of them apparently posing any obstacle to the subsequent reorganization of existing knowledge and competencies into other innovative products. In other words, the company displayed a capability to periodically reorganize the patterns of knowledge integration that underlay its product technologies. In part, this capability rests on the indeterminacy of the role system that leaves the structure more open to periodic redefinition and allows patterns of cooperation and communication to evolve over time as new products become established and project teams evolve into product management structures that do not overlap or replace those that already exist but co-exist with them. The "multi-job" system, the loose affiliation to professional areas, the absence of physical constraints to mobility, the free allocation of time, skills and attention are all elements that, besides facilitating the integration of dispersed individual knowledge, contribute to preserving the capacity to reorganize patterns of cooperation and knowledge integration embodied in products and activities.

The loosely-coupled nature of the new organization, however, is offset by the centralized coordination of the various development projects and initiatives performed by a so-called "development group". The development group is composed of seven senior managers - the CEO, the head of the Eriksholm research group and the coordinators of Quality Assurance, Product Development, and Marketing and Audiology activities. The development group is the only hierarchical structure that has been maintained and is sometimes referred to as a sort of "board of directors" for the different projects. The development group's main responsibilities are evaluating new project initiatives, allocating financial resources among new and ongoing projects and periodically monitoring them. The development group sets and communicates the strategic priorities of the company at monthly information meetings. Priorities are discussed with all the employees and project proposals are evaluated according to these priorities.

The evaluation process is kept as simple and informal as possible. A member of the group – a VP coordinating the product development - described it as follows:

> Someone comes along and says: "I have an idea, a proposal." We say: "Fine. Could you make a sort of proposal?" At the next meeting of the development group we call that person in and have him explain his idea and have a discussion.

The proposal is a rather simple business plan, based on a rapid pre-investigation regarding project feasibility and the potential costs and benefits for the organization. It is interesting to note that ideas proposed are not necessarily evaluated from their economic perspective. The development group sets priorities based on their understanding of what is most important for the company and on the available resources. The same person told us:

> I wish I could say that we have a nice formalized system, that we calculate certain parameters, etc. But in fact we have not, we do not: it is all 'gut feeling'. We obviously

> calculate such things as expected costs and benefits; we try to assess what is the market size of the new products, at what price it can be sold, etc. But every project is evaluated in itself. We do not have a formal system. We try very much to work out ourselves a consensual decision. Then, again, we are all basically experts.

The high level of skills of all the people involved turns the absence of this evaluation system into a flexible feature of the organization. Although there is usually general agreement on the choices made, the CEO's opinion is the prevailing one in case consensus is not reached. Since most of the members of the development group are not directly involved in day-to-day activities, assistance is provided by the Review group which is composed of four persons from marketing, software, sales, and information technology. The role of this group is to review short and long-term plans and programs twice a year.

This system facilitates the continuous reorganization of the company resources since it gives rise to initiatives that may ultimately lead to substantial changes in strategies and products. An informal and open culture encourages the spontaneous initiatives of groups or individuals. As the CEO said: :

> *Even though sometimes projects are initiated by the management group, most of the projects actually start because a person or a group of people have had what they think is a good idea and want to realize it. A group of engineers and marketing people may want to develop a project: they do some skunk work and then they may come to us and say: "Hey, do you want to see what we can do? Here we have a sort of prototype..." And hopefully we will say: "That sounds like a fantastic idea, why don't you do that?" And they are ready: the group is already there.*

This statement reflects an organization culture that is open to dispersed individual contributions and helps sustain continuous innovation through the reorganization of existing resource combinations. Individual knowledge is, in fact, the seed that generates innovative ideas and an open mind represents the most fertile ground. The ancient Latin motto *cogitate incognita* is the emblematic company vision displayed on almost every floor of the company headquarters and subsidiaries to remind employees of the constant need to "think the unthinkable" in order to go beyond current practices and ideas and strive for greater innovation.

To sum up, our study suggests that Oticon's capacity to continuously reorganize patterns of knowledge embodied in products and activities rests on a loosely-coupled architecture based on the absence of permanent formal structures, multiple and evolving relational patterns, and an open and informal culture. Oticon's architecture does not offer only a favorable environment for the continuous emergence of creativity at the individual and organizational level, it also performs a fundamental role in keeping the structure open to further reconfiguration of specialized knowledge patterns. A fundamental feature of these arrangements, however, is the simultaneous presence of elements of rationality and indeterminacy in the fundamental coordination mechanisms and processes of the organization which ensures coordination despite ample individual freedom and indeterminacy of the role system. At Oticon, coordinating all the innovative efforts in one specific strategic direction is the primary responsibility of the development group. Although project leaders enjoy a high degree of freedom in using the funds they receive, they, in fact, operate within the framework established by the development group through the communication of priorities and the centralized allocation of financial resources. In

this respect, a loose architecture – that is, the capacity to preserve elements of determinacy and spontaneous self-design in the mechanisms and processes that coordinate the development process – supports the continuity of the innovative process fueled by knowledge creation and absorption, and knowledge integration. Figure 4 shows the fundamental elements of this capability.

Discussion and conclusions

The purpose of this study was to improve our understanding of dynamic capabilities. Almost ten years after the theoretical diffusion of this concept (Teece and Pisano, 1994), little empirical evidence has supported this fundamental organizational concept. In the article we have presented and discussed a longitudinal case study of a leading company in the hearing-aid industry, Oticon A/S, which demonstrated an outstanding ability to sustain continuous innovation. The company seemed to provide an appropriate setting even because, from the longitudinal analysis, it was possible to establish the starting point of the new product sequencing (introduced in the '90s) that allowed Oticon to become profitable again and largely regain its market position. In the next pages, we discuss the main findings of our exploratory analysis.

The first result of Oticon's in depth study indicates that in order to sustain product innovation a firm must build dynamic capabilities that allow the simultaneous and continuous creation, absorption, and integration of knowledge. At Oticon, knowledge creation is deeply rooted in the concept of a long-term commitment to creating scientific knowledge through investments in a unique research center with a world reputation for pursuing scientific knowledge in the acoustic, audiology, and psychoacoustic fields. This capability allows the continuous creation and absorption of new knowledge without which no product innovation can be sustained in the long run. Moreover, a peculiar project-based structure promotes the combination of knowledge components dispersed within the organization by transforming specialized scientific and technical knowledge into new products. It is important to highlight that the relevance of these processes is confirmed by past research on product innovation. Knowledge creation has been emphasized in some empirical studies focusing on experimentation (e.g., Henderson and Cockburn, 1994; Pisano, 1994). As maintained by Cohen and Levinthal (1990), the ability to acquire knowledge is directly related to the presence of previous related knowledge, meaning that firms must already have invested in technical knowledge if they want to benefit from the knowledge they absorb. Likewise, Oticon's strong commitment to the scientific community has become a way to continuously exchange knowledge with the outside environment. The case of the pharmaceutical industry shows how academic publications by company researchers allows the industry to acquire important knowledge (Henderson e Cockburn, 1994). Our case study extends this literature by showing that effective integration is not simply a matter of the structural organization of the product development process. In order to facilitate integration it is also essential to go beyond structural arrangements and eliminate physical and cultural barriers between experts from different departments and "professional families". Most of all, the Oticon findings show us that it is the *co-presence*, that is the *conjoint* use of knowledge creation, absorption, and knowledge integration that provides the very foundation of continuous innovation.

The second result emphasizes that, in the long run, sustaining continuous innovation requires a further dynamic capability. If a company wants to sequence product innovations, it must create a context that spurs creativity from all parts of the organization at any time. The theory of dynamic capabilities has already shown the relevance of continuous learning in order to introduce new product innovations and adapt to changing market conditions. This idea is also

consistent with the fact that "core capabilities" can transform themselves into "core rigidities" (Leonard Barton, 1992). Product sequencing can be seen as the consequence of a structured system of core and integrative knowledge which, by itself, depends upon continuous, individual and collective learning within the organization (Helfat and Raubitschek, 2000). Similarly, the problem-solving activity of an organization involved in continuous product development is at the basis of the creation of specialized and integrated knowledge aimed at developing and launching new products (Iansiti and Clark, 1994). The study of Oticon offers empirical evidence of these theoretical ideas and improves our understanding of how systems of learning actually work. Oticon has, in fact, shaped an organizational context that allows individual and organizational creativity to emerge. Moreover, it provides a framework showing how the way organization culture, systems and structures are managed enables the company to tap dispersed knowledge and stimulate local creativity. The specific ability to shape such an organizational context represents a necessary complement in order to focus on autonomous scientific research and permit scientific and technical knowledge to become integrated into specific product development projects.

This context seems to rest on a loosely-coupled arrangement as the distribution of tasks and resources is not strictly regulated by the designed structure. It is rather the interplay of people at all levels who possess the ability to identify resources and combine them in new ways and continuously redesign the organization by redistributing roles, tasks and responsibilities. At Oticon, the development group coordinates activities by allocating resources among different projects and defining the strategic context that orients the project initiatives and guides the overall process of change. The process of setting priorities and reviewing projects carried out by the development group directs the combination and recombination of dispersed knowledge that results in autonomous strategic initiatives. However, the centralized management of the process of strategic context determination leaves ample room for the decentralized allocation of resources like time, attention and skills that is left to individual initiative and collective negotiation. An important consequence of the latter is the substantial indeterminacy of individual positions within the organization. The roles of the Oticon employees are not defined a priori but are continually redefined according to their changing job portfolio which reflects the changing needs of the organization and the evolution of their skills and inclinations. As a matter of fact, the structure is not super-imposed on the flow of the process, as occurs in a tightly coupled organization, but is defined at any time by the allocation of people, resources and tasks among the projects. The division of labor, therefore, changes continually, as people take part in new projects, develop new skills and eventually redefine their roles. In this sense, the structure is continually reproduced according to the current needs and emerges from the interaction between people initiating, running and taking part in the projects. It is this continual interaction, and not a pre-determined plan or design, that determines the allocation of time, resources and attention, and ultimately the structure of the organization.

The third result of the Oticon analysis shows that each dynamic capability actually leverages company resources, especially those regarding human and physical resources, structures and systems, and company culture. In order to be effective, each capability must be composed of these four resources which must also be designed to be coherent and fit their task perfectly. These four organizational resources therefore represent the building blocks of product innovation although it is the dynamic capability that leverages them and leads to new product creation. Past studies showed the relevance of each of the four variables. Culture has been considered an essential resource in strategic processes (Barney, 1986), and has also been considered a core capability for product innovation (Nonaka, 1994; Leonard Barton, 1992). Likewise, the presence

of incentive systems has also been considered an important tool to spur new product development (Cockburn, Henderson, Stern, 2000). There is also evidence on the importance of individual skills in giving rise to product innovation (Leonard Barton, 1995; Iansiti, 1997). However, what we discovered from the Oticon experience is that the four organizational resources *must coexist* and *be coherent* in order to generate competitive advantage through continuous innovation. Let us take the case of the dynamic capability that we called Knowledge creation and absorption. The Oticon ability in scientific knowledge absorption is deeply rooted not only in the superior physical and human resources of the firm, but also in the structural, managerial and, to some extent, even "cultural" autonomy which the research center enjoys. Earlier in the paper we have shown how these building blocks are tightly connected: how, for instance, loose connection between the center and the company helped to introduce Eriksholm in academic networks of knowledge creation; how this network of relations facilitated the exchange of information and the further accumulation of knowledge about audiology and psychoacustics; how this knowledge guided to the development of processing sounds in digital hearing aids.

While past studies have repeatedly indicated the need for consistency between the elements of a firm, such as its structure, its strategy, its culture (Miller and Friesen, 1980; Drazin and Van de Ven, 1985; Siggelkov, 2002), literature on capabilities has privileged individual resources and structures. Building on evidence from our study, we argue that dynamic capabilities are not the individual resources, practices or structures that characterize new product development or strategic decision making, but the higher order knowledge-related processes that are performed through these combination of elements. A dynamic capability can therefore be represented as an "organizational mix" – i.e., each dynamic capability can be seen as a mix that makes up the main organizational resources of the firm. The specific composition and correct weighting of the organizational resources (human and physical resources, structure and systems, and culture) thus creates a peculiar organizational formula regarded as the idiosyncratic dynamic capability. What changes in the formation of each capability is the content of the specific organizational variables and the way in which they combine the variables themselves. Since each firm is naturally based on different capabilities, each necessarily has different dynamic capabilities based on different *organizational mixes*.

It is important to highlight that this feature denotes a profound change in the design of organizational variables. Traditionally, the design of the organizational structure, managerial systems and culture, was aimed at consistency between the firm and the market (Lawrence and Lorsch, 1997). The most recent theories have taken insights from the theory of transaction costs in terms of the opportunism of economic actors and investment specificity (Williamson, 1975). Even these theories, however, have always aimed to find an organizational *fit* between the company and the environment (Grandori, 1987). As described by Chandler (1963), in the development of American firms, organizational designers have opted for functional structures in the case of limited market complexity, and divisional structures in the case of greater complexity and little synergy among the core businesses. The product/market (that is, the strategic business unit) has therefore always been at the core of organizational design. The shift in the emphasis to dynamic capabilities shows that contemporary organizational design has to focus on the creation of *mixes* that can foster company resources. In other words, organizational design must create and sustain the competencies through which the firm continuously acts on the market. Human and physical resources, structure and systems, and culture should thus be combined to stimulate the dynamic capabilities through which the firm generates and sustains competitive advantage. It is not simply by chance that the last ten years have seen a progressive movement from functional

and divisional structures focused on products/markets towards structures that value customers, management processes and business projects (Clark and Wheelwright, 1993; Hammer and Champy, 1993).

In conclusion, by describing the dynamic capabilities that enhance the ability to continuously innovate, the study contributes to shedding light on the complex process of adaptation that must take place at the organizational level whenever firms face a change in technological and market conditions. Although the emerging model is based on the specific experience of Oticon, we believe that the combination of the three knowledge-related processes and the resources they leverage, may provide a more analytical and systemic framework. This framework may now be amenable to quantitative investigation across a wider range of companies and industries.

In changing environments, technological development and the imitative or innovative behavior of competitors quickly erode competitive advantage created through innovation. As a consequence, firms are continually engaged in a process of creative destruction (Schumpeter, 1934) that calls for a periodic reconfiguration of basic patterns of integration that are embodied in products and market strategies. This paper identifies the three dynamic capabilities and their resource-based nature as an important basis for continuous innovation. In addition to contributing to the emerging literature on continuous innovation, the capabilities we mentioned also contribute to the Resource-based View of the Firm by pointing out new issues not previously identified. Since "a fuller appreciation of the origins of competitive advantage is to be found in a better analytical and empirical understanding of the managerial processes which allows some firms to be ahead and stay ahead of the game" (Cockburn, Henderson, Stern, 2000, p. 1142), we hope that this study has contributed to clarifying the nature and content of some of these valuable managerial processes.

References

Abernathy, W., Utterback, J. (1978), 'Patterns of industrial innovation', *Technology Reviews*, June-July: 40-47.

Barney, J.B. (1986), 'Organizational culture: Can it be a source of competitive advantage?', *Academy of Management Review*, 1986, 11: 656-665.

Barney, J.B. (1991), 'Firm resources and sustained competitive advantage', *Journal of Management*, 17: 99-120;

Brown, S.L., Eisenhardt, K.M. (1997), 'The Art of continuous change: Linking complexity theory and time-paced evolution in relentlessly shifting organizations', *Administrative Science Quarterly*, 42: 1-34.

Burgelman, R.A. (1991), 'Intraorganizational ecology of strategy making and organizational adaptation: Theory and field research', *Organization Science*, 2: 239-62;

Business Week (1999) "Is That a Computer in Your Ear?", Sept. 13, p. 126.

Chandler, A.D. (1963), *Strategy and structure*, Mit press, Cambridge.

Christensen, C. (1998), *The innovator's dilemma*. Harvard Business School Press, Boston.

Clark, K.B., Wheelwright, S.C. (1993), *Managing New Product and Process Development*, The Free Press, New York

Cockburn, I.M., Henderson, R.M., Stern, S. (2000), 'Untangling the origins of competitive advantage', *Strategic Management Journal*, 21:1123-1145.

Collis, D.J. (1994) 'Research note: how valuable are organizational capabilities?' *Strategic Management Journal*, Winter Special Issue, 15: 143-152.

Cohen, W.M., Levinthal, D.A. (1990), 'Absorptive capacity: A new perspective on learning and innovation', *Administrative Science Quarterly*, 35: 128-152

Daneels E. (2002), 'The dynamics of product innovation and firm competences', *Strategic management journal*, forthcoming.

Dougherty, D. (1992), 'Interpretative barriers to successful product innovation in large firms', *Organization Science*, , 3: 179-202.

Drazin, R., Van de Ven, A. H. (1985), Alternative forms of fit in contingency theory', *Administrative Science Quarterly*, 30: 514-539.

Eisenhardt, K.M. (1989), 'Building theories from case study research', *Academy of Management Review*, 14 (4): 532-550.

Eisenhardt K.M., Martin, J.A. (2000), 'Dynamic capabilities: what are they', Strategic Management Journal, 21: 1105-1123.

Eisenhardt, K.M., Tabrizi, B.N. (1996), 'Accelerating adaptive process: Product innovation in the global computer industry', *Administrative Science Quarterly*, 40: 84-110.

Galunic D.C., Rodan, S. (1998), 'Resource recombinations in the firm"', *Strategic Management Journal*, 19: 1193-1201.

Glaser B., Strauss A., (1967), *The Discovery of Grounded Theory*, Chicago: Aldine

Grandori, A. (1987), *Perspective on organizational theories*, Ballinger, Cambridge.

Grant, R. (1996), 'Prospering in dynamically-competitive environments: Organizational capability as knowledge creation'. *Organization Science*, 7: 375-387.

Hammer, M., Champy, J. (1993), *Rengineering the corporation*, The Free Press, New York.

Hargadon, A.B., Sutton, R., (1997), 'Technology brokering and innovation in a product development firm', *Administrative Science Quarterly*, 42: 716-749

Helfat C.E., Raubitschek, R.S. (2000), 'Product sequencing: co-evolution of knowledge, capabilities and products', *Strategic Management Journal*, 21: 961-979.

Henderson, R., (1994), 'The evolution of integrative capability: Innovation in cardiovascular drug discovery', *Industrial and Corporate Change*, 3 (3): 607-630.

Henderson, R., Clark, K. (1990), 'Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms', *Administrative Science Quarterly*, 35: 9-30.

Henderson, R., Cockburn, I. (1994), 'Measuring competence? Exploring firm effects in pharmaceutical research', *Strategic Management Journal*, 15: 63-84.

Iansiti, M. (1993), 'Real world R&D: Jumping the product generation gap', *Harvard Business Review*, May June: 138-147.

Iansiti, M. (1997), *Technology integration*. Harvard Business School Press, Boston..

Iansiti, M., Clark, K. (1994), 'Integration and dynamic capability: Evidence from product development in automobiles and mainframe computers', *Industrial and Corporate Change*, 3 (3): 557-605.

Kogut, B., Zander, U. (1996), "What firms do? Coordination, identity, and learning". *Organization Science*, 7: 502-518.

Lawrence, P.R., Lorsch, J.W. (1967), *Organization and environment*. Harvard Business School Press, Cambridge.

Lee, T. W. (1999) *Using qualitative methods in organizational research.* Thousand Oaks, CA: sage Publications.

Lee, K., Lotz, P. (1998) *Noise and silence in the hearing instrument industry*. CISTEMA working paper, Copenhagen Business School.

Leonard Barton, D. (1992), 'Core capabilities and core rigidities: A paradox in developing new product development', *Strategic Management Journal*, 1992, 13: 111-125.

Leonard Barton, D. (1995), *Wellsprings of knowledge. Building and sustaining the sources of innovation*. Harvard Business School Press, Boston.

Lovas, B., Goshal, S. (2000), 'Strategy as guided evolution', *Strategic Management Journal*, 21: 875-896.

Miles, M. B., Huberman, A. M. (1994) *Qualitative data analysis. An expanded sourcebook.* Thousand Oaks, CA: Sage Publications.

Miller, D., Friesen, P.H. (1980), 'Momentum and revolution in organizational adaptation', *Academy of Management Journal*, 23: 591-614.

Malerba, F., Orsenigo, L. (1996), 'Technological regimes and firm behavior', *Industrial and Corporate Change*, 2 (1): 74-89.

Nelson, R.R., Winter, S.G. (1982), *An evolutionary theory of economic change*. Harvard University Press, Cambridge.

Nonaka, I. (1994), 'A dynamic theory of organizational knowledge creation', *Organization Science*, 5: 14-37.

Peters, T. J. (1992), *Liberation Management: Necessary Disorganization for the Nanosecond Nineties*, New York: Alfred A. Knopf.

Peteraf, M.A. (1993), 'The cornerstones of competitive advantage: A resource-based view', *Strategic Management Journal*, 14: 179-191.

Pettigrew, A. (1990), 'Longitudinal field research on change: Theory and practice', *Organization Science*, 3: 267-292.

Pisano, G., (1994), 'Knowledge, integration, and the locus of learning: An empirical analysis of process development', *Strategic Management Journal*, 15: 85-100

Ravasi, D., Verona, G. (2001), "Organizing the process of knowledge integration: the benefits of structural ambiguity", *Scandinavian Journal of Management*, 17: 41-66.

Rouse, M.J., Daellenbach, U.S. (1999), "Rethinking research methods for the resource-based perspective: Isolating sources of sustainable competitive advantage", *Strategic Management Journal*, 20: 487-494.

Schumpeter, J. (1934), *The Theory of Economic Development*, Harvard University Press: Boston.

Siggelkow, N. (2002), 'Evolution toward Fit', Administrative Science Quarterly (47): 125-150.

Teece, D.J., Pisano, G. (1994), 'The Dynamic Capabilities of Firms: an Introduction', *Industrial and Corporate Change*, 3 (3): 537-556.

Teece, D.J., Pisano, G., Shuen, A. (1997) 'Dynamic capabilities and strategic management'. *Strategic Management Journal*, 18: 509-533.

Tripsas M. (1997). **Surviving radical technological change through dynamic capability: evidence from the typesetter industry.** *Industrial and Corporate Change* (6): 341-377.

Tushman, M.L., O'Really III, C.A. (1997), *Winning through innovation: A practical guide to leading organizational change and renewal.* Harvard Business School Press: Boston.

Verona, G. (1999), 'A Resource-based View of Product Development', *Academy of Management Review,* 24 (1): 132-142.

Williamson, O.E. (1975), *Market and Hierarchies: Analysis and Antitrust Implication*, Free press: New York.

Zollo, M., Winter, S.G. (2002) Deliberate learning and the evolution of dynamic capabilities', *Organization Science*, 13: 339-351.

Table 1. Competitive and financial results of Oticon over a 10-year period.*

	1988	1989
MultiFocus	1992	First fully automatic non-linear amplifier
Personic	1992	Pleasant design and surface texture, and wide color range to harmonize with facial features
Oticon 4 kids	1993	Colors and design more appealing and easy-to-wear for kids
MultiFocus Mild	1994	Same quality of sound processing, smaller size; designed for younger users
MicroFocus	1995	First programmable instrument, based on analog amplification process
DigiFocus	1996	First 100% digital hearing aid
DigiLife	1997	Simpler and faster fitting principle, programmable via a portable unit

Figure 1. Unbundling dynamic capabilities: the knowledge-based processes at Oticon.

Figure 2. The building blocks of Knowledge creation and absorption at Oticon.

Figure 3. The building blocks of Knowledge integration at Oticon.

Figure 4. The building blocks of Knowledge reconfiguration at Oticon.

---

* The paper greatly benefited from the insightful suggestions of Anna Grandori, Nicolai Foss, Rebecca Henderson, and Salvio Vicari. Other relevant suggestions were made by the participants in the 1999 Academy of Management Conference, Chicago, and the 2001 Industrial Economics and Organizational Theory seminars organized at the Copenhagen Business Schools. The two authors, however, take full responsibility for the ideas contained in the paper.

[1] As it has been described by Teece and collegue in one of their paper: "the term "dynamic" refers to the capacity to renew competences so as to achieve congruence with changing business environments (…). The term "capabilities" emphasizes the key role of strategic management in appropriately adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competences to match the requirements of a changing environment" (Teece, Pisano, Shuen, 1997: 515). In this way, the theory of dynamic capabilities helps overcoming the main limits of the resource-based View which presents a model of strategy emphasizing efficiency characterized by a clearly static framework.

[2] For a few exception, see the pioneering research by Iansiti and Clark (1994) and Henderson (1994). See also works by Brown and Eisenhardt (1997), Tripsas (1997), and Helfat and Raubitschak (2002).

[3] See the work by Lee and Lotz (1998) for a detailed analysis of the competitive dynamics in the industry.

[4] Oticon's CEO described a hearing aid itself as "a creative combination of technology, audiology and psychology".

[5] See Ravasi and Verona (2001) for a detailed explanation of the knowledge integration mechanisms.

KNOWLEDGE CREATION AND ABSORPTION

Culture

1. Orientation to scientific, rather than applied research
2. Unrestricted exploration of audiological issues
3. Open attitude towards the scientific community: willingness to share research results

Actors

4. Skilled researchers graduated from Danish universities
5. Long-term relationships with an extensive pool of patients
6. Collaborations with experts from international research centers and universities

Structures and Systems

8. Complete autonomy of the research center director over the use of the annual budget

9. Scientists at the research center focused on base research

10.

Physical resources

11. Separate research facility in an attractive location
12. Comprehensive library on audiology and acoustics
13. The Eriksholm collection museum

KNOWLEDGE INTEGRATION

Culture

15. Openness to creativity
16. Absence of departmental identification
17. Interaction and dialogue encouraged

Actors

19. Technical experts loosely affiliated with professional areas
20. Employees with eclectic skills, able to work in an unconventional environment

Structures and systems

22. Cross-functional teams
23. Competence centers
24. Professional areas
25. “Multi-job” system
26. Hiring mechanisms
27. Self-participation in projects

Physical resources

29. New workplace layout (open space offices, meeting points, coffee counters, etc.)
30. Mobile workstations
31. Easily accessible electronic archive

KNOWLEDGE RECONFIGURATION

Culture

33. Openness to individual proposals and individual creativity
34. Broad involvement in strategic processes

Actors

36. Contributive and motivated employees
37. Experienced senior managers

Physical resources

39. Flexible workplace design
40. Cogitate incognita on the company walls

Structures and Systems

42. Absence of departments
43. Development group
44. Continuous collection and evaluation of proposals
45. Free allocation of time and skills
46. CentralIzed allocation of financial resources

Knowledge Integration

CONTINUOUS INNOVATION

Knowledge Reconfiguration

Knowledge Creation
and Absorption