INDIVIDUAL, TEAM AND ORGANIZATIONAL ANTECEDENTS OF EXPLORATIVE AND EXPLOITATIVE INNOVATION IN MANUFACTURING FIRMS

Matthias de Visser

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1
INTRODUCTION

New product development (NPD) is seen as crucial for the long-term survival and growth of the firm (Baumol, 2002; Schumpeter, 1939). Many manufacturing companies face intense pressures to innovate to meet customer requirements and especially to produce innovations that will draw the market spotlight and market share to them (Brown and Eisenhardt, 1995). Product development is critical because new products are becoming the nexus of competition for many firms (Clark and Fujimoto, 1991). Firms whose employees quickly develop exciting products that people are anxious to buy are likely to win. In contrast, firms introducing "off-the-mark" products are likely to lose. New product development is thus a potential source of competitive advantage for many firms (Brown and Eisenhardt, 1995). New product development is also important because it is a critical means by which members of organizations diversify, adapt, and even reinvent their firms to match evolving market and technical conditions (e.g. Schoonhoven et al., 1990). Thus, new product development is among the essential processes for success, survival, and renewal of organizations, particularly for firms in either fast-paced or competitive markets.

A central component of success in new product development is the maintenance of a balance of exploration and exploitation within the firm. Exploration can be defined as “the pursuit of new knowledge of things that might come to be known” and exploitation as “the use of and development of things already known” (Levinthal and March, 1993). A one-sided focus on exploitation may enhance short-term performance, but it can result in a competency trap because firms may not be able to respond adequately to environmental changes (Leonard-Barton, 1992). Conversely, too much exploration may enhance a firm’s ability to renew its knowledge base but can trap organizations in an endless cycle of search and unrewarding change (Volberda and Lewin, 2003). Therefore, near consensus exists among scholars on the need for balancing both types of activities (Gupta et al., 2006). Organizations thus have to continuously reconfigure their activities to meet changing demands in the internal and external environments (e.g. Tushman and Anderson, 1986; Webb and Pettigrew, 1999). However, organizations encounter various challenges in balancing these activities (Lavie and Rosenkopf, 2006; Levinthal and March, 1993;

Siggelkow and Rivkin, 2006; Tushman and O'Reilly, 1996) as they entail inherent contradictions that need to be managed (Tushman and O'Reilly, 1996).

The first challenge concerns investment in long-term and short-term innovation processes. Organizations making conscious choices to support exploration or exploitation activities by making resource allocation decisions, face trade-offs between the expected consequences of these activities (Lavie et al., 2010). Within a business unit, exploration and exploitation compete for scarce organizational resources. More resources devoted to exploitation imply fewer resources left over for exploration and vice versa (Gupta et al., 2006). This implies that organizations have to decide between short-term productivity and long-term innovation. Compared to returns from exploitation, returns from exploration are less certain, more remote in time, and more distant from the locus of action (March, 1991). Investing in explorative activities therefore involves higher risk investments which challenges organizations to decide whether certain, immediate success should be hedged for a chance of future success.

Another tension between exploration and exploitation that challenges manufacturing companies to balance exploration and exploitation, involves the differences in mindsets and organizational routines needed for both activities. Whereas mechanistic structures support routine operations, functional specialization, formal duties, responsibilities and power, organic structures entail less rigid establishments (Burns and Wholey, 1993; Burns and Stalker, 1961). These alternative structures can correspondingly facilitate exploitation or exploration. Exploration entails non-routine problem solving and search for new knowledge that may make information processing inefficient under centralized decision-making. In turn, formalization is expected to constrain exploration and facilitate exploitation via incremental improvements in processes and products (Lavie et al., 2010). Idea generation requires out-of-the-box thinking, risk taking, and tolerance of mistakes. Idea implementation, in contrast, happens within organizational constraints. These differences in nature between exploration and exploitation imply that organizations that have invested in organizing exploitation face major challenges when attempting exploration, and vice versa (Sorensen and Stuart, 2000).

A third contradiction between exploration and exploitation concerns the iteratively self-enforcing nature of both types of activities. Because of the broad diffusion in the range of possible outcomes, exploration often leads to failure, which in turn promotes the search for even newer ideas and thus more exploration (Gupta et al., 2006), which may trap organizations in an "endless cycle of failure and unrewarding change" (Levinthal and March, 1993). In contrast, exploitation often leads to early success, which in turn reinforces further exploitation along the same trajectory. The more immediate returns from exploitation tend to cause organizations to exhibit a myopic bias whereby exploitation is overemphasized at the expense of exploration (Levinthal and March, 1993). Individuals and organizations tend to pursue solutions similar to already-known solutions because bounded rationality limits their ability to search all possible domains of knowledge (Simon, 1979) and biases them toward more salient areas of their own prior experiences (Cyert and March, 1963). Over time, these behaviors become deeply embedded in the organization (McNamara and Baden-Fuller, 1999) and once changes in an organization's environment asks for reconfiguration of exploration and exploitation, the switching costs involved in changing core capabilities may have become high (Kogut and Zander, 1992).

In the past decades, an emerging stream of research has suggested several organizational alternatives to overcome the contradictions between these conflicting activities (for an overview of this research, see Lavie et al., 2010; Raisch and Birkinshaw, 2008), and to improve effectiveness of explorative and exploitative NPD processes (for an overview, see Damanpour, 1991; Brown and Eisenhardt, 1995; Ernst, 2002). Conflicting demands between exploration and exploration can be addressed by using spatial differentiation, such as creating organizational spinouts to pursue new opportunities (Christensen and Bower 1996, Galunic and Eisenhardt 2001, Gilbert, 2005). Other studies described an alternative path to combining exploration and exploitation by managing them separately within the same organizational unit. The use of parallel structures allows people to switch back and forth between two or more types of structures, depending on the structure that their specific task requires (Bushe and Shani, 1991; McDonough and Leifer, 1983; Stein and Kanter, 1980; Zand, 1974). Here, an organizational unit's main structure serves exploitative activities and can be used for routine tasks and for maintenance of stability and efficiency. Additional structures, such as cross-functional team structures (Griffin, 1997; Pittiglio et al., 1995; Song et al., 1997) balance the primary structure's shortcomings and support non-routine tasks and innovation (Goldstein, 1985). The supplementary structure coexists with the primary task structure to ensure efficiency and flexibility (Adler et al., 1999).

In this literature, focus has been on structural factors. Relying on structural contingency theory, these studies assume that innovation is determined by organizational characteristics and "share a common deterministic orientation by which organizational behavior is seen to be shaped by a series of impersonal mechanisms that act as external constraints on actors" (Astley and Van de Ven, 1983). However, few studies pay attention to innovation in terms of the characteristics and actions of organizational participants that work in these structures. Much of the applied literature on the management of new product development has ignored the research by cognitive psychologists and social-psychologists about the capacity of human beings to handle complexity and maintain attention (Van de Ven, 1986). The way people acquire and process information can be a better predictor of an individual's success in a particular situation than situational factors (Kozhenikov, 2007). In the field of industrial and organizational behavior, cognitive style is considered a fundamental factor determining both individual and organizational behavior as it affects problem-solving, decision-making and creativity (Sadler-Smith and Badger, 1998). Several scholars suggested that cognitive inclinations of senior-management might have significant impact on the ability of a firm to deal with contradictions and engage in explorative and exploitative activities (e.g. Lewin et al., 1999; Hambrick et al., 2005; O'Reilly and Tushman, 2008). It has also been proposed that different cognitive styles vary in their effectiveness in initiating and implementing innovations (Sadler-Smith and Badger, 1998). Besides structural factors, cognitive characteristics of individuals and groups of individuals thus might play an important role in balancing and organizing explorative and exploitative NPD processes within manufacturing firms. To date, however, very few empirical studies have examined the relationship between cognitive characteristics and the ability to engage in exploration and exploitation (e.g. Gupta et al., 2006; Raisch and Birkinshaw, 2008; Papadakis and Bourantas, 2007).

In this thesis we investigate effects of cognitive and structural factors in NPD, taking into account the multi-dimensionality of innovation. The central question of this thesis is: *To what extent do cognitive and structural factors influence explorative and exploitative innovation in manufacturing firms?* In this thesis, this question will be addressed in four chapters (see figure 1), which build on previous studies on exploration and exploitation that were conducted within the strategic research orientation Management of Innovation and Entrepreneurship at the University of Twente (e.g. Bernasco et al., 1999; Visscher et al., 2005; Visscher and De Weerd-Nederhof, 2006; De Weerd-Nederhof et al., 2008; Faems et al., 2011). Moreover, the work contained in this thesis has been conducted within the scope of the Competenties voor Innovatie project, which is supported by Pieken in de Delta Oost Nederland.

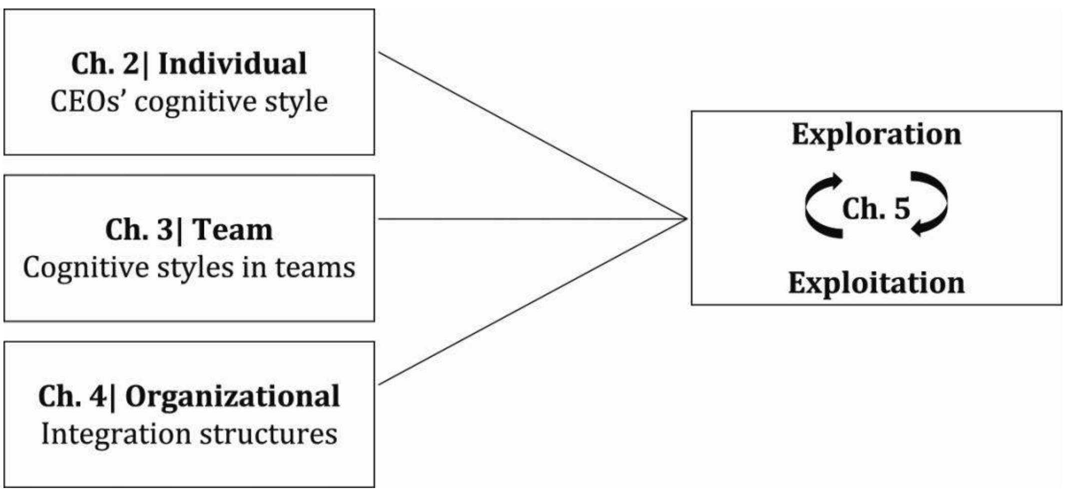


Figure 1: key concepts and their relationships

Ch. 2: To what extent do cognitive styles of CEOs influence exploration and exploitation?

Previous studies have provided valuable insights into how environmental and organizational factors may influence levels of explorative and exploitative innovation in firms (e.g. Duncan, 1976; Tushman and O'Reilly, 1996; Jansen et al., 2009; Jansen et al., 2005; Tushman and O'Reilly, 1996; Benner and Tushman, 2003). At the same time, scholars suggest that individual characteristics, such as cognitive and behavioral inclinations of top executives, might also have significant impact on the ability of a firm to engage in explorative and exploitative activities (e.g. Lewin et al., 1999; Hambrick et al., 2005; O'Reilly and Tushman, 2008). The importance of the

CEO is of interest, especially in medium-sized companies, where the CEO appears to be most influential (Miller and Toulouse, 1986). Very few studies, however, have quantitatively examined the relationship between individual characteristics of top managers and firm-level exploration and exploitation (e.g. Gupta et al., 2006; Raisch and Birkinshaw, 2008; Papadakis and Bourantas, 2007). Most of the existing research focuses on observable managerial characteristics and the composition of top management teams (e.g. Lubatkin et al., 2006; Mom et al., 2009; Papadakis and Bourantas, 2007). Therefore, some important psychological issues may have been bypassed. With our first study, we complement prior research in two fundamental ways. First, whereas previous studies focus on extrinsic organizational factors that influence individual exploration and exploitation, we rely on insights from cognitive psychology (e.g. Bruner et al., 1956; Witkin et al., 1962; Miller, 1987; Hayes and Allinson, 1994) to hypothesize a relationship between intrinsic factors (i.e. cognitive style) and individuals' tendency for exploration versus exploitation. Second, whereas existing research remains silent on the implications of individual CEO characteristics for firm performance, we hypothesize a relationship between the CEOs' tendency for exploration or exploitation and firm-level innovation performance.

Ch. 3: To what extent do cognitive styles in teams influence exploration and exploitation?

To date, only few studies investigated the link between NPD team members' personal attributes and project performance (Miron-Spektor et al., 2011). Most studies that have tested the performance effects of team characteristics have focused on demographic variables, such as education and functional background, age, and organizational tenure (e.g., Ancona and Caldwell, 1992; Hulsheger et al., 2009; Lovelace et al., 2001). Although demographic differences have been shown to influence team performance, underlying psychological characteristics such as personality attributes have been found to be better predictors of team performance over time (Bell, 2007; Harrison et al., 2002). While others have offered some evidence on how cognitive styles may affect creativity (Kurtzberg, 2005) or the innovative quality of team's activities (Miron-Spektor et al., 2011), our second study offers a perspective on how teams may be composed to foster the kinds of psychological states that lead to overall project performance in explorative and exploitative new product development projects.

Ch. 4: To what extent do organizational integration structures influence exploration and exploitation?

During the past decades, scholars have increasingly studied the NPD process within firms (for an overview of this research, see Damanpour, 1991; Brown and Eisenhardt, 1995; Ernst, 2002). In these studies, the structural design of the NPD process has been recognized as one of the critical success factors to arrive at successful innovation (Cooper, 2003). In particular, the implementation of structural mechanisms such as cross-functional integration structures (Griffin, 1997; Pittiglio et al., 1995; Song et al., 1997), stage-gate processes (Cooper, 1996; Cooper et al., 2004), and formalized NPD procedures (Kerssens-van Drongelen and De Weerd-Nederhof, 1999; Lilly and Porter, 2003) have been found to positively influence the innovation performance of firms. At the same time, it is increasingly recognized that the NPD process is a multidimensional phenomenon, encompassing development processes that focus on the improvement of existing products as well as processes that focus on the generation of new products. Moreover, several scholars (Olson et al., 1995; Olson et al., 2001; Song and Xie, 2000) have provided evidence that, within a particular NPD project, the product innovativeness moderates the relationship between the effectiveness of the integration structure (i.e. formal versus cross-functional integration structure) and the performance of the NPD project. However, these studies have solely focused on the project level (Sánchez and Pérez, 2003; Brettel et al., 2011). As a result, we do not know whether firms tend to apply different kinds of integration structures for different kinds of NPD processes and how the application of particular integration structures in particular NPD processes influences firm-level innovation performance. In the third study of this thesis, we therefore conduct a firm-level assessment of the impact of different kinds of integration structures in different kinds of NPD processes on different kinds of firm innovation performance.

Ch. 5: How do structural and cognitive factors influence the evolution of exploration and exploitation over time?

Previous studies have emphasized the complexity of balancing exploration and exploitation levels (e.g. Sorensen, 2002; Voss et al., 2008; Benner, 2007) and have provided insights into structural and individual factors that influence them (e.g. Nohria and Gulati, 1996; Burns and Stalker, 1961; Benner and Tushman, 2003; Tushman and O'Reilly, 1996; Scott and Bruce, 1994). Whereas the individualist perspective seeks to explain innovative behavior in terms of characteristics and actions of organizational participants, the structural perspective assumes that innovation is most strongly influenced by organizational characteristics such as formalization, slack resources and organizational structure. Although these studies have provided valuable insights into the factors that influence exploration in organizations, only few have unraveled the process of how these structural and individual factors affect changing exploration levels in growing organizations. Since the time dimension is mostly absent in existing studies (Gibson and Birkinshaw, 2004; Jansen et al., 2005) and only partial relationships are illuminated (Eisenhardt et al., 2010), it remains unclear how structural and individual antecedents in growing organizations interrelate and how they affect exploration decline and recovery. Therefore the purpose of the fourth study in this thesis is to provide in-depth insights into the dynamics of a growing organization's exploration levels and to explain how structural and individual factors impact these over time. In order to do so, we conduct a single case study in a fast growing R&D organization in the wind turbine blade industry. Based on a unique collection of time-accounting data and descriptions of all R&D activities performed within a timeframe of 100 months, we measure the dynamics of exploration levels, visualizing in great detail how a firm goes through transitions from focus on exploration to exploitation and vice versa. Based on a series of interviews with employees of this organization, we demonstrate how structural and individual factors interact and impact this evolution.

2

EXPLORATION AND EXPLOITATION WITHIN FIRMS: THE IMPACT OF CEOs' COGNITIVE STYLE ON INCREMENTAL AND RADICAL INNOVATION PERFORMANCE[1]

INTRODUCTION

Many scholars (e.g. Ancona et al., 2001; Benner and Tushman, 2002; Dougherty, 1992; Eisenhardt and Martin, 2000; Feinberg and Gupta, 2004; Levinthal and March, 1993; March, 1991, 1996, 2006) stress the need for companies to manage an appropriate mix of explorative and exploitative innovation activities in order to survive in the long-term. Explorative activities can be characterized by terms such as search, variation, risk-taking, experimentation, play, flexibility and discovery (March, 1991). Exploitative activities are associated with aspects such as refinement, choice, production, efficiency, selection, implementation and execution (March, 1991).

Although both types of activities are essential for a firm's survival and prosperity (Lavie et al., 2010), many scholars have indicated a challenging tension between exploration and exploitation as they compete for the same scarce resources and demand radically different mindsets and organizational routines (e.g. March, 1991; Hannan and Freeman, 1977; Sorensen and Stuart, 2000). Existing research on organizational ambidexterity has provided valuable insights into how structural characteristics of firms or business units influence the ability to combine explorative and exploitative activities (e.g. Duncan, 1976; Tushman and O'Reilly, 1996; Jansen et al., 2009; Jansen et al., 2005; Tushman and O'Reilly, 1996; Benner and Tushman, 2003). At the same

[1] This chapter is based on previous papers:

De Visser, M., Faems, D., Van den Top, P., 2011. Exploration and exploitation within SMEs: connecting the CEO's cognitive style to product innovation performance. In proceedings of the International Product Development Management Conference, Delft, The Netherlands, June 5-7.

De Visser, M., Faems, D., Van den Top, P., 2011. Exploration and exploitation within SMEs: connecting the CEO's cognitive style to product innovation performance. Presented at the INSCOPE Conference, Enschede, The Netherlands, October 12.

time, scholars suggest that individual characteristics, such as cognitive and behavioral inclinations of senior-management, might also have significant impact on the ability of a firm to engage in explorative and exploitative activities (e.g. Lewin et al., 1999; Hambrick et al., 2005; O'Reilly and Tushman, 2008). However, very few studies have quantitatively examined the relationship between individual characteristics of top managers and the firms' ability to engage in exploration and exploitation (e.g. Gupta et al., 2006; Raisch and Birkinshaw, 2008; Papadakis and Bourantas, 2007). A recent study of Mom et al. (2009) is a notable exception in this respect. This study demonstrates that managers can substantially differ in their explorative and exploitative behavior. In addition, they show that managers' individual engagement in explorative and exploitative activities depends on organizational design factors such as managers' decision-making authority.

With this study, we complement this prior research on individual exploration and exploitation in two fundamental ways. First, whereas Mom et al. (2009) focus on extrinsic organizational factors that influence individual exploration and exploitation, we rely on insights from cognitive psychology (e.g. Bruner, 1956; Witkin et al., 1962; Miller, 1987; Hayes and Allinson, 1994) to hypothesize a relationship between intrinsic factors (i.e. cognitive style) and individuals' tendency for exploration versus exploitation. Second, whereas existing research remains silent on the implications of individual exploration and exploitation for firm performance, we rely on Upper Echelon theory (e.g. Hambrick and Mason, 1984; Hambrick and Finkelstein, 1987) to hypothesize a relationship between the CEOs' tendency for exploration or exploitation and firm-level product innovation performance.

In order to test our hypotheses, we rely on a unique dataset, containing information on (i) the cognitive style of 122 CEOs of Small and Medium Sized Businesses (SMEs) in the Dutch manufacturing industry as well as (ii) their firms' product innovation performance. As previous studies emphasized the decisive role of CEOs in leading organizations with respect to entering new technological domains (e.g. Kaplan, 2008; Tushman et al., 2011), we investigate their particular individual characteristics. We focus our study on SMEs because CEOs have been found to be a major factor in contributing to innovativeness in small manufacturing firms

(Lefebvre and Lefebvre, 1992) and more influential than in larger companies (Papadakis and Bourantas, 2007).

Conducting structural equation analyses, our findings show that CEOs with a more analytic cognitive style tend to engage more in activities related to exploitation of existing products and markets, whereas CEOs with a more intuitive cognitive style tend to engage more in activities related to exploration of new products and markets. In line with upper-echelon theory, our data also show that such individual tendency toward exploration or exploitation significantly influences the allocation of R&D resources within the firm, which in-turn impacts firms' incremental and radical innovation performance.

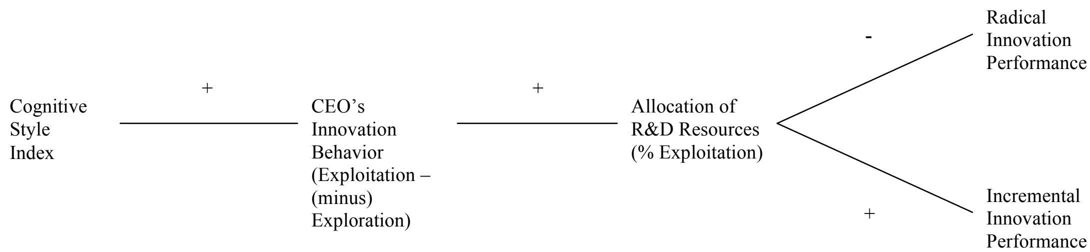
From a theoretical perspective, our findings point to the relevance of applying insights from cognitive psychology to better understand innovation behavior of top managers. At the same time, we contribute to integrating insights from Upper Echelon theory in research on new product innovation, illuminating how individual characteristics, resource allocation decisions and innovation performance are linked to each other. From a managerial perspective, our data suggest that, in the context of SMEs, the intrinsic characteristics of the CEO might have strong predictive value for firms' innovation performance.

This paper is structured in five sections. First, we rely on insights from cognitive psychology and Upper Echelon theory to develop our hypotheses. Second, the methodology is discussed. Next, the results of the analyses are presented. Fourth, we point to the main theoretical and managerial implications of the findings. Finally, discuss the study's main limitations, and suggest avenues for future research.

HYPOTHESES

In this section, we develop hypotheses on (i) the impact of CEOs' cognitive style on their tendency toward exploitation or exploration, and (ii) the effects of such individual innovation behavior on firms' R&D investments and product innovation performance. Figure I provides a graphical illustration of our hypotheses.

Figure I: hypotheses



The impact of cognitive style on CEOs' innovation behavior

In order to investigate the relationship between CEOs' individual characteristics and their innovation behavior (i.e. individual tendency toward exploitation and/or exploration), we focus on CEOs' information processing strategies or the way they acquire, store and use knowledge. More specifically, we concentrate on cognitive style, a core concept in cognitive psychology that is defined as 'the consistent individual differences in preferred ways of organizing and processing information and experience' (Messick, 1976).

Several scholars stress the importance of cognitive style to better understand organizational behavior. Schweiger (1983), for instance, provides the following statement:

> 'if research indicates [. . .] that particular cognitive styles are more appropriate than others for the conduct of particular managerial activities, then normative recommendations concerning the selection and placement of individuals for these activities may be warranted. In addition, if it is found that cognitive styles are subject to modification, then the development of training programs in the industrial setting, or modifications of current business school curricula in the academic setting, may be critical.'

In line with these arguments, scholars (e.g. Kirton, 1980; McHale and Flegg, 1985; Ash, 1986; Mitchell et al., 2004; Armstrong and Hird, 2009) study the relevance and consequences of cognitive style in contexts such as team composition and training and development. In these studies, cognitive style is operationalized in terms of Wilson's (1988) cognitive style classification, which relies on Ornstein's (1977) brain hemispherical research to identify different cognitive functions and associate them with the right and left hemispheres in the human brain.

Individuals that have a cognitive style associated with left-brain functions prefer to converge information. The term often used to describe left-brain thinking is "analysis" (e.g. Agor, 1986; Hammond et al., 1987; Allinson and Hayes, 1996). Analysis refers to judgment based on mental reasoning and a focus on detail. Analysts (left-brain dominant people) tend to be more compliant, favor a structured approach to problem solving, depend on systematic methods of investigation, recall verbal material most readily and are especially comfortable with ideas requiring step by step analysis (Allinson and Hayes, 1996).

Individuals that have a cognitive style associated with right-brain functions prefer to diverge information. The term often used to describe right-brain thinking is "intuition" (e.g. Agor, 1986; Hammond et al., 1987; Allinson and Hayes, 1996). Intuition refers to immediate judgment based on feeling and the adoption of a global perspective. Intuitivists (right-brain dominant people) tend to be relatively nonconformist, prefer an open-ended approach to problem solving, rely on random methods of exploration, remember spatial images most easily, and work best with ideas requiring overall assessment (Allinson and Hayes, 1996).

Relying on these existing insights, we expect that CEOs' cognitive style might strongly impact their tendency toward exploration or exploitation. Exploration is rooted in variance-increasing activities and creates futures that may be quite different from organizations' past routines (Smith and Tushman, 2005). It is associated with experimentation, improvisation, and creativity (Chatman and Flynn, 2001; Rivkin and Siggelkow 2003; Van de Ven et al. 1999). For these activities, diverging information is essential (Allinson and Hayes, 1996), suggesting the importance of right-brain functions. We therefore expect that individuals, who have an intuitive cognitive style, are likely to engage more in explorative activities than exploitative activities.

Exploitation is rooted in variance-decreasing activities and builds on organizations' past routines (Smith and Tushman, 2005). It is associated with efficiency, focus and standardization (Chatman and Flynn, 2001; Rivkin and Siggelkow, 2003; Van de Ven et al., 1999). Hence, for these activities, converging information and left-brain functions are essential (Allinson and Hayes, 1996). We therefore expect that individuals with an analytic cognitive style are likely to engage more in exploitative activities above explorative activities. Jointly, these expectations result into the following hypothesis.

Hypothesis 1

The more analytic (intuitive) the cognitive style of CEOs, the stronger their focus on exploitative (explorative) activities

The impact of a CEO's innovation behavior on R&D resource allocation and firm innovation performance

Upper Echelon theory (Hambrick and Mason, 1984) states that organizational outcomes such as strategic choices and performance levels are partially predicted by managerial background characteristics. From this perspective, organizational outcomes are viewed as reflections of the values and cognitive bases of powerful actors in the organization. If strategic choices have a large behavioral component, they are likely to reflect the idiosyncrasies of decision makers. March and Simon (1958), for instance, argued that each decision maker brings his or her own set of cognitive base to an administrative situation, reflected by knowledge or assumptions about future events, knowledge of alternatives, and knowledge of consequences attached to alternatives. They also reflect his or her values: principles for ordering consequences or alternatives according to preference. These are in place at the same time the decision maker is being exposed to an ongoing stream of potential stimuli both within and outside the organization. The decision maker brings a cognitive base and values to a decision, which create a screen between the situation and his or her eventual perception of it (Hambrick and Mason, 1984; Child, 1972; Miller and Toulouse, 1986).

Following these Upper Echelon Theory arguments, we expect that CEOs' innovation behavior has a significant impact on strategic decision making. Building on previous findings by Barker and Mueller (2002), who found that CEO characteristics explain a significant proportion of a firm's relative R&D spending, we expect that CEOs' individual characteristics are also reflected in how firms' resources are allocated to different types of innovation activities. Specifically, we hypothesize that CEOs' orientation toward exploration and exploitation significantly influences how firms allocate R&D resources to explorative and exploitative activities.

Hypothesis 2

The degree to which CEOs focus on exploitative (explorative) activities is positively related to the percentage of R&D resources that is allocated to exploitative (explorative) activities within the firm

The distinction between incremental and radical innovation is one of the central notions in the existing literature on technical innovation (Mansfield, 1968; Freeman, 1982). Incremental innovation introduces relatively minor changes to the existing product, exploits the potential of the established design, and often reinforces the dominance of established firms (e.g. Nelson and Winter, 1982; Tushman and Anderson, 1986). This type of innovation is the result of exploitative activities, characterized by refinement and extension of existing competencies, technologies, and paradigms, and involves the use and development of things already known (March, 1991). Radical innovation, in contrast, is based on a different set of engineering and scientific principles and often opens up whole new markets and potential applications (e.g. Dess and Beard, 1984; Dewar and Dutton, 1986). These innovations are facilitated by exploration, which is in essence the experimentation with new alternatives and involves the pursuit of new knowledge. Therefore, we expect that the allocation of R&D resources across exploitative and explorative activities substantially influences a firms' incremental and radical innovation performance:

Hypothesis 3a

Higher allocation of R&D resources to exploitative activities increases firms' incremental product innovation performance

Hypothesis 3b

Higher allocation of R&D resources to exploitative activities decreases a firms' radical product innovation performance

METHODOLOGY

Data and sample

In order to test our hypotheses, we rely on a sample of Dutch SMEs. To select firms, we started from the Nedsoft database containing company information of 703432 Dutch companies, which represents 94% of all Dutch companies registered by the Dutch Central Bureau of Statistics (CBS). As this study focuses on product innovation in SME companies, we excluded all non-manufacturing companies and all companies with more than 250 employees. We also removed all companies of which no contact information was available. We sent a questionnaire to the CEO of the 2523 remaining companies and a reminder a week after, which resulted in 254 valid responses (10%). Out of these 254 companies, 122 indicated to invest in R&D (48%). This is close to SME information provided by the Statistics Netherlands agency, that reports an R&D investment percentage of 55%. This indicates that our initial sample is representative for Dutch manufacturing SMEs.

This study relies on single informant data and uses perceptual scales. To check for potential bias from using a single source, we performed a Harman's one-factor test on the items that were included in the hypothesized models. This test calculates whether a single factor accounts for most of the covariance in the dependent and independent variables (Podsakoff and Organ, 1986). We did not find such a single factor as only 26% of the variance was explained by a single factor solution, which indicates that our data did not face major common method bias problems.

Measures

Independent variable: cognitive style

There are many instruments available to measure cognitive style, of which the most commonly used are the Myers-Briggs Type Indicator (Myers, 1962), the Kirton Adaptation-Innovation Inventory (Kirton, 1976) and the Cognitive Style Index (Allinson and Hayes, 1996). To measure CEOs' cognitive style, we adopted the Cognitive Style Index (CSI) from Allinson and Hayes

(1996) as it is specifically designed for managerial and professional individuals (Armstrong et al., 2011). The CSI measures cognitive style on a bipolar analytic - intuitive dimension and contains 38 items (true; uncertain; false). Some examples of these items are:

> "Formal plans are more of a hindrance than a help in my work"
> "I am most effective when my work involves a clear sequence of tasks to be performed"
> "My approach to solving a problem is to focus on one part at a time"
> "I am inclined to scan through reports rather than read them in detail"

The CSI score is calculated by the sum of all 38 item scores (true = 2, neutral = 1, false = 0), of which some are reverse coded. The higher the CSI score, the more analytic the cognitive style of the respondent. A low CSI score, on the other hand, refers to the presence of an intuitive cognitive style.

Since the inter-item correlations of the CSI tend to be low with little variance, Allison and Hayes used a factor analysis of parcels of items to test the internal structure of the index. Following the proposed method by Allison and Hayes, we grouped the 38 items in six parcels and performed confirmatory factor analysis to test the structure of the scale. Our results indicate that the hypothesized single factor solution is confirmed and that this accounts for over half of the variance. The CSI scores as composed by our data show a sample mean score of 37.86 (see table III). To check for reliability, we computed the Cronbach's alpha (0.75), which indicates that these 38 items represent one single construct.

Dependent variables: CEO's innovation behavior, R&D resource allocation and indicators of product innovation performance

In order to measure exploration and exploitation on the individual level, we adopted the scale from Mom et al. (2009). This scale is based on the features by which March (1991) characterized exploration and exploitation, and uses seven items to measure the level of managers' exploration orientation, and seven items measuring managers' exploitation orientation. All items are measured on a five-point Likert scale ranging from "a very small extent" to "a very large extent" of engagement in explorative and exploitative activities. Results of factor analysis (see table I) confirm a two-factor structure of the data. We removed one of the exploration activities items for cross-loading, and one of the exploitation activities items because of low factor loading (<.5). We checked the reliability of the scale by computing Cronbach's alpha (0.79 for exploration and 0.83 for exploitation).

Table I: Factor analysis for CEO's innovation behavior

Items	*Factors*	
To what extent did you, last year, engage in work related activities that can be characterized as follows:	1	2
A manager's exploration activities (Cronbach's alpha = 0.79):		
Searching for new possibilities with respect to products/services, processes, or markets	-.487	.514
Evaluating diverse options with respect to products/services, processes, or markets	-.397	.568
Focusing on strong renewal of products/services or processes	-.296	.574
Activities of which the associated yields or costs are currently unclear	-.018	.684
Activities requiring quite some adaptability of you	.190	.703
Activities requiring you to learn new skills or knowledge	-.027	.752
Activities that are not (yet) clearly existing company policy	-.181	.572
A manager's exploitation activities (Cronbach's alpha = 0.83):		
Activities of which a lot of experience has been accumulated by yourself	.674	.002
Activities which you carry out as if it were routine	.727	-.213
Activities which serve existing (internal) customers with existing services/products	.636	.011
Activities of which it is clear to you how to conduct them	.806	-.066
Activities primarily focused on achieving short-term goals	.390	-.141
Activities which you can properly conduct by using your present knowledge	.759	-.155
Activities which clearly fit into existing company policy	.629	-.073

Extraction method: Principal Component Analysis. Rotation Method: Varimax

By combining the scales for exploration and exploitation, we created a measure for CEOs' innovation behavior. We subtracted the mean score of the six exploration items from the mean score of the six exploitation items. In this way, CEOs, who have an exploration focus, will have a negative score (min. -4) and CEOs, who have an exploitation focus, will have a positive score (max. 4) on this innovation behavior variable.

We measured firms' R&D resource allocation by asking respondents how during the past three years their respective R&D resources were allocated across (i) explorative innovation projects, which were defined as projects focused on R&D activities such as fundamental research, experiments and building of prototypes, and (ii) exploitative innovation projects, which were defined as projects focused on R&D activities such as standardization, optimization, fine-tuning and up-scaling. Based on this information, we constructed the variable R&D Resource Allocation representing the percentage of R&D resources invested in exploitative activities. Variable scores can range from 0 (no R&D resources allocated to exploitation) to 100 (all R&D resources allocated to exploitation).

Following previous research (Faems et al. 2005; De Visser et al., 2010; Neyens et al., 2010) we used the composition of turnover in 2009 in order to make a distinction between incremental and radical product innovation performance. The proportion of turnover in 2009 attributed to new products that were introduced during the last three years is regarded as an indicator of radical product innovation performance. Likewise, the percentage of turnover in 2009 attributed to improved products that were introduced during the last three years is seen as an indicator of incremental product innovation performance. In order to obtain a normal distribution, our analyses include the logarithm of 1+ the proportion of turnover attributed to (1) new products and (2) improved products.

Control variables

The period of time a CEO is active in the firm might impact his or her orientation toward exploration and exploitation (Tushman and O'Reilly, 1996). In order to control for this effect, we included a variable measuring how long CEOs have been working in the company. The degree to which a manager engages in risk-taking activities is also influenced by the managers' age (Vroom and Pahl, 1971). Older managers are less likely to engage in risky activities than young managers. As exploration is associated with risk-taking activities (March, 1996), we included a variable to control for age effects on CEOs' innovation behavior. Education is related to the cognitive ability of individuals to process information and may therefore be related to a managers' innovation behavior (Papadakis, 1998). We controlled for educational effects on CEOs' innovation behavior by including a dummy variable measuring whether CEOs have a master's degree or not.

In the innovation literature considerable attention is devoted to the relationship between innovation performance and environmental dynamics (e.g. Jansen et al., 2005; Sorensen and Stuart, 2000; Levinthal and Posen, 2009; Sainio et al., 2012). Firms that operate in a dynamic environment, tend to be more innovative than firms that operate in a stable environment (Hannan and Freeman, 1984). We therefore adopted a four-item scale from Jansen et al. (2006) to control for environmental factors that might influence radical and incremental innovation performance. To check for reliability, we computed the Cronbach's alpha (0.83), which is satisfactory.

We also expect that R&D intensity impacts innovation performance (Singh, 1986). Therefore, we included a variable measuring the R&D investments / sales ratio to control for this effect. Finally, because of potential industry differences in terms of product innovation performance, we controlled for them by introducing industry dummies. A distinction was made among 7 industries. The "other" sector was used as the reference category in the study's analyses. Table II provides an overview of the frequencies of the different industries.

Table II: Industry frequencies

Industry	*Frequency*	*Percent*
Textile	8	6.6
Wood	3	2.5
Construction	8	6.6
Plastic	11	9.0
Metal	49	40.2
Software	14	11.5
Other	29	23.8

RESULTS

Descriptive statistics

Table III gives an overview of the most important descriptive statistics. The means for the variables radical innovation performance and incremental product innovation performance are 0.22 and 0.26. Taking into account that this study uses logarithmic transformation for these variables, the implication is that, on average, respondents attributed 26.4% of their sales to new

Table III: Descriptive statistics and correlations

Variable	Mean	Min/max	S	LN (Incremental Innovation Performance)	LN (Radical Innovation Performance)	Allocation of R&D Resources (% Exploitation)	CEO's Innovation Behavior (Exploitation – (minus) Exploration)	Cognitive Style Index	R&D Investments (% of Sales)	Market Dynamics	CEO's Age	CEO's Tenure in the Firm
LN (Incremental Innovation Performance)	.2584	.00/.59	.13120	1								
LN (Radical Innovation Performance)	.2232	.00/.69	.14268	-.099	1							
Allocation of R&D Resources (% Exploitation)	53.20	0/100	26.861	.176	-.299**	1						
CEO's Innovation Behavior (Exploitation – (minus) Exploration)	-.1780	-2.57/2.00	.98997	-.161	-.216*	.206*	1					
Cognitive Style Index	37.86	13/63	10.680	-.007	-.051	-.055	.214*	1				
R&D Investments (% of Sales)	2.87	1/4	.872	.192*	.379**	-.137	-.193*	-.025	1			
Market Dynamics	3.55	2/5	.788	.073	.245**	-.057	-.248**	-.141	.338**	1		
CEO's Age	49.14	29/66	9.217	-.030	-.016	-.005	.002	.199	.082	.037	1	
CEO's Tenure in the Firm	16.23	1/40	8.915	-.078	-.111	-.082	.151	.151	-.040	-.042	.441**	1

* correlation is significant at the 0.05 level (two-tailed)
** correlation is significant at the 0.01 level (two-tailed)

products and 30.6% to improved products. This also implies that on average 43.0% of their sales was attributed to products that were introduced before 2007 and have not been improved since then.

To test the hypotheses, structural equation modeling (SEM) with manifest variables is used. Compared with ordinary linear regression models, this technique has two advantages (Sels et al., 2006). First, the method enables hypothesized relationships between variables to be defined and tested. The output indicates whether the model is supported by the data as a whole and gives a significance test for the various individual relationships. Second, a variable in a SEM can be either dependent or independent. This allows for testing the indirect influence, if any, of certain variables (Faems et al., 2010).

The goodness-of-fit overview (Table IV) indicates that the theoretical model is not adequately supported by the data. To optimize the model, paths were added from industry, market dynamics and R&D investments to CEO's innovation behavior and allocation of R&D resources. The resulting model is presented in Figure II. The goodness-of-fit measures indicate that the optimized model is effectively supported by the data.

Table IV: Goodness-of-fit measures

Fit measure	*Theoretical Model*	*Optimized Model*
Bentler's Comparative Fit Index	0.9302	0.9687
Bentler and Bonett's Normed Fit Index	0.8519	0.9298
Chi-Square Test (p-Value)	0.0771	0.1607

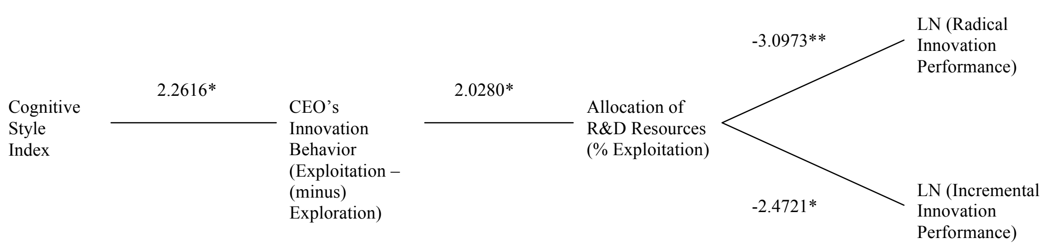
The Goodness-of-fit measures in Table IV indicate that our optimized model is effectively supported by the data. Below, we first discuss the effect of Cognitive Style on CEOs' Innovation Behavior. Subsequently, the effect of CEOs' Innovation Behavior on Firms' Allocation of R&D Resources is reported. Finally, we show the effects of a Firms' Allocation of R&D Resources on Radical and Incremental Product Innovation Performance. The standardized path coefficients are listed in Table V. The results of the test of the optimized model are also represented in Figure II.

Table V: Standardized path coefficients

Path from / to	(2)	(3)	(4)	(5)
(1) Cognitive Style Index	2.2616*			
(2) CEO's Innovation Behavior (Exploitation – (minus) Exploration)		2.0280*		
(3) Allocation of R&D Resources (% Exploitation)			-3.0973**	2.4721*
(4) LN (Radical Innovation Performance)				
(5) LN (Incremental Innovation Performance)				
Control Variables				
(6) Market Dynamics	-2.0664*	0.0590	1.3036	-0.0843
(7) Textile	-0.1758	-0.6720	-1.7062†	-2.4320*
(8) Wood	-0.9494	0.1127	-1.5358	-0.4028
(9) Construction	-1.9223†	-0.2328	-0.9807	-1.1783
(10) Plastic	-1.9009†	0.2752	-1.1930	-1.1349
(11) Metal	-1.1968	-1.0450	-0.9839	-0.6074
(12) Software	-2.5323*	-0.7920	0.9123	1.0576
(13) R&D Investments (% of Sales)	-1.4802	-1.0073	2.2391*	0.1009
(14) CEO's Tenure in the Firm	.06126			
(15) CEO's Age	-0.2891			
(16) CEO's Master's Degree	1.2629			

*† p<.10; * p<.05; ** p<.01*

Figure II: Results of optimized model



* *p*<.05; ** *p*<.01

In line with our first hypothesis, we observe a positive relationship between the Cognitive Style Index score and CEOs' Innovation Behavior. This result confirms that a more analytic cognitive style has a positive impact on a CEOs' tendency toward exploitation, whereas a more intuitive cognitive style has a positive impact on CEOs' tendency toward exploration. Our data also show a positive relationship between CEOs' Innovation Behavior and firms' Allocation of R&D Resources. Based on how these variables are measured, this result implies that, when the CEO has a stronger focus on exploitation, the share of R&D resources that are spent on exploitative activities will be larger. In contrast, a stronger focus on exploration will trigger an increase in the allocation of R&D resources to explorative activities. These results confirm that, within SMEs, the CEOs' innovation behavior has a strong impact on firm-level allocation decisions.

As stated in H3, firms that allocate more R&D Resources to exploitative activities were expected to perform higher in terms of Incremental Innovation Performance, and lower in terms of Radical Innovation Performance. These hypotheses are supported by our data as Allocation of R&D Resources (% Exploitation) has a significant ($p<.05$) positive direct effect on Incremental Innovation Performance, and a significant ($p<.01$) negative effect on Radical Innovation Performance.

Regarding our control variables, we did not observe any significant impact of Market Dynamics on innovation performance. However, we observed a significant ($p<.05$) negative impact of Market Dynamics on CEOs' Innovation Behavior; in more dynamic markets, CEOs have a stronger tendency toward explorative activities. This complements earlier findings by Sidhu et al. (2004), who found a positive relationship between environmental dynamism and managers' scope of information search to reduce uncertainty.

Further, a significant ($p<.05$) positive relationship between R&D intensity and Radical Innovation Performance was found; companies that invest more in R&D display higher Radical Innovation Performance. The data also point to a number of industry effects. Compared to other industries, companies in the Textile Industry perform significantly lower in terms of Incremental ($p<.05$) and Radical ($p<.10$) Innovation Performance. Finally, CEOs in the Software industry demonstrate a significantly ($p<.10$) lower engagement in exploitative activities compared to other industries.

DISCUSSION

In this section, we first discuss the theoretical implications of our study. In particular, we discuss (i) the relevance of cognitive psychology to better understand CEOs' innovation focus and (ii) the relevance of Upper-Echelon theory to better understand the link between individual innovation focus and innovation performance. Subsequently, we point to the main managerial implications. Finally, we discuss the main limitations of this study.

Implications for CEOs' innovation behavior

Whereas the current literature on exploration and exploitation mainly focuses on factors on the business unit and firm level, some scholars have suggested the relevance of investigating individual characteristics to explain differences in orientation toward explorative and exploitative activities. Recently, Mom et al. (2009) identified structural factors that impact a manager' tendency toward exploration and exploitation (e.g. formal structural mechanisms and personal coordination mechanisms). This study complements the findings of Mom et al. (2009), identifying cognitive style as an important personal factor that plays a significant role in explaining individuals' focus on exploration or exploitation.

Our data support our hypotheses that CEOs, who have analytic cognitive styles, prefer to converge information and therefore engage more in exploitative activities than CEOs, who have an intuitive cognitive style. These findings point to the relevance of applying insights from cognitive psychology to better understand innovation behavior of top managers.

Innovation performance implications of CEO's innovation behavior

We contribute to integrating insights from upper-echelon theory in research on new product innovation. Our findings illuminate how individual characteristics, resource allocation decisions and innovation performance are linked to each other. The upper echelon approach views strategic choice as a function of the demographic and psychological composition of top managers and suggests several factors that impact the strategic direction and performance levels of a firm, such as age, functional tracks, other career experiences, education, socioeconomic roots and financial position (Hambrick and Mason, 1984). Because of the difficulties of studying the mental representations and other psychological characteristics of the organization's executive members, Hambrick and Mason (1984) advocated indirect methods of cognitive assessment, whereby executives' background characteristics (e.g. education, functional specialization) are used as proxies for cognitive variables in the prediction of organizational outcomes (Hodgkinson and Healey, 2008).

Using a direct method to assess cognitive style of CEOs, our study supports the view that strategic decision-making is influenced by the cognitive base of top managers. In particular, our findings show how cognitive characteristics and individual inclinations for explorative and exploitative activities influence strategic decision-making on allocating resources to exploration and exploitation and firms' product innovation performance. Previous studies (e.g. Raisch and Birkinshaw, 2008; Virany et al., 1992; He and Wong, 2004) already pointed to the important role of senior managers in organizations' decisions between investing in exploration and exploitation. Our study emphasizes the relevance of upper echelon theory in explaining these strategic decisions.

Managerial implications

In drawing practical implications, this paper has underpinned the importance of the CEO in innovation. Our data suggest that cognitive styles of CEOs and their engagement in different types of innovation activities significantly impact resource allocation decisions and innovation performance in SMEs. Although we acknowledge the practical disadvantage of psychological measures compared to demographics, which are much easier to obtain, we argue that, in some situations, special attention should be paid to the fit between the individual characteristics of CEOs in cognitive style and organizational contexts. For instance, when a CEO is close to retirement and on the lookout for a replacement, he or she might assess the cognitive style of potential candidates in order to successfully continue the existing strategy of the firm. SMEs that are at the beginning of the innovation lifecycle with the majority of their products in more exploratory stages, might benefit from an intuitive CEO, whereas small firms that are in later stages of the cycle would benefit from a more analytic leader. CEOs characteristics might also be relevant for organizations that face the need to transition into a new strategic configuration. In cases where the cognitive style of the CEO in charge misfits with the strategic transition pursued, this transition could benefit from a CEO with a different style. Finally, our data suggest that, when investors are considering to buy stakes in SME companies, it might be interesting to take a close look at the personality of the CEO, as this might provide valuable information on the future innovation strategy and performance of the focal firm.

LIMITATIONS AND FUTURE RESEARCH

A first limitation of our study concerns generalizability. It is an interesting empirical question as to whether our findings are generalizable to larger firms. Compared to SMEs, innovation outcomes at larger firms are often influenced by a broader set of factors besides the CEO's innovation behavior, such as more complex organizational systems, which make strategic decision-making less straightforward. In addition, the influence of CEO at larger firms may also be affected by external governance pressures from an independent board of directors and shareholders. We expect that the statistical relationships between CEOs' Cognitive Style, CEOs' Innovation Behavior, Allocation of R&D Resources and Innovation Performance may not be as strong as what we found with our sample of SMEs (cf. Mom et al., 2009).

A second limitation is related to the cross-sectional nature of our data. Although we built in time lags between some of our variables, we were not able to assess long-term effects of changes in CEOs' innovation behavior. Future studies may adopt a longitudinal approach to increase insight into how changes in CEOs' innovation behavior, allocation of R&D resources and innovation performance causally relate to each other.

Furthermore, we limited the focus of this study by investigating how personal characteristics relate to innovation behavior and performance, and did not pay attention to how structural characteristics influence innovation behavior and firm performance. It would be interesting to study how personal characteristics and structural characteristics interact. For instance, we could expect that structural characteristics moderate the relationship between cognitive style and innovation focus. Future research could investigate the interactions between personal characteristics and structural characteristics, such as the formalization of tasks and involvement in cross-functional structures, and how they together affect R&D resource allocation and innovation performance.

In this paper, we have provided a richer understanding of exploration and exploitation within firms, acknowledging the relevance of cognitive style of senior executives in explaining differences in innovation behavior and their effects on incremental and radical innovation performance. We hope that practitioners in manufacturing firms will consider our practical suggestions and that our results may motivate researchers to continue exploring micro-level antecedents of innovation in a wide variety of organizational settings.

3
TEAM COMPOSITION AND NPD PROJECT PERFORMANCE: DO COGNITIVE STYLES MATTER?

INTRODUCTION

The new product development (NPD) process is complex and entails numerous uncertainties (Brettel et al., 2011). This results in interdependencies between different functional departments (Song et al., 1998). To successfully innovate and deal with the complexity of new technologies and information, organizations therefore increasingly rely on teams. Existing research on NPD teams has mainly focused on the performance implications of cross-functional collaboration. These studies show the extent to which teams have members with different functional backgrounds (e.g. research and development, marketing, manufacturing) (Lovelace et al., 2001) influences team performance because it affects the knowledge, skills, and effort team members apply to their task (Bell, 2007; Kozlowski and Klein, 2000). Functionally diverse product development teams have access to expertise that would not be available if all team members were from the same area. Moreover, the inclusion of various functional backgrounds facilitates the product transfer between the departments.

To date, only few studies investigated the link between NPD team members' personal attributes and project performance (Miron-Spektor et al., 2011). Most studies that have tested the performance effects of team characteristics have focused on demographic variables, such as education and functional background, age, and organizational tenure (e.g., Hulsheger et al., 2009; Lovelace et al., 2001). Although demographic differences have been shown to influence team performance, underlying psychological characteristics such as personality attributes have been found to be better predictors of team performance over time (Bell, 2007; Harrison et al., 2002). Much of the applied literature on the management of new product development, however, has ignored the research by cognitive psychologists and social-psychologists about the capacity of human beings to handle complexity and maintain attention in teams (Van de Ven, 1986).

A personality variable that is believed to be crucially important for both effective decision-making and successful interpersonal relationships in teams is cognitive style (Agor, 1986; Armstrong, 1999; Doktor, 1978; Kirton, 1989; Leonard and Strauss, 1997; Taggart et al., 1985). Cognitive style entails two fundamentally different modes of processing information. The intuitive style of processing information is preconscious, rapid, non-verbal, holistic and intimately associated with affect (Pacini and Epstein, 1999). Conversely, analytical thinking is conscious, relatively slow, primarily verbal and intentional, and operates by a person's understanding of culturally transmitted rules of reasoning (Pacini and Epstein, 1999). Previous research has indicated that different cognitive styles have a different impact on individual production and implementation of novel and useful ideas (Isaksen, 1987; Scott and Bruce, 1994).

Whereas most research on cognitive styles has focused on the individual level, analyzing the impact of individual information processing preferences and abilities on innovative behavior (e.g. idea-generation and creativity), strong indications are present that cognitive styles can also influence team behavior and effectiveness (Armstrong et al., 2011). Taggart (2001), for instance, found that cognitive styles influence the ability of teams to generate a variety of new ideas and the likelihood to identify problems. Relying on these insights from cognitive psychology, we expect that the ability of teams to develop new products might depend on their members' cognitive styles.

In addition, some cognitive psychologists provide indications that the impact of thinking styles on performance might depend on the task environment and other contextual conditions (Payne et al., 1990; Armstrong and Priola, 2001). Armstrong and Priola (2001), for instance, found that team performance is influenced by the fit between team cognitive styles and the nature of the work environment. In line with these observations, we expect that the impact of teams' cognitive styles might be differential in different innovation settings. In particular, we expect that analytical thinking in teams has a positive impact on project performance in exploitative settings, whereas in explorative settings, we expect intuitive thinking to have a positive performance impact.

The purpose of this study is to explore (i) the impact of NPD team cognitive styles on project performance (ii) in different types of innovation settings. In order to test our hypotheses, we rely on a unique dataset, comprising survey data from individual team-members of 95 NPD projects that were conducted in four Dutch manufacturing companies. Conducting general linear modeling analyses, our findings show that teams' analytical information processing has a positive effect on project performance, whereas the relationship between teams' intuitive information processing and project performance is moderated by the degree of exploration of project activities.

Our findings contribute to the literature on team innovation, suggesting that, next to demographic and functional characteristics, the composition of the team in terms of cognitive styles also significantly influences project performance. In particular, our study provides insights into the different effects of team thinking styles in different innovation settings. From a managerial perspective our findings provide valuable recommendations on how to compose NPD teams for different kinds of innovation activities (i.e. exploitative versus explorative innovation activities). Our data suggest that project managers should choose teams with strong analytical and weak intuitive processing for projects with high degrees of exploitation. In projects with high degrees of explorative activities, project performance benefits from teams with high levels of both intuitive and analytical processing of information.

This paper is structured in five sections. First, we rely on insights from cognitive psychology and dual processing theory to develop our hypotheses. Second, the methodology is discussed. Third, the results of the analyses are presented. Finally, we point to the main implications of the findings, discuss the study's main limitations, and suggest avenues for future research.

THEORETICAL BACKGROUND AND HYPOTHESES

Psychologists from various fields have proposed two fundamentally different thinking styles including intuitive and analytic modes of processing information (Epstein et al., 1996). Intuitive thinking can also be labeled as experiential, automatic, heuristic, associative, holistic and impulsive (Evans, 2008). Analytic thinking can also be characterized as rational, controlled, rules-based, conscious and reflective (Evans, 2008). Whereas previous studies conceptualized both processing modes as opposing ends of a continuum (e.g. Allinson and Hayes, 1996), more recent studies have provided evidence that the two modes of processing have an orthogonal relationship (Kozhevnikov, 2007). According to dual process theory, people can be intuitive and rational at the same time (Epstein et al., 1996; Pacini and Epstein, 1999). According to this view (Epstein, 1994; Kahneman, 2003; Stanovich and West, 2003), both thinking styles operate in an independent, parallel, and interactive manner (Kahneman, 2003). Together both systems contribute to behavior, with their relative contributions varying from none at all to complete dominance by either one of the modes (Pacini and Epstein, 1999). One of the most elaborated dual process theories is the cognitive-experiential self-theory (CEST) developed by Epstein (1994) (Evans, 2008). This theory assumes that people process information in two different modes. Analytical processing is identified by terms such as rational, deliberative, propositional, and extensional, whereas intuitive processing is described by terms such as experiential, automatic, intuitive, narrative, and natural (Denes-Raj and Epstein, 1994). According to CEST, individuals apprehend reality by these two interactive, parallel processing systems. The rational system is a deliberative, verbally mediated, primarily conscious analytical system that functions by a person's understanding of conventionally established rules of logic and evidence. The experiential system operates in an automatic, holistic manner, is intimately associated with the experience of affect, and is able to generalize and to construct relatively complex models for organizing experience and directing behavior by the use of prototypes, metaphors, scripts, and narratives (Denes-Raj and Epstein, 1994). These are independent systems that operate in parallel and interact to produce behavior and conscious thought (Epstein, 2003).

Several scholars have stressed the importance of cognitive style to better understand organizational behavior and studied its relevance and consequences in contexts such as team composition and training and development (e.g. Kirton, 1989; McHale and Flegg, 1985; Ash, 1986; Mitchell et al., 2004; Armstrong and Hird, 2009). Previous studies provide first indications that cognitive styles influence innovation behavior. Scott and Bruce (1994), for instance, found that individuals do not need to be highly intuitive problem solvers to be innovative, but that being systematic problem solvers inhibited high levels of innovative behavior. Results of a recent study by De Visser (2011) demonstrated that thinking styles of individuals may be indicative for their tendency toward explorative or exploitative innovation behavior. However, most of these studies are on the individual level of analysis. Secondly, the few empirical studies that focus on innovation teams (e.g. West and Anderson, 1996; Miron-Spektor et al., 2011) concentrate on single project outputs (e.g. idea generation, project output novelty) and do not investigate the impact of team cognitive style on overall performance of the innovation project. Finally, these studies do not take into account contextual factors, such as the radicalness of the project. In this paper, we therefore develop hypotheses on the impact of team analytical and intuitive cognitive styles on overall NPD project performance in different innovation settings.

The relationship between thinking styles and task performance seems to be influenced by the context in which activities take place. Both individual and team performance seem to be contingent on the degree of match between thinking style and requirements of the task. Empirical research has shown that individuals with a strong analytic thinking style tend to be more task oriented and prefer more structured, less ambiguous environments in which they can function within existing rules and procedures (Armstrong et al., 2011; Kirton; 1976; Cools et al., 2009). Individuals with a strong intuitive thinking style, on the other hand, have been shown to favor less structure and more ambiguity in their work environment in which they can work autonomously and in freedom from rules and regulations (Kirton, 1976; Cools et al., 2009). Consequently, Scott and Bruce (1994) found that individuals with a strong intuitive thinking style are more likely to induce innovative behavior than those with a strong analytical style. Project-level studies have demonstrated similar results. Intuitive teams have been found to outperform their analytical counterparts when the nature of the work environment was unstructured and organic (Armstrong and Priola, 2001). Conversely, analytical teams have been found to outperform their intuitive counterparts when the nature of the work environments is relatively well structured and mechanistic (Priola et al., 2004).

The NPD process is a multidimensional phenomenon, encompassing development processes that focus on the improvement of existing products (incremental NPD processes) as well as processes that focus on the generation of new products (radical NPD processes). Incremental technological innovations and innovations designed to meet the needs of existing customers are exploitative and build upon existing organizational knowledge. In contrast, radical innovations or those for emergent customers or markets are exploratory, since they require new knowledge or departures from existing skills (Levinthal and March, 1993; March, 1991).

Exploration is rooted in variance-increasing activities and creates futures that may be quite different from organizations' past routines (Smith and Tushman, 2005). It is associated with experimentation, improvisation, and creativity (Chatman and Flynn, 2001; Rivkin and Siggelkow 2003; Van de Ven et al. 1999). For these activities, we expect intuitive processing of information to be essential as it is characterized by overlapping separate domains of thought simultaneously, a lack of attention to existing rules and disciplinary boundaries, and an emphasis on imagery (Scott and Bruce, 1994). In general, exploration is associated with organic structures (Ancona et al. 2001, Brown and Eisenhardt, 1997; Lewin et al. 1999). These kinds of working environments are not preferred by analytic thinkers. Therefore we expect high levels of analytic thinking in teams to be counter-effective in projects with high levels of exploration.

Hypothesis 1a

In NPD projects with high exploration intensity, the relationship between teams' intuitive information processing and project performance is positive

Hypothesis 1b

In NPD projects with high exploration intensity, the relationship between teams' analytical information processing and project performance is negative

Exploitation is rooted in variance-decreasing activities and builds on organizations' past routines (Smith and Tushman, 2005). It is associated with efficiency, focus and standardization (Chatman and Flynn, 2001; Rivkin and Siggelkow, 2003; Van de Ven et al., 1999). For these activities, we expect analytic processing to be essential as it is based on habit, or following set routines, adherence to rules and disciplinary boundaries, and use of rationality and logic (Scott and Bruce, 1994). As exploitation is associated with mechanistic structures and routinization (Ancona et al. 2001, Brown and Eisenhardt 1997, Lewin et al. 1999), which do not fit with the working environment preferred by intuitive thinkers, we expect high levels of intuitive thinking to be counter-effective in projects with low degrees of exploration.

Hypothesis 2a

In NPD projects with high exploitation intensity, the relationship between teams' intuitive information processing and project performance is negative

Hypothesis 2b

In NPD projects with high exploitation intensity, the relationship between teams' analytical information processing and project performance is positive

METHODOLOGY

Sample

Our sampling was based on the method used by Gladstein et al. (1992). We studied 102 NPD teams in four technology companies in the rubber tires, sensors and controls, membrane technologies and pipeline systems industries. In these four companies, we were given access to their documentation system of all the NPD projects that had been conducted in the past five years. We also obtained time-accounting data of all projects, which enabled us to list the members of all of the teams that worked on these projects. We then verified with the project managers whether the members we selected were considered to be on the team. Each team was responsible for developing a product or product component in a project setting. The average group size was approximately 4. Of the 352 questionnaires distributed to team members, 261 were returned (82%). Because we were analyzing at the group level, teams were included in the final sample only if at least two-thirds of the members responded. This reduced the number of teams in the final sample to 95. The average age of individuals in the sample was 40 of which 96% male. Approximately 74% of the respondents in the sample were from engineering or research and development; the remaining 26% were primarily from manufacturing or marketing.

Measures

Dependent variable: indicator of overall project performance

In this study, we define project performance as the extent to which a team is able to meet established project objectives. To capture overall project performance, we adopted a 5-point Likert scale from Hoegl et al. (2004) who based them on scales used by Lechler (1997) and Hoegl and Gemuenden (2001). This scale consists of five items referring to project success, achievement of project goals, output quality, team satisfaction about project performance and top management satisfaction about project progress. All team members of each project were asked to evaluate project performance using this scale (Cronbach's alpha = 0.95). We computed an overall project performance variable by calculating the mean score of the individual factor scores of the team members.

Independent variables: team analytical and intuitive processing

To measure the degree to which NPD team members process information intuitively, we used the "Faith in intuition" scale (Epstein et al., 1996; Pacini and Epstein, 1999). We measured analytical processing of team members by the "Need for cognition" scale (Epstein et al., 1996; Pacini and Epstein, 1999). We selected the 7-point Likert scale items for both systems from the latest version of the "Need for cognition" and "Faith in intuition" instrument based on the highest factor loadings (Pacini and Epstein, 1999). We conducted confirmatory factor analysis of the 10 items pertaining to intuitive and analytical processing on the sample of 123 individuals. Due to low factor loadings (below 0.58) we deleted two items. Table 1 displays results of the hypothesized 2-factor model with significant factor loadings for the remaining 4 intuitive processing (α=0.79) and the 4 analytical processing (α=0.80) items. The goodness-of-fit measures indicate that the data fit the hypothesized model adequately. These findings provided strong support for the reliability and validity of our measurements for intuitive and analytical processing of NPD team members. We computed team intuitive and team analytical processing by calculating the mean scores on both scales of all team members.

Table 1: Results of confirmatory factor analysis

Item	Intuitive processing	Analytical processing
I like to rely on my intuitive impressions	0.7141	
Using my gut feeling usually works well for me in figuring out problems in my life	0.7476	
I believe in trusting my hunches	0.5935	
I often go by my instincts when deciding on a course of action	0.7388	
I try to avoid situations that require thinking in depth about something *(reverse coded)*		0.6913
I enjoy solving problems that require hard thinking		0.6441
I am much better at figuring things out logically than most people		0.7664
I have a logical mind		0.8419

Bentler’s Comparative Fit Index 0.9715
Bentler and Bonett’s Non-normed Index 0.9557
Bentler and Bonett’s Normed Fit Index 0.9187
Chi-Square Test (p-Value) 26.4801

Moderator: exploration

In this study we expect the degree of exploration activities to moderate the relationship between team cognitive styles and overall NPD project performance. Exploration includes activities such as fundamental research, experimentation, and search (Benner and Tushman, 2003). In order to measure the degree of exploration in NPD projects, we asked all team members of each project which percentage of total project time was dedicated to explorative activities such as fundamental research, experimentation and prototyping (Tushman and Smith, 2002). We created the exploration variable by calculating the mean of all team members’ scores.

Control variables

For new product development teams, organization tenure and the mix of functional specialties are likely to be of particular importance to project performance (Gladstein et al., 1992). Organization tenure has been related to the frequency of communication (Zenger and Lawrence, 1989), social integration (O’Reilly et al., 1989) and performance (O’Reilly and Flatt, 1989). Given the technical nature and complexity of the product development process, the effect of tenure is likely to influence the way the NPD team operates (Gladstein et al., 1992) and affect project performance. We therefore controlled for tenure effects by measuring company experience of teams. We asked all team members about the tenure in the firm and calculated the mean company experience for each team in years. An NPD team might be made up entirely of individuals from research and development or may also involve members of manufacturing, marketing. For product development teams functional diversity has been shown to have significant effect on project performance (Brettel et al., 2011; Gladstein et al., 1992). We controlled for performance effects of cross-functionality by including a dummy variable that indicates whether multiple departments were involved in the NPD teams. Finally we controlled for company effects as project performance of NPD teams might be nested in their specific company contexts.

RESULTS

Descriptive statistics

Harman's single factor test as suggested by Podsakoff and Organ (1986) provided initial evidence that common method bias was not a major problem in our study, as only 28,6% of the variance was explained by a single factor solution. Addressing the potential for multicollinearity, we standardized the variables and found that the VIF scores (see table 2) did not exceed 10. This indicates that multicollinearity is not a major concern (Hair et al., 1995).

Table 2: VIF scores

Variable	VIF
Cross-functionality	1.15463
ZExploration	1.34665
ZCompany experience	1.15818
ZIntuitive processing	1.35492
ZAnalytical processing	1.76873
ZIntuitive processing*ZExploration	1.29129
ZAnalytical processing*ZExploration	1.62491

An overview of the descriptive statistics on the continuous variables can be found in table 3. As we see in table 3, the variable analytical processing negatively correlates with company experience. Also, a significant correlation between the two processing styles and exploration can be observed. Finally, analytical and intuitive processing in teams are significantly correlated.

Table 3: Descriptive statistics and correlations (two-tailed)

Variable	Mean	Standard deviation	Overall project performance	Company experience	Analytical processing	Intuitive processing	Exploration
Overall project performance	3.5169	.7543	1				
Company experience	14.2215	8.1317	.040	1			
Analytical processing	5.2942	.8593	.108	-.226**	1		
Intuitive processing	4.5397	.6850	.138	-.016	.283***	1	
Exploration	54.8815	23.6567	-.141	-.025	.371***	.254**	1

*p<0.1

**p<0.05

***p<0.01

Impact of intuitive and analytical processing on project performance

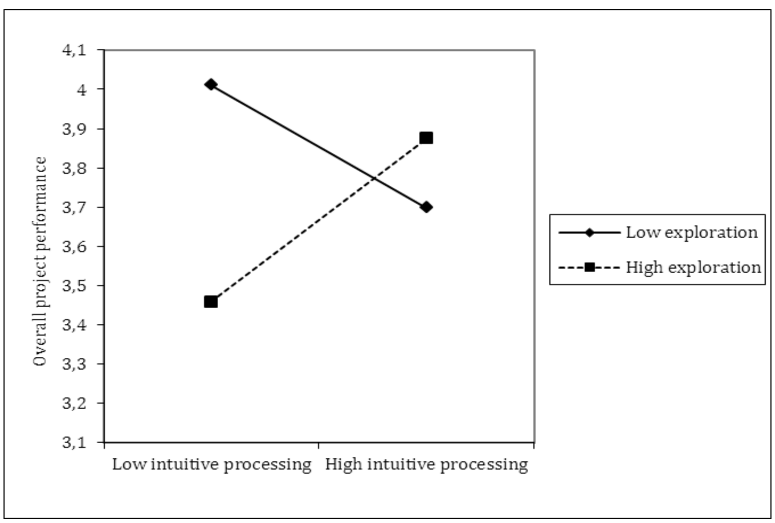
Table 4 summarizes the findings of the General Linear Modeling analyses whereby overall project performance acts as the dependent variable. It can be observed that there is a significant interaction effect between intuitive processing and exploration on overall project performance. Figure 1 visualizes this interaction effect. In line with our first hypothesis, in NPD projects with higher degrees of exploration, intuitive processing has a significant positive effect on overall project performance. In addition, intuitive processing has a significant negative effect on overall project performance in NPD projects with lower degrees of exploration, which is also in line with what we hypothesized. In contrast to what we hypothesized, our results show no significant interaction effect between analytical processing and exploration. However, a direct positive effect of analytical processing on overall project performance can be observed. Our data thus suggest that team analytical thinking has a positive effect on overall project performance, independent of the degree of exploration of the NPD project that is conducted. It can also be observed that cross-functionality has a positive impact on overall project performance. Furthermore, the results show that company C significantly underperforms compared to company D. Finally, we did not observe significant company experience effects for overall project performance.

Table 4: Results of General Linear Modeling analyses-dependent variable: overall project performance (N=95)

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	.423*	.378*	.350	.336	.323
Company A	-.231	-.142	-.123	-.089	-.206
Company B	.005	.129	.166	.199	.047
Company C	-.881**	-.961***	-.731**	-.778**	-.785**
Company D	reference	reference	reference	reference	reference
Cross-functionality=0	-.403*	-.376*	-.485**	-.377*	-.405*
Cross-functionality=1	reference	reference	reference	reference	reference
ZCompany experience	-.106	-.059	-.071	-.045	.006
ZAnalytical processing		.232**		.175	.285**
ZIntuitive processing			.173*	.123	.035
ZExploration				-.085	-.124
ZAnalytical processing *ZExploration				-.090	
ZIntuitive processing*ZExploration					.242***
R Squared / Adjusted R Squared	.177 / .131	.222 / .169	.204 / .149	.246 / .166	.302 / .228

*p<0.1 **p<0.05 ***p<0.01

Figure 1: Effects of intuitive processing on overall project performance at different levels of exploration



DISCUSSION AND CONCLUSION

In this section, we first present the main implications of our findings. We rely on our findings to discuss the relevance of cognitive styles in NPD teams, point to the main limitations of our study and suggest interesting avenues for future research.

Many scholars (e.g. Gupta et al., 1987; Olson et al., 2001) have emphasized the benefits of cross-functional integration structures in product development projects. In line with their research, our data confirm the positive relationship between NPD team composition of various functional backgrounds and project performance. However, the results of our analyses also point at the relevance of psychological factors that have received less attention in the NPD literature. In particular, our data suggest that team cognitive styles have significant predictive value in explaining project performance. Our analyses of the impact of analytical and intuitive thinking styles on performance thus indicate that organizations might benefit from configuring teams not only based on functional backgrounds, but also based on thinking styles of team members.

These findings are relevant to management of NPD as we found evidence that the effectiveness of thinking styles in teams is different among different kinds of innovation setting. This implies that teams can be configured in terms of thinking styles for optimal performance of different types of projects. We observed that high levels of intuitive processing in NPD teams have significant positive impact on overall performance, whereas this thinking style has a significant negative impact on project performance in less explorative settings. At the same time, we observed that team analytical processing has a positive impact on project performance, independent of the explorative degree of the project activities.

Olson (1985) proposed that analytical processing would be especially effective in the implementation phase of a project. Our data show that analytical processing has a positive effect on project performance in exploitative, less explorative projects where relative focus lies on the implementation of existing knowledge. Previous research has indicated that individuals that heavily process information in an analytical way do not prefer working in environments that are unstructured and ambiguous (Armstrong et al., 2011; Kirton; 1976; Cools et al., 2009). Also, teams with strong analytical processing have been found to perform worse in these settings compared to teams with lower analytical processing (Armstrong and Priola, 2001). Therefore we expected a negative relationship between team analytical processing and project performance in explorative settings. However, our results indicate that team analytical processing is positively related to performance, both in exploitative and explorative projects. This might be explained by the NPD setting of our study, where all projects typically include solving technological and mathematical problems which require analytical processing (Denes-Raj and Epstein, 1994). Strong analytical processing in NPD projects might therefore also have a positive effect on performance in more explorative settings.

At the same time, our results indicate that the effectiveness of NPD teams seems to be contingent on the fit between intuitive thinking style and the task of the team. This is in line with findings by scholars who emphasized that a match between job demands and thinking style is expected to yield positive outcome (Fuller and Kaplan, 2004; Sadler-Smith and Badger, 1998). Our findings also confirm the points earlier made by Burns and Stalker (1994), who argued that different thinking styles might be required to optimize overall performance when interacting in organic and mechanistic work environments (Burns and Stalker, 1994).

Our findings suggest that intuitive processing has a negative impact on project performance in less explorative projects. In these settings, project goals and relationships and linkages between product components and core concepts are relatively clear. Here intuitive processing and associated divergent thinking might only slow down project results. Previous research has already pointed at the limitations of intuitive processing. In numerous studies that have examined judgmental processes, people relying on intuitive thinking ignored basic statistical concepts (Fiske and Taylor, 1991; Kahneman et al., 1982; Nisbett et al., 1983). This may explain the negative effects of intuitive processing that our data suggest.

At the same time, though, intuitive thinking seems to be complementary to analytical thinking in the uncertain settings of more explorative projects where relationships between a new product's components and core concepts become more complex. This is in line with Olson (1985) who proposed that intuitive thinking would be more effective for idea generation, which is relatively important in more explorative projects. In these settings, optimal project performance seems to be achieved when both levels of analytical processing and intuitive processing are high.

Radical, highly explorative NPD projects include drawing new relationships between new product components and core concepts. The unconscious, intuitive mode of processing information seems to be of vital importance in making such associations. The human ability to save highly complex relationships in its working memory and process them in a rational and conscious manner is very limited (Van de Ven, 1996). Multiple empirical studies have demonstrated that most individuals lack the capability and inclination to deal with this complexity (Tversky and Kahneman; 1974; Johnson, 1983). Most people have short spans of attention and can retain raw data in short-term memory for only a few seconds (Van de Ven, 1996). In exploitative settings, where complexity is limited, processing information in the analytical mode seems to be effective, but in more complex and explorative settings, working memory is not sufficient. Then analytical processing of working memory data has to be complemented with intuitive processing by linking it to pre-existing schemas and world views that an individual has stored in long-term memory (Simon, 1947; Evans, 2008).

Managerial implications

Our study has practical implications for managers of NPD projects. Our results have demonstrated that including multiple functional backgrounds in a team has a positive effect on project performance. However, our data also show significant effects of composing NPD teams in terms of thinking styles. In organizations where potential team members share the same functional expertise, project managers might consider selecting team members based on their information processing style, for instance by using the "need for cognition" and "faith in intuition scales" developed by Pacini and Epstein (1999). Based on our findings and insights, we argue that for optimal overall project performance, managers should compose NPD teams with mostly analytical thinkers for their incremental, less explorative projects, and compose teams with high-level intuitive and high-level analytical thinking for more radical, explorative NPD projects.

Limitations and future research

We see several limitations of our study that provide interesting avenues for further research on cognitive styles in NPD teams. From a methodological perspective, it has to be noted that the findings are based on subjective perceptions of project performance. Using more objective data might prove beneficial. Moreover, inherent to survey-based research, the study is cross-sectional. Project performance was measured only at one point in time. This approach thereby neglects potential dynamic effects of cognitive styles on project performance. To accommodate this effect appropriately would require a longitudinal data set.

Although we were able to examine the degree to which thinking styles were present in NPD teams, we have not paid attention to their effect on performance throughout the stages of a project. Previous research, however, suggests that the effects of thinking styles may differ depending on the stage in the NPD process. Olson (1985), for instance, proposed that individuals with a more intuitive cognitive style would be more effective in the initiation phase were the focus is on idea generation, whereas those with a more analytical style would be better in the implementation phase where ideas come into practice. Also, the effects of cognitive style may be dependent on the functional background of team members. It would therefore be relevant for future research to provide more fine-grained insights into the implications of thinking styles of team members with different functional backgrounds in different phases of the project.

It also needs to be stressed that we only examined overall project performance. However, project performance is a multi-dimensional construct. For a product development team charged with designing a specific part of a larger product, several properties may be important, such as including functionality, manufacturability and dimensional integrity (Hoegl et al., 2004). As analytical and intuitive processing may have different effects on these different dimensions of performance (Miron-Spektor et al., 2011), we suggest that future studies on thinking styles in NPD teams distinguish between more dimensions of project performance.

Despite these limitations, this study seems to have provided valuable insights in the implications of NPD team composition of cognitive styles for project performance. We hope that these findings will help project managers in optimizing their teams and that the suggestions provided herein for future research might stimulate academic research in further examining the implications of different thinking styles in new product development.

4

STRUCTURAL AMBIDEXTERITY IN NPD PROCESSES: A FIRM-LEVEL ASSESSMENT OF THE IMPACT OF DIFFERENTIATED INTEGRATION STRUCTURES ON INNOVATION PERFORMANCE[2]

INTRODUCTION

New product development (NPD) is seen as crucial for the long-term survival and growth of the firm (Baumol, 2002; Schumpeter, 1939). During the past decades, scholars have therefore increasingly studied the NPD process within firms (for an overview of this research, see Damanpour, 1991; Brown and Eisenhardt, 1995; Ernst, 2002). In these studies, the structural design of the NPD process has been recognized as one of the critical success factors to arrive at successful innovation (Cooper, 2003). In particular, the implementation of structural mechanisms such as cross-functional integration structures (Griffin, 1997; Pittiglio et al., 1995; Song et al., 1997), stage-gate processes (Cooper, 1996; Cooper et al., 2004), and formalized NPD procedures (Kerssens-van Drongelen and De Weerd-Nederhof, 1999; Lilly and Porter, 2003) have been found to positively influence the innovation performance of firms.

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[2] This chapter is based on previous papers:

De Visser, M., de Weerd-Nederhof, P., Faems, D., Song, M., van Looy, B., Visscher, K., 2008. Ambidexterity in NPD processes: an exploration of performance effects of - differentiated - organizational practices. Presented at the R&D Management conference, Ottawa, Canada, June 17-20.

De Visser, M., de Weerd-Nederhof, P., Faems, D., Song, M., Van Looy, B., Visscher, K., 2009. Structural ambidexterity in NPD processes: the impact of differentiated integration structures on innovation performance. In Best Paper Proceedings of the Academy of Management Conference, Chicago, USA, August 7-11.

De Visser, M., De Weerd-Nederhof, P., Faems, D., Song, M., Van Looy, Visscher, K., 2010. Structural ambidexterity in NPD processes: The impact of - differentiated - structures on firm-level innovation performance. Technovation, 30, 5-6, 291-299.

At the same time, it is increasingly recognized that the NPD process is a multidimensional phenomenon, encompassing development processes that focus on the improvement of existing products (incremental NPD processes) as well as processes that focus on the generation of new products (radical NPD processes). Moreover, several scholars (Olson et al., 1995; Olson et al., 2001; Song and Xie, 2000) have provided evidence that, within a particular NPD project, the product innovativeness moderates the relationship between the effectiveness of the integration structure (i.e. formal versus cross-functional integration structure) and the performance of the NPD project. However, these studies have solely focused on the project level (Sánchez and Pérez, 2003). As a result, we do not know whether firms tend to apply different kinds of integration structures for different kinds of NPD processes and how the application of particular integration structures in particular NPD processes influences firm-level innovation performance. In this paper, we therefore conduct a firm-level assessment of the impact of different kinds of integration structures (i.e. functional versus cross-functional) in different kinds of NPD processes (i.e. incremental versus radical) on different kinds of firm innovation performance (i.e. derivative versus breakthrough innovation performance).

Based on a survey study of 155 US firms, we observe that most firms apply similar integration structures for their incremental and radical NPD processes. At the same time, though, we find strong evidence that 1) firms that apply a cross-functional integration structure for the radical NPD process perform significantly better in terms of breakthrough innovation performance than firms that apply a functional integration structure for the radical NPD process and, 2) firms that apply a functional integration structure for the incremental NPD process perform significantly better in terms of derivative innovation performance than firms that apply a cross-functional integration structure for the incremental NPD process. In other words, our findings point to the relevance of adopting structural ambidexterity (Gibson and Birkinshaw 2004; O'Reilly and Tushman, 2004) where firms make an explicit distinction between incremental and radical NPD processes and organize them in a different way. The remainder of this paper consists of 4 sections. First, we situate our study in the existing NPD literature. Second, we discuss our methodology. Subsequently, we present our main result. Finally, we point to the main theoretical and managerial implications of our findings, discuss the main limitations of our study and suggest interesting avenues for future research.

THEORETICAL BACKGROUND AND HYPOTHESES

A project-level assessment of the integration-performance relationship

Numerous scholars (e.g. Cormican and O'Sullivan, 2004; Griffin, 1997, Griffin and Hauser, 1992; Gupta et al., 1986; Pinto and Pinto, 1990) have examined the structure of the NPD process and how it influences NPD performance. These studies emphasize that firms can choose between different kinds of integration structures for the NPD process. On the one hand, firms can choose for a cross-functional integration structure, where specialists of different departments (R&D, manufacturing and marketing) are brought together within a single team structure for a particular NPD project (Griffin, 1997). The antithesis of a cross-functional integration approach to NPD is the functional approach, where work is done by various specialized departments independently (Song et al., 1998).

In the NPD literature (e.g. Eisenhardt and Tabrizi, 1995; Ernst, 2002; Garcia et al., 2008; Griffin, 1997; Lee and Chen, 2007; Imai et al., 1985; Clark and Fujimoto, 1991), the advantages of cross-functional integration structures for NPD projects have been emphasized. Cross-functional project teams foster interdepartmental communication and co-operation which in turn facilitates coordination (Ernst, 2002). In addition, the presence of an NPD team, which is composed of members with various functional specializations, facilitates the access to a diverse pool of information, which increases the probability of successful innovation (Balbontin et al., 1999). Such cross-functional structure also allows engaging in overlapping development stages, which in-turn speeds up the development process (Brown and Eisenhardt, 1995).

Adopting a contingency perspective, some scholars (Moenaert et al., 1995; Olson et al., 1995; Song et al., 1998; Song and Xie, 2000), however, have argued that the relationship between cross-functional integration and innovation performance is more complex. In particular, they provide evidence that certain contingencies may moderate the relationship between the effectiveness of cross-functional integration structures and the outcomes of NPD projects. The degree of project innovativeness has been recognized as an important contingency in this respect (Olson et al., 1995; Song and Xie, 2000). Within NPD processes, the degree of innovativeness can vary between incremental and radical (Dewar and Dutton, 1985; Tushman and Anderson, 1986). The objective of incremental NPD processes is to improve existing products through conducting exploitative activities such as optimization, standardization and refinement. Within radical NPD processes, the objective is to generate really new products through conducting explorative activities such as fundamental research, experimenting and prototyping (Tushman and Smith, 2002).

Relying on resource dependence theory, scholars (e.g. Gupta et al., 1986; Olson et al., 1995; Olson et al., 2001; Ruekert and Walker, 1987) have argued that product innovativeness might influence the need for cross-functional integration structures in NPD projects. In particular, it is emphasized that radical innovation projects are associated with high levels of external and internal uncertainty, triggering substantial task interdependence between the involved project members. To address such increased interdependence levels, more participative coordination structures such as cross-functional teams become necessary. In contrast, incremental innovation projects typically are characterized by relatively low levels of uncertainty. In such circumstances, task interdependence levels are likely to be relatively low, reducing the need for participative coordination structures.

Adopting insights from information processing theory, other scholars have come to similar conclusions. They argued that, within radical innovation projects, the need to bring together organizational members with diverse backgrounds is relatively high. Schön (1963), for instance, argued that novel solutions and insights ask for problem-defining and problem-solving interaction sequences, whereby multiple opinions and viewpoints become integrated into a new synthesis or artifact. Similarly, Pelz and Andrews (1966) came to the conclusion that differences in approaches between individuals may provide the intellectual jostling or 'dither' which is needed for really creative work. In addition, scholars have pointed to cross-functional integration structures as an effective coordination mechanism to bring together members of diverse backgrounds. Allen (2001) and Hargadon (2003), for instance, emphasize that, when domain specialists are integrated in a cross-functional team, these specialists can contribute to connecting previously unrelated knowledge sets, stimulating breakthrough innovation.

At the same time, though, indications are present that, because of such increased diversity, cross-functional structures might be less beneficial for NPD projects of a more incremental nature. Bringing together members of diverse backgrounds also leads to conflicting expectations and an excess of opinions from different individuals (Song et al., 1998). This might lead to disruption of existing work routines and difficult decision making, which in-turn hampers the ability for continuous optimization and refinement of existing products and technologies (Song and Xie, 2000).

On the level of individual NPD projects, first empirical evidence has been provided that supports the moderating impact of product innovativeness on the relationship between the effectiveness of cross-functional integration structures and project performance. Examining 45 NPD projects, Olson et al. (1995) provided evidence that product innovativeness moderates the relationship between the effectiveness of coordination structures and the project success. In particular, they observed that the better the fit between the newness of the product concept and the participatory nature of the integration structure used the better the outcomes of the development process in terms of 1) objective measures of product and team performance, 2) the attitudes of team members toward the process, and 3) the efficiency and timeliness of the new product development process. More recently, other scholars have provided more fine-grained assessments of the moderating impact of product innovativeness on the relationship between integration structures and the performance of single NPD projects.

Based on data from 788 Japanese and 612 US NPD projects, Song and Xie (2000) found that product innovativeness significantly moderates the integration-performance relationship in Japanese firms but not in US firms. Relying on fine-grained data from 34 NPD processes, Olson et al. (2001) observed that 1) late stage cooperation between marketing and operations, and R&D and operations is a key determinant of project performance for innovative products but not for non-innovative products, and 2) early stage cooperation between marketing and operations is associated with superior performance for low innovation projects but is also associated with poor performance for highly innovative projects.

Toward a firm-level assessment of the integration-performance relationship

Although previous studies have provided valuable insights into how product innovativeness moderates the integration-performance relationship at the individual project level, a firm-level assessment of the impact of different integration structures on innovation performance is lacking. We therefore do not know whether single firms tend to use different kinds of integration structures for different kinds of NPD processes or rather prefer to apply a standardized integration regime across different kinds of NPD processes. In the NPD literature, several scholars (e.g. Gibson and Birkinshaw, 2004; Jansen et al., 2008; Raisch and Birkinshaw, 2008; O'Reilly and Tushman, 2004; Tushman and Anderson, 1986; Tushman and O'Reilly, 1996; Van Looy et al., 2005) seem to suggest the relevance of adopting different structures for different kinds of innovation activities. In particular, these scholars argued that, if a company wants to excel in both improving existing products (i.e. derivative innovation performance) and generating new products (i.e. breakthrough innovation performance), it should apply structural ambidexterity, meaning that it explicitly separates incremental and radical NPD processes and organize them in a different way. Based on these arguments, we hypothesize that:

Hypothesis 1

Firms apply different integration structures (i.e. functional versus cross-functional) for different kinds of NPD processes (i.e. incremental versus radical NPD processes)

In addition, because of the previous focus on single projects, we lack empirical data on how the application of specific integration structures in specific kinds of NPD processes influences the ability of firms to generate sales from product improvements (i.e. derivative innovation performance) and from radically new products (i.e. breakthrough innovation performance). We therefore assess the following hypotheses:

Hypothesis 2

Firms that apply a functional integration structure for their incremental NPD process display significantly higher levels of derivative innovation performance than firms that apply a cross-functional integration structure for their incremental NPD process.

Hypothesis 3

Firms that apply a cross-functional integration structure for their radical NPD process display significantly higher levels of breakthrough innovation performance than firms that apply a functional integration structure for their radical NPD process.

METHODOLODY

Data and sample

Our sample population consisted of 500 randomly selected non-service US firms listed in the World Business Directory. We sent a pre-survey letter to all 500 firms requesting pre-approval of participation. A total of 186 firms agreed to participate and provided a contact person, while 36 companies declined to participate; 42 letters were returned due to invalid contact person or addresses, and 236 companies did not respond.

In administering the final survey, we followed Dillman's (1978) total design method for survey research. The first mailing packet included a personalized letter, the survey, a priority postage-paid envelope with an individually typed return-address label, and a list of research reports available to participants. The package was sent by priority mail to 422 firms (186 firms agreeing to participate and 236 non-responding firms from the pre-survey). We asked the contact person (president, division manager, strategic business manager, new business program manager, or R&D director) to distribute the questionnaire to a manager who has been involved in developing new products in their organization or who has knowledge of overall new product programs in their organization.

To increase the response rate, we sent four follow-up mailings to the companies. One week after the mailing, we sent a follow-up letter. Two weeks after the first follow-up, we sent a second package with the same content as the first package to all non-responding companies. After two additional follow-up letters, we received usable questionnaires from 155 firms, representing a response rate of 38% (155/422).

The industries represented in the final samples are: Chemicals and Related Products; Electronic and Electrical Equipment; Pharmaceutical, Drugs and Medicines; Industrial Machinery and Equipment; Telecommunications Equipment; Semiconductors & Computer Related Products; and Instruments and Related Products. The annual sales of respondent firms ranged from $500,000 to $461 million and the total number of employees in the business unit ranged from 11 people to 1017 people.

Measures

Dependent variables: indicators of innovation performance

Following Faems et al. (2005) we use the composition of turnover in 2005 in order to make a distinction between derivative and breakthrough innovation performance. The proportion of turnover in 2005 attributed to breakthrough new products that were introduced during the last three years is regarded as an indication of breakthrough innovation performance. Likewise, the percentage of turnover in 2005 attributed to improved products that were introduced during the last three years is seen as an indicator of derivative innovation performance. In line with the study of Faems et al. (2005), our analyses include the logarithm of 1 + the proportion of turnover attributed to 1) breakthrough new products and 2) improved products in order to obtain a normal distribution.

Independent variable: integration structure.

The purpose of this paper is to examine to what extent the integration structure of the incremental and radical NPD process influences the innovation performance of firms. Based on previous research on the structuring of NPD processes (i.e. Griffin, 1997; Griffin and Page, 1996) we made a distinction between two different ways to structure the NPD process: 1) functional integration structure; and 2) cross-functional integration structure. In addition, we made an explicit distinction between the incremental and radical NPD process. In particular, we first asked respondents to indicate which kind of structure they applied for organizing the incremental development processes. Subsequently, we asked respondents to indicate the applied structure for organizing the radical development processes. Based on these questions, we constructed two dummy variables, representing the applied integration structure within 1) the incremental NPD processes and 2) the radical NPD processes. If firms applied a functional integration structure for their incremental/radical NPD process, they received a value of 0. If firms applied a cross-functional integration structure for their incremental/radical NPD process, they received a value of 1.

Control variables

Previous studies (e.g. Cooper, 1996, 1999, 2001; Griffin, 1997) have provided evidence that firms can differ in terms of the extent to which their NPD strategy is professionalized. Moreover, these studies indicate that the professionalization of the NPD strategy might impact a firm's innovation performance. For instance, Cooper et al. (2004) identified a clear and well-communicated NPD strategy as one of the most important performance drivers for new product success. In this study, we therefore measured the professionalization of a firm's NPD strategy. In particular, we asked respondents to indicate on a 7-point Likert scale to what extent they applied the following 5 strategy-related NPD best practices as identified by Cooper et al. (2004); 1) the role of NPD in achieving business goals is clearly articulated 2) there is a formally stated NPD strategy 3) we have clearly defined goals for all of our individual new products 4) systematic portfolio management is in place 5) the project portfolios are aligned with the business strategy. Reliability analysis indicated that these 5 items represented one single construct (Cronbach's alpha 0.72). We therefore built the construct 'Professionalization of NPD strategy' by calculating the mean of the scores on these 5 items.

In order to control for industry effects, we made a distinction between sectors based on the Standard Industrial Classification. Table I displays the frequencies and percentages of the sectors in our data collection.

Table I: Sector frequencies and percentages

Sector	*Frequency*	*Percent*
Automotive	20	12.9
Chemical	13	8.4
Electronics	7	4.5
Instruments	12	7.7
Leather	16	10.3
Metal	48	31.0
Stone	18	11.6
Textile	17	11.0
Other	4	2.6

In the NPD literature, considerable attention is devoted to the relationship between firm size and innovation performance (e.g. Schumpeter, 1939; Freeman, 1994). Therefore, we included the variable "firm size", measured by the natural logarithm of the total number of employees.

RESULTS

In this section, we discuss the results of our analyses. As one dependent variable (breakthrough innovation performance) contained a substantial amount of left-censored values, we relied on Tobit regressions (McDonald and Moffit, 1980) to analyze hypotheses 2 and 3.

Descriptive statistics

Table II and Table III provide an overview of the frequencies on integration structure variables for both the incremental and radical NPD processes. These frequency tables clearly indicate that for both the incremental and radical NPD processes, cross-functional integration structures are much more common than functional integration structures.

Table II: Incremental NPD process type (frequencies and percentages)

Incremental NPD process	*Frequency*	*Percent*
Functional integration structure	20	12.9
Cross-functional integration structure	135	87.1
Total	155	100

Table III: Radical NPD process type (frequencies and percentages)

Radical NPD process	*Frequency*	*Percent*
functional integration structure	40	25.8
cross-functional integration structure	115	74.2
Total	155	

An overview of the descriptive statistics on the continuous variables can be found in table IV. The means for the variables breakthrough innovation performance and incremental innovation performance are respectively 3.07 and 3.39. Taking into account that this study uses logarithmic transformation for these variables, the implication is that, on average, the respondents attributed 25.91% of their turnover to breakthrough products and 31.69% to improved products. As we see in table IV, the control variable Professionalization of NPD significantly correlates with the dependent variables. In the next two paragraphs we will further elaborate on these relationships.

Table IV: Descriptive statistics and correlations

Variable	*Mean*	*Standard deviation*	*Derivative innovation performance*	*Break-through innovation performance*	*Log (Company size)*	*Professio-nalization NPD strategy*
Incremental innovation performance	3.3889	.46088	1			
Breakthrough innovation performance	3.0660	.87942	-.648**	1		
Log(Company size)	5.2658	1.33460	-.023	-.001	1	
Professionalization NPD strategy	4.6710	.98554	-.269**	.248**	.079	1

* correlation is significant at the 0.05 level (two-tailed)
** correlation is significant at the 0.01 level (two-tailed)

The application of different integration structures for different NPD processes

Table V shows which kind of combinations of integration structures firms apply for their incremental and radical NPD processes. This table clearly illustrates that the majority of the responding firms apply a standardized approach for structuring different kinds of NPD processes. In particular, 67.1% of the firms rely on cross-functional integration structures for both their incremental and radical NPD processes. At the same time, we observe that only 27.1% of the firms under study deploy a differentiated integration structure for their incremental and radical NPD processes. Our first hypothesis is therefore not supported by our data.

Table V: Combinations of integration structures

		Radical NPD Process	
		Functional integration structure	*Cross-functional integration structure*
Incremental NPD Process	*Functional integration structure*	9 (5.8 %)	11 (7.1 %)
	Cross-functional integration structure	31 (20 %)	104 (67.1 %)

Impact of integration structure on derivative innovation performance

Table VI summarizes the findings of the Tobit analysis whereby derivative innovation performance acts as the dependent variable.

Table VI: Results of Tobit analysis – dependent variable: Derivative innovation performance (N = 155; Pseudo R^2= 0.13)

Variable	Estimate	St Error	Chi-Square	Pr > ChiSq
Intercept	4.2963	0.2182	387.55	<.0001
Industry: (Reference category : Automotive)				
- Other	-0.1124	0.2348	0.23	0.6323
- Chemical	-0.1297	0.1537	0.71	0.3989
- Electronics	-0.2905	0.1896	2.35	0.1255
- Instruments	-0.2230	0.1572	2.01	0.1560
- Leather	-0.1584	0.1441	1.21	0.2717
- Metal	-0.0949	0.1141	0.69	0.4057
- Stone	-0.0928	0.1410	0.43	0.5102
- Textile	-0.0332	0.1463	0.05	0.8206
Cross-functional integration structure for the incremental NPD process	**-0.2624**	0.1077	5.94	**0.0148**
Log (Company size)	-0.0000	0.0001	0.06	0.8042
Professionalization NPD Strategy	**-0.1205**	0.0360	11.19	**0.0008**

In line with hypothesis 2, we find that organizations that rely on a cross-functional integration structure for their incremental NPD process perform significantly lower on derivative innovation performance than organizations that apply a functional integration structure for their incremental NPD. It can also be observed that professionalization of NPD has a negative impact on derivative innovation performance. Finally, we did not observe significant industry or size effects for derivative innovation performance.

Impact of integration structure on breakthrough innovation performance

Table VII summarizes the findings of the Tobit analysis whereby breakthrough innovation performance acts as the dependent variable.

Table VII: Results of Tobit analysis – dependent variable: Breakthrough innovation performance (N = 155; Pseudo R^2= 0.17)

Variable	*Estimate*	*St Error*	*Chi-Square*	*Pr > ChiSq*
Intercept	1.6120	0.3863	17.41	<.0001
Industry: (Reference category: Automotive)				
- Other	-0.8460	0.4601	3.38	0.0660
- Chemical	0.1271	0.2983	0.18	0.6700
- Electronics	0.4101	0.3688	1.24	0.2663
- Instruments	0.4858	0.3030	2.57	0.1088
- Leather	0.3882	0.2783	1.95	0.1630
- Metal	0.0902	0.2212	0.17	0.6833
- Stone	0.0898	0.2714	0.11	0.7406
- Textile	-0.0259	0.2741	0.01	0.9247
Cross-functional integration structure for radical NPD Process	**0.5245**	0.1562	11.28	**0.0008**
Log (Company size)	-0.0003	0.0003	1.04	0.3079
Professionalization NPD Strategy	**0.2196**	0.0703	9.77	**0.0018**

In line with hypothesis 3, we observe that companies that rely on a cross-functional integration structure to organize their radical NPD process outperform companies that do not apply a cross-functional approach for structuring radical NPD in terms of breakthrough innovation performance. We also observe a significant positive relationship between professionalization of NPD and breakthrough innovation performance. Again, we did not observe significant industry or size effects on breakthrough innovation performance.

DISCUSSION AND CONCLUSION

In this section, we first present the main implications of our findings. In particular, we rely on our findings to discuss the relevance of structural ambidexterity in NPD processes. In addition, we discuss the impact of professionalization of NPD strategy on different kinds of innovation performance. Subsequently, we point to the main limitations of our study and suggest interesting avenues for future research.

Relevance of structural ambidexterity in NPD processes

Relying on organizational learning theory (e.g. March, 1991; Levinthal and March, 1993), several scholars (e.g. Gibson and Birkinshaw, 2004; Jansen et al., 2005; Raisch and Birkinshaw, 2008; Tushman and O'Reilly, 1996; Van Looy et al., 2005) have argued that, if a company wants to excel in both improving existing products (i.e. derivative innovation performance) and generating new products (i.e. breakthrough innovation performance), it should apply structural ambidexterity, meaning that organizations explicitly separate incremental and radical NPD processes and organize them in a different way (Gibson and Birkinshaw, 2004). Such structural ambidexterity ensures that each NPD process is configured according to its specific task requirements (Raisch and Birkinshaw, 2008). Although the structural ambidexterity argument has become increasingly popular in the academic literature, our data seem to suggest that the popularity of this strategy among practitioners is rather low. Making an explicit distinction between the incremental and radical NPD process in our survey, we were able to examine whether firms tend to apply a different integration structure for different kinds of NPD processes. However, our data show that the majority of our firms preferred a standardized approach concerning their integration structure. In particular, 67.1 % of the respondents indicated that they used a cross-functional integration structure for both their incremental and radical NPD processes.

At the same time, though, our analyses of the impact of different integration structures (i.e. functional versus cross-functional) in different kinds of NPD processes (i.e. incremental versus radical) on different kinds of innovation performance (i.e. derivative versus breakthrough) indicate that organizations might indeed benefit from adopting structural ambidexterity. In line with previous research that focused on the relationship between integration structures and performance on the project level (i.e. Olson et al., 1995; Song and Xie, 2000; Olson et al., 2001), we found evidence that the effectiveness of integration is different among different kinds of NPD processes. In particular, we observed that, while adopting a cross-functional integration structure - instead of a functional integration structure - in radical NPD processes has a significant positive impact on breakthrough innovation performance, the implementation of a cross-functional integration structure in incremental NPD processes has a significant negative impact on incremental innovation performance. Based on these findings, we argue that firms that manage to apply a cross-functional integration structure for their radical NPD processes and a functional integration structure for their incremental NPD processes will be the most successful in terms of balancing derivative and breakthrough innovation performance.

Professionalization of NPD and its impact on innovation performance.

The implementation of a professional NPD strategy, characterized by strategically aligned NPD activities and by a systematic portfolio management system, has been identified as an important driver of innovation performance (Cooper, 1996, 1999, 2001; Cooper et al., 2004; Griffin, 1997). While these studies approached innovation performance in quite general terms, we have made an explicit distinction between derivative and breakthrough innovation performance. In this way, we were able to show that changes in the professionalization of a firm's NPD strategy trigger a trade-off between breakthrough and derivative innovation performance. In particular, our findings indicate that investing in the professionalization of the NPD strategy enhances the breakthrough innovation performance of firms, but, at the same time, reduces their derivative innovation performance. These findings suggest that professionalization of the NPD strategy does not influence the innovation performance in absolute terms, but rather changes the balance between different kinds of innovation performance (i.e. derivative versus breakthrough innovation performance).

Limitations and future research

A first limitation of this study is that we focused on one particular country (i.e. US). However, previous project-level research (i.e. Song and Xie, 2000) already indicated that the relationship between integration structures, product innovativeness and project performance is influenced by the national culture in which the firm is embedded. In a similar vein, it can be expected that national differences might influence the effectiveness of integration structures on firm-level innovation performance. We therefore encourage researchers to conduct an international comparison of the impact of integration structures in different kinds of NPD processes on different kinds of innovation performance.

In this study, we made a distinction between functional and cross-functional integration structures. However, previous research on individual NPD projects (e.g. Olson et al., 2001; Song et al., 1998; Souder, 1988) indicates that firms can implement different kinds of cross-functional integration structures. In particular, they have made a distinction between 1) cross-functional team structures in which both R&D, manufacturing, and marketing people are present and 2) cross-functional team structures in which only two departments are represented.

Moreover, these studies provide first indications that the particular composition of cross-functional integration teams might influence project performance. We therefore point to the need for future firm-level research on the relationship between integration structures and innovation performance in which more fine-grained measures for the applied integration structure are used.

It also needs to be stressed that we only examined the difference between incremental and radical development processes in terms of their applied integration structure. However, incremental and radical development processes can also differ on other dimensions. For instance, it might be interesting to assess whether critical roles such as idea generators, project champions and gatekeepers (Roberts and Fusfeld, 1982) are present in incremental and radical development processes and how the presence of these roles in different kinds of NPD processes influences different kinds of innovation outcomes.

Although we were able to examine which kind of integration structure firms applied for their incremental and radical NPD processes, we do not know why firms chose a particular integration structure. This latter question seems to be very relevant as we observed that firms tend to prefer a standardized approach (i.e. cross-functional integration structure for both incremental and radical NPD processes) despite the fact that we found clear indications of the benefits of adopting a more diversified approach (i.e. functional structure for the incremental NPD process and cross-functional structure for the radical NPD process). We therefore emphasize the need for future case study research that provides fine-grained insights in why companies make particular integration structure choices for their NPD activities.

Despite these limitations, this paper has contributed to a firm-level perspective on the management of NPD processes, acknowledging the relevance of structural ambidexterity in organizing NPD. We hope that NPD managers will consider our practical suggestions and that our results may motivate researchers to continue exploring the NPD process in a wide variety of organizational settings.

5

GONE WITH THE WIND?
A LONGITUDINAL STUDY OF EXPLORATIVE INNOVATION IN A GROWING WIND TURBINE BLADE TECHNOLOGY COMPANY[3]

INTRODUCTION

Many scholars have stressed the need for balancing exploitation with sufficient levels of exploration (e.g. Ancona et al., 2001; Benner and Tushman, 2002; Dougherty, 1992; Levinthal and March, 1993; March, 1991, 2006). Organizations that have a one-sided focus on exploitation by allocating resources to refinement of existing technologies rather than to developing new skills and capabilities, achieve immediate success at the future risk of becoming obsolete (Holmqvist, 2004; Leonard-Barton, 1992).

For growing companies, maintaining sufficient levels of exploration is challenging. Investing in exploration competes with investing in exploitation, of which the outcomes are more secure and less remote in time (March, 1991). When organizations grow, they tend to skew to efficiency and develop core capabilities for exploitation of current success (Sorensen and Stuart, 2000). These establishing mindsets, expertise and routines are different from those required for exploration (Gupta et al., 2006). The more they become embedded, the more challenging it becomes to transition the organization toward revival of exploration.

Previous studies have emphasized the complexity of balancing exploration and exploitation levels (e.g. Sorensen, 2002; Voss et al., 2008; Benner, 2007) and have provided insights into structural and individual factors that influence them (e.g. Nohria and Gulati, 1996; Burns and Stalker, 1961; Benner and Tushman, 2003; Tushman and O'Reilly, 1996; Scott and Bruce, 1994). Whereas the individualist perspective seeks to explain innovative behavior in terms of

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[3] This chapter is based on a previous paper:

De Visser, M., Faems, D., Visscher, K., De Weerd-Nederhof, P.C., 2010. Toward a dynamic perspective on explorative and exploitative innovation activities: a longitudinal study in the wind blade industry. In proceedings of the International Product Development Management Conference, Murcia, Spain, June 13-15.

characteristics and actions of organizational participants, the structural perspective assumes that innovation is most strongly influenced by organizational characteristics such as formalization, slack resources and organizational structure.

Although these studies have provided valuable insights into the factors that influence exploration in organizations, only few have unraveled the process of how these structural and individual factors affect changing exploration levels in growing organizations. Since the time dimension is mostly absent in existing studies (Gibson and Birkinshaw, 2004; Jansen et al., 2005) and only partial relationships are illuminated (Eisenhardt, 2010), it remains unclear how structural and individual antecedents in growing organizations interrelate and how they affect exploration decline and recovery.

The purpose of this paper is to provide in-depth insights into the dynamics of a growing organization's exploration levels and to explain how structural and individual factors impact these over time. In order to do so, we conduct a single case study in a fast growing R&D organization in the wind turbine blade industry. Based on a unique collection of time-accounting data and descriptions of all R&D activities performed within a timeframe of 100 months, we are able to measure the dynamics of exploration levels, visualizing in great detail how a firm goes through transitions from focus on exploration to exploitation and vice versa. Based on a series of interviews with employees of this organization, we demonstrate how structural and individual factors interact and impact this evolution.

Together our findings provide new insights into multi-level interactions among antecedents of exploration, in particular the interactions between slack resources, formalization, tenure and cognitive style. For practitioners, the method we present could serve as a tool to detect exploration trends and evaluate the effectiveness of innovation policy. Our findings also help managers to understand and tackle the challenges involved in the transformation process of growing R&D organizations from decline to recovery of exploration.

THEORETICAL BACKGROUND

Young organizations have a higher tendency to die than old organizations (Stinchcombe, 1965) because of a limited customer base, a lack of specific resources, and the need to learn new roles. In order to develop these, young organizations invest in exploration (Lavie et al., 2010). Once they have become successful, however, they run the risk to over-invest in the exploitation of their early gained success. In maturing and growing organizations, exploitation tends to drive out exploration (Levinthal and March, 1993). This can be explained by the iteratively self-enforcing nature of exploitative activities.

Exploitation often leads to early success, which in turn reinforces further exploitation along the same trajectory. The more immediate returns from exploitation tend to cause organizations to exhibit a myopic bias whereby exploitation is overemphasized at the expense of exploration (Levinthal and March, 1993). Within an organizational unit, exploration and exploitation are mutually exclusive and compete for scarce organizational resources. More resources devoted to exploitation imply fewer resources left over for exploration and vice versa (Gupta et al., 2006). Organizations thus have to decide between short-term productivity and long-term innovation. Compared to returns from exploitation, returns from exploration are less certain, more remote in time, and more distant from the locus of action (March, 1991). Investing in explorative activities therefore involves higher risk investments which challenges organizations to decide whether certain, immediate success should be hedged for potential future success. Many organizations tend to be become risk-averse in making these investment decisions.

Furthermore, maturing organizations become more efficient as they leverage accumulated experience and established ties to vendors and customers (Penrose, 1959). Stakeholders may favor organizations that demonstrate rational action, accountability, and reliable performance (Benner, 2007; Hannan and Freeman, 1984), encouraging further commitment of existing routines, structures, and competencies. These pressures reinforce the tendency to exploit existing capabilities and leverage past experience (Lavie et al., 2010). Also, individuals tend to pursue solutions similar to already-known solutions because bounded rationality limits their ability to search all possible domains of knowledge (Simon, 1979) and biases them toward more salient areas of their own prior experiences (Cyert and March, 1963). Over time, these structures and individual behaviors become deeply embedded in the organization (McNamara and Baden-Fuller, 1999). Once changes in an organization's environment ask for recovery of activities, switching costs may have become high (Kogut and Zander, 1992) because the structures and individuals that have been developed for efficient exploitation, are substantially different from those required for exploration (Gupta et al., 2006). In the past decades, scholars have described various structural and individual antecedents of exploration. For innovation in growing organizations, particularly slack resources, organizational structures, tenure and cognitive styles are relevant factors (Faems et al., 2011; Eisenhardt et al., 2010; Lavie et al., 2010). These will be discussed below.

Slack resources

As companies grow, they often attain access to resources that are in excess of the minimum necessary to produce a certain level of output (Nohria & Gulati, 1996). These slack resources facilitate search, experimentation, and innovation while avoiding some harmful consequences in case of failure (Levinthal and March, 1993; Damanpour, 1992). Besides, they allow employees to take their mind of day-to-day survival and to consider long-term development of the firm (Nohria and Gulati, 1996). Increasing availability of slack resources might thus positively influence the level of an organization's exploration activities. However, the relationship between the slack resources and exploration may be not that straightforward as it seems to be contingent on several factors.

In the face of a major environmental threat, the availability of slack steers an organization toward exploration (Voss et al., 2008). Especially when the survival of the firm depends on the ability to come up with new engines of growth (Lavie et al., 2010), slack is likely to be deployed for new purposes (Bourgeois, 1981). When competitive intensity is mitigated, organizations are more likely to consume slack resources by sustaining current operations (Voss et al., 2008).

The relationship between the availability of slack and exploration might also be dependent on the degree to which it is absorbed. For instance, opposed to financial resources, human resources are absorbed when they are tied up in the organization's current operations. Human resources that are acquired and developed to build existing routines likely possess skills that are most applicable to incumbent product domains. As a result, they might be less readily reallocated to exploration than slack financial resources (Voss et al., 2008).

Organizational structure

Organizations execute their operations via structures that define the distribution of power, resources, and responsibilities across different functions and units. Whereas mechanistic structures support routine operations, functional specialization, standardization, formalization and hierarchy, organic modes of organizing rely on less rigid establishments, allow for more freedom and support flexibility (Burns and Wholey, 1993; Burns and Stalker, 1961). Duncan (1976) suggests that organizations require organic modes for the initiation of innovations, and mechanistic structures to implement and deploy them.

As organizations grow, they tend to become more structured (Sorensen and Stuart, 2000). This can be explained by the contingency theory of innovation developed by Zaltman et al. (1973). According to this theory, the gathering and processing of information, which is crucial at the initiation stage, is facilitated by high complexity, low formalization, and low centralization. During the implementation phase, however, higher levels of formalization and centralization, combined with low complexity are likely to facilitate innovation because role conflict and ambiguity are reduced. Consequently, Zaltman et al. (1973) argue that an organization must be able to shift its structure as it moves through the various stages of innovation. An organic structure seems to be required for the initiation of innovations, whereas implementation may be best supported by a mechanistic structure (Zaltman et al., 1973; Greiner, 1972).

Several authors argue that mechanistic and organic structures are difficult to reconcile within a single firm because of their opposed natures (Lawrence and Lorsch, 1967; Lewis, 2000). For organizations that have implemented rigid mechanistic structures for the exploitation of innovation, it might therefore be challenging to un-structure and regain more organic modes of organizing for the initiation of a new stream of innovations. Recent studies, however, have provided views on how to resolve the tension between both activities by combining mechanistic and organic features in separated or parallel structures (Adler et al., 1999; Jansen et al., 2005; Sheremata, 2000).

The first view that examines how the tension between exploration and exploitation can be resolved emphasizes structural ambidexterity. The conflicting demands between exploration and exploration can be addressed by using spatial differentiation, such as creating organizational spinouts to pursue new opportunities (Christensen and Bower, 1996; Galunic and Eisenhardt, 2001; Gilbert, 2005). Small, decentralized organization units focused on flexible exploration are physically separated from large centralized organizational units focused on efficient exploitation (Benner and Tushman, 2003). These spatially separated units remain isolated, securing the independence of their activities, culture, and cognitive framing (Gilbert, 2006).

In contrast to the spatial separation concept, several studies described an alternative path to combining exploration and exploitation by managing them separately within the same organizational unit. The use of parallel structures allows people to switch back and forth between two or more types of structures, depending on the structure that their specific task requires (Bushe and Shani, 1991; McDonough and Leifer, 1983; Stein and Kanter, 1980; Zand, 1974). An organizational unit's main structure serves exploitative activities and can be used for routine tasks and for maintenance of stability and efficiency. Additional structures, such as cross-functional team structures, balance the primary structure's shortcomings and support non-routine tasks and innovation (Goldstein, 1985). The supplementary structure coexists with the primary task structure to ensure efficiency and flexibility (Adler et al., 1999). Contrary to the spatial separation concept, parallel structures therefore allow competing demands for exploitation and exploration to be addressed within a single business unit (Gibson and Birkinshaw, 2004).

Cognitive style

Beside structural organizational factors that prescribe and guide human behavior, also individual characteristics have an impact on exploration. In the analysis of organizational behavior, individual differences in information processing tendencies have been widely adopted. These encompass a range of cognitively based variables, reflecting in general terms the distinction between analytic and intuitive processing (Chaiken and Trope, 1999).

In R&D task environments, both types of information processing are significantly related to exploration and exploitation (Scott and Bruce, 1992). Individuals that have a tendency toward analytic processing tend to be more compliant, favor a structured approach to problem solving, depend on systematic methods of investigation, recall verbal material most readily and are especially comfortable with ideas requiring step by step analysis (Allinson and Hayes, 1996).

Individuals having a tendency toward intuitive information processing tend to make judgments based on feeling and the adoption of a global perspective. Intuitivists are relatively nonconformist, prefer an open-ended approach to problem solving, rely on random methods of exploration, remember spatial images most easily, and work best with ideas requiring overall assessment (Allinson and Hayes, 1996).

Neither style is considered preferable per se; it is the fit between problem-solving style and a task and work environment that determines individual task performance (Payne et al., 1990). Whereas intuitive thinkers perform better in unstructured, organic organizational modes by which young organizations are often characterized, analytic thinkers favor structured, mechanistic organizational modes (Armstrong and Priola, 2001). In aging and growing organizations that skew toward efficiency and increase formalization, work environments might therefore become less motivating for individuals that tend to prefer an intuitive thinking style (Greiner, 1972).

Tenure

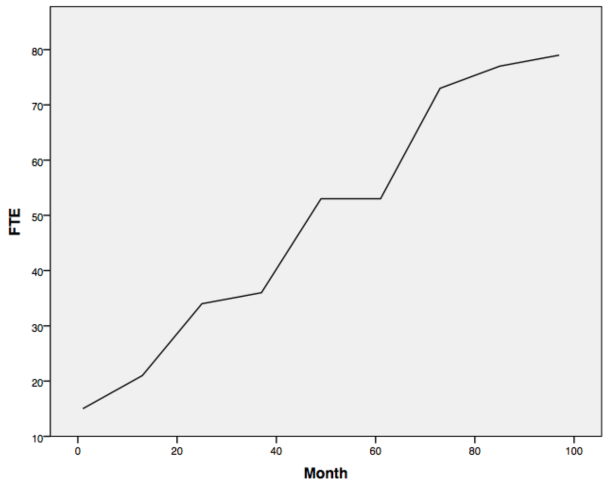
Length of tenure is negatively associated with explorative behavior of individuals in R&D environments (e.g. Pierce and Delbecq, 1977; Scott and Bruce, 1994), which implies that individuals become less explorative as they age and enter later stages of their career. In addition, the cognitive templates that are developed among employees that collaborate for long periods of time have a negative impact on exploration. According to the Not Invented Here syndrome, groups can become increasingly cohesive over time and begin to separate themselves from external sources of technical information and influence by communicating less frequently with professional colleagues outside their teams (Katz, 1982). Rather than striving to enlarge the scope of their information processing activities, long-tenured groups become increasingly complacent about outside events and new technological developments. The extent to which they may be willing or even feel the need to expose themselves to new or alternative ideas and ways of problem solving, lessens with time (Katz, 1982). Similarly, as senior-management teams mature, they get more internally focused and more homogeneous. This homogenizing process is accentuated in high-performing organizations and, in turn, facilitates exploitation while driving out exploration (Hambrick et al., 2005; O'Reilly and Tushman, 2008).

Although these studies have provided valuable insights in the factors that influence exploration, they do not reveal the complexity of this process and illuminate only part of the story (Eisenhardt et al., 2010). It remains unclear how structural and individual antecedents of exploration interact and in which way they influence exploration levels in growing organizations. In particular, the process of how growing organizations manage to recover explorative activity after a phase of intense exploitation has been underinvestigated (Faems et al, 2011). Also more in general, scholars (e.g. Andriopoulos and Lewis, 2009; Groysberg and Lee, 2009; Raisch et al., 2009) have stressed the need to develop a longitudinal perspective on the evolution of exploration in order to provide a better understanding of this process. With this paper we address this need by providing in-depth insights into the dynamics of a growing organization's exploration levels and by explaining how the structural and individual factors influence this process. In order to investigate this process, an accurate method for longitudinal measurement of exploration intensity is required. As objective, replicable methods for exploration measurement are absent in the literature, we developed a new method, which will be introduced in the next section.

METHODOLOGY

Our study was conducted in a wind turbine blade technology company, which was founded in 1999 and acquired by an Asian wind power company in 2001. As can be seen from figure 1, it faced a steady growth of employees since the year of 2003. We were informed in 2009 that this particular company had experienced a decline of innovation and that it had attempted to recover fundamental research activities, which made it the optimal setting to study exploration dynamics in a growing company. Our study consisted of two stages. In the first stage we reconstructed the evolution of exploration and exploitation dynamics in the company in the past 100 months. In the second stage, we investigated the drivers of these dynamics.

Figure 1: full time equivalents (FTE) between 2003 and 2011



Reconstruction of exploration dynamics

A longitudinal perspective on exploration and exploitation levels requires a methodological shift in research on exploration and exploitation (Raisch et al., 2009). Due to the limited reliability of informants' retrospective accounts (e.g. Golden, 1992), surveys are less appropriate for measurement of exploration levels over time. In order to draw causal relationships between structural and individual factors and the impact they have on exploration dynamics, we need a more accurate understanding of exploration levels related to specific points in time. We therefore develop a new method by deploying archival data on all R&D activities performed in the firm. We gained access to the company's network drive containing descriptions of all 391 research and development projects that were realized in a period of 100 months in the years 2003 to 2011. These descriptions were obtained from various standardized documents that were used for project budget requests: activity release notes (ARN), budget release notes (BRN), project request forms (PRF), release note budget (RNB), release note project (RNP) and release note small project (RNSP). Projects that were not focused on development of technology and products (e.g. help desk related activities or activities related to organizational development) were removed from the database, resulting in a total amount of 384 project descriptions. The following example illustrates the way projects were described:

XX403 blade went into serial **production** before the blade was structurally tested and certified. The structural test revealed two weak blade **detail**s that need to be **updat**ed, both in new **production** and in **exist**ing blades. This project addresses the **update** of **exist**ing blades and provides a feasible solution for this. Currently no blade failures on **exist**ing blades (containing the weak **detail**s) have been reported. Further no turbines having these blades have been preventively stopped. Hence consequential costs are **minim**al. This project aims in **keep**ing any damage costs on **exist**ing blades to a **minim**um, by developing an economic **upgrad**e solution to be **execut**ed before any failures on **exist**ing blades can occur (with consequential damage costs). Objectives of this project are: define feasible solution for structural **upgrad**e of **exist**ing XX403 blades; verify solution on critical aspects (such as safety, quality, economics, ergonomics, etc.); achieve commitment from STS for **upgrad**e **execut**ion; **execut**e trials to confirm **upgrad**e solution; handover **upgrad**e solution to STS.

In order to measure the amount of resources the focal company allocated to exploitative and explorative activities over time, we first labeled projects in which explorative activities were dominant as explorative, and projects in which exploitative activities were dominant as exploitative. This was done in a manner similar to the method applied by Uotila et al. (2009), which is based on word-counts of key words. As proposed by Lavie et al. (2010) we related back to March's (1991) original definitions of exploration and exploitation. Perceiving them as opposing activities along a continuum, we used a single variable for capturing exploration–exploitation (e.g. Lavie and Rosenkopf, 2006; Lin et al., 2007; Uotila et al., 2009).

The classification of the projects into explorative and exploitative activities was based on the definition provided by March (1991): "Explorative activities can be characterized by terms such as search, variation, risk-taking, experimentation, play, flexibility and discovery. Exploitative activities can be characterized by aspects such as refinement, choice, production, efficiency, selection, implementation and execution." We searched for synonyms of the nouns and verbs in the thesaurus that is part of the current version of Apple's operating system, which resulted into 75 keywords for exploration and 75 keywords for exploitation. We then stemmed all of these words and calculated their frequencies in the project descriptions. We labeled each project either "explorative" or "exploitative" based on the category with the highest count of the key words. In the examples above, the underlined words are associated with exploration and the words in bold are associated with exploitation. As the amount of word counts in the description of the project in the example is higher in the exploitation category (23) compared to the exploration category (4), this project is labeled exploitative.

Together, the collection of project descriptions contained 4243 counts of our key words of which 2271 in the exploration category and 1972 in the exploitation category. Based on our method, of all 389 projects that were performed in the time frame of 100 months, 200 were labeled explorative and 189 were labeled exploitative.

In order to measure the change of exploration levels over time, we made use of the company's time-accounting system in which all project members had entered the amount of time spent on each project they were involved in. Combining these data with the categorized projects, we could calculate how the total amount of project time had been divided over explorative and exploitative projects in the past 100 months. On the project described before, for instance, 283 hours were spent. The total amount of project time that was spent in this time frame consisted of 209547 explorative and 513838 exploitative working hours.

In order to validate our reconstruction of the way the focal company divided attention over exploration and exploitation, we asked the R&D director and the head Product Market Technology (PMT) to label the 50 projects the organization spent most working hours on as explorative or exploitative, and compared their classification with our results. We chose to have the largest projects checked, because these would have the biggest impact on our reconstruction of exploration and exploitation dynamics and would probably be best remembered by our informants. In 82% of the cases the classification based on our measurements was identical to the classification made by the R&D director and head of PMT, which indicates that project classification based on our word counting method is quite accurate. In addition, we presented our reconstruction of exploration levels to two senior engineers, one junior engineer and one of the co-founders of the company and asked them to judge our measurements. All four informants unanimously agreed on the organization's tendencies toward exploration over time based on our calculations.

Antecedents of exploration dynamics

In the second stage we conducted retrospective semi-structured interviews in order to investigate how structural and individual factors influenced the changes of exploration levels we measured. Each interview was conducted individually, face-to-face, and in the native language of the interviewee to maximize his or her ability to express thoughts, feelings, and opinions. During these interviews, we introduced the concepts of exploration and exploitation and asked about the informants' perception of how the amount of time invested in both types of activities had evolved in the selected timeframe of 100 months, and about their explanations for the changes in the exploration levels they described.

Retrospective data collection allowed for a focused process because it reduced the danger of data overload and collecting much unusable data (Poole et al., 2000). However, documenting cases in a retrospective way also has its disadvantages (Golden, 1997). For instance, respondents have the tendency to filter out events that do not fit or that render their story less coherent (Poole et al., 2000). To improve the validity and reliability of these retrospective reports and prevent accepting respondent bias, we applied a number of strategies.

First, we attempted to verify individual reports by asking similar questions to multiple informants. We interviewed eight employees with various backgrounds: the R&D director (DRD), the Product Market Technology manager (PMT), one of the co-founders of the company who had worked in the company until 2007 (COF), two senior engineers (ENS), one junior engineer (ENJ), one project manager (PM) and the manufacturing technology manager (MT). These interviewees were selected at multiple levels in the organization in order to be able to study relations between antecedents of exploration and exploitation on both strategic and operational levels.

Second, interview data were coded into three categories (structural, individual and environmental) and compared with minutes of meetings, management reports, archival project data and newspapers to triangulate and supplement the information obtained during the interviews (Eisenhardt, 1989; Yin, 1994).

Third, we asked informants to reflect on concrete events (e.g. development of specific product types) rather than abstract concepts to reduce the risk of cognitive biases and impression management.

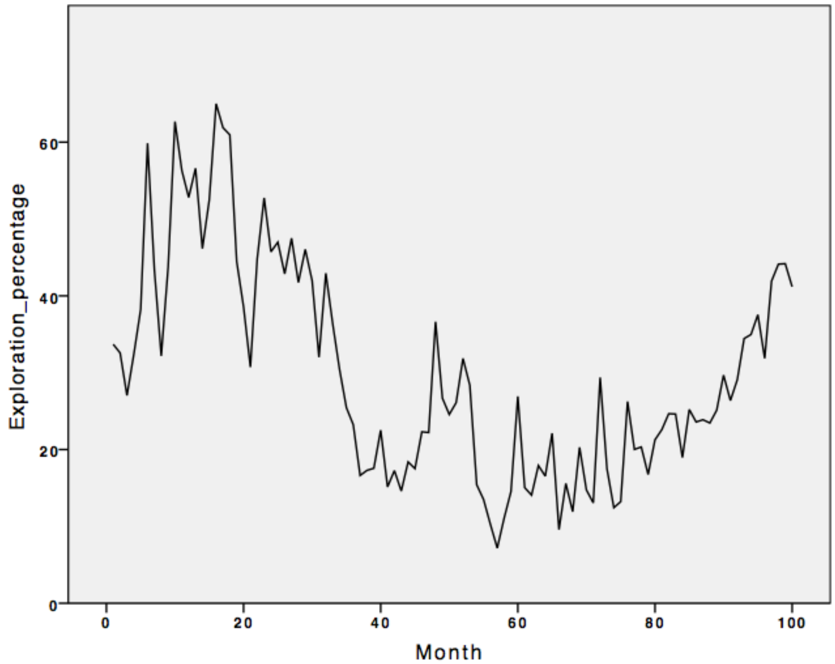
Finally, as we examine changes in structural and individual variables in relation to the passage of time, the time factor must be accounted for in our study's design (Street and Ward, 2012). We therefore paid considerable attention to the chronological sequence of events by linking statements of our informants to the 100-month timeline and exploration graph in the second part of the interviews.

The interviews proved to be an excellent source of data and, despite their small number, showed a surprising degree of agreement and comprehensiveness. We have no indication that further interviews among seniors or juniors would reveal any significant new insights.

RESULTS

Figure 2 displays the levels of explorative innovation activities as a percentage of total working hours spent on innovation projects within a timeframe of 100 months. It shows fluctuations of exploration levels from month to month, which can be explained by heavy fluctuations of time spent within explorative and exploitative projects. At the same time, a clear trend can be observed. Initial high levels of explorative activities decline from month 20 onwards to a level that is about half the initial level. Around month 50, a significant but short revival of exploration is visible. Only in the last 20-30 months, a steady growth of exploration can be observed. In the remainder of this section, we will explain what influenced this evolution of innovation activities over the years.

Figure 2: evolution of explorative innovation activities in a period of 100 months



In the mid-nineties, wind energy was in its very early stage of development. At that time, when most wind blade manufacturers relied on hand laminating techniques, a Dutch company explored the manufacturing of epoxy wind blades using vacuum injection techniques. These vacuum injection techniques turned out to be a success and were adapted by new players in the wind energy market. The company grew steadily, but suffered from financial problems and went bankrupt. It then was taken over by a large energy company. In 2001, the key engineers of the initial blade company left and teamed up again as a full daughter company of an Asian wind energy company.

At the beginning of the 100-month timeframe we investigated, working hours were almost equally divided between exploration and exploitation. Engineers were given the task by the mother company to implement technologies for a 1 Megawatt wind turbine that had been developed before:

> *"The implementation of 666 technology was a matter of off-the-shelf engineering. We developed it ourselves, so it was relatively easy to effectuate it." (COF)*

As the implementation went smooth, engineers had time left to explore new technologic trajectories for the development of a completely new blade model. It was decided to not build any further on existing blade models. Much effort was put into developing new technologies and designing a blade that could "compete on a global scale" and serve a higher capacity, 1.25 Megawatt turbine. All engineers at that time were eager to innovate in their field of expertise and worked long days to make the new blade model a success. One engineer, who joined the company later during this period, illustrated the entrepreneurial character of his colleagues:

> *"You could call them self-propelling technology owners. Most of them started their own firm afterwards". (ENS)*

During this period the total amount of employees was no more than 25. Employees had no job titles and task descriptions and there were hardly any formalized procedures. There was little focus on control of speed, budget and quality and there was hardly any management. Only slight attention was paid to write down detailed manuals for production. As a consequence, workers at the production facilities in Asia had to work with very concise instructions. That wasn't problematic at that time as the blades were small and allowed for relatively high tolerances without causing any trouble when in use.

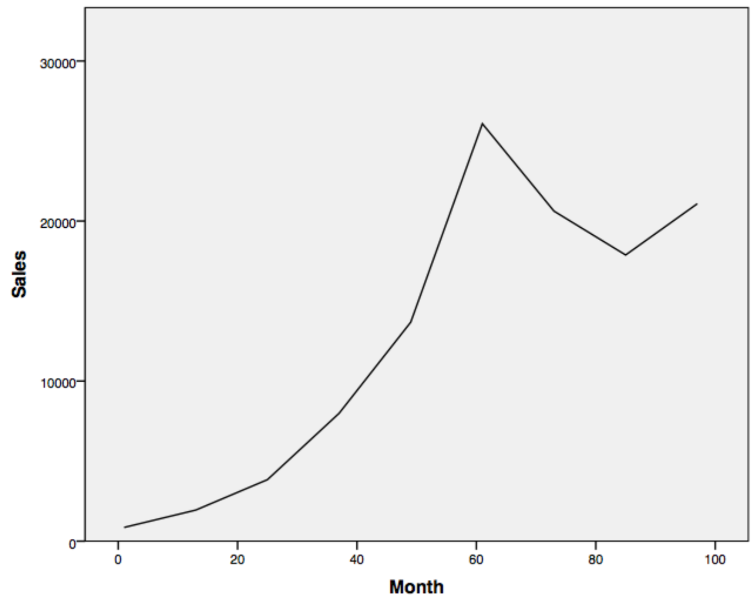
Exploration decline

The mother company, which was one of the later entrants in the global wind energy market, competed aggressively with low-cost wind turbines and soon sales increased dramatically (see figure 3). In order to compete with the largest wind energy companies, cheaper and bigger wind blades had to be developed quickly. The new "31/32" blade design became the basis for a range of models that followed, named "V2" extensions. The dimensions of the initial new blade design were pushed to its limits in a fast pace to make it fit with higher capacity 1.5 and 2.0 MegaWatt turbines. The following statements are illustrative in this respect:

> *"We just boosted the dimensions of the design to fit with a set of blades for 1.5 and 2.0 turbines" (COF)*

"I think [the company's] credo was: let's go for it, full throttle, we know we'll sometimes lose control and fail, but we'll mend and manage." (SEN)

Figure 3: sales of the mother company



Although more personnel was attracted to support the fast development of new blade designs, one interviewee mentioned that there was not sufficient time available to test new versions of blades thoroughly:

"Sometimes prototypes went straight into production" (COF)

The fast-pace adjustments to existing blade designs were made without sufficient tests before they went into production. The wind blades seemed to suffer severely from their increase in size and soon serious problems including "blade cracks" were reported in the field. Some blades even broke off the turbines while they were in operation. Due to these technological issues and the huge increase in sales, the number of root cause analyses and problem solving support requests snowballed and the blade company became occupied with fixing problems. Most engineers were busy handling requests from the help & support desk, leaving little time available for fundamental research and product innovation.

Some engineers that formed the original team became unhappy with the situation in this phase. The mother company stimulated transfer of wind blade expertise to the production facilities in Asia, but the key engineers from the early days were reluctant to release their professional knowledge and experience. Before the huge increase in sales, they thought they were promised to receive sales-dependent royalties for their efforts on the original blade design. However, when that design became successful, they never received the royalties they were promised before. As a result, some of the key engineers that were the driving force behind new blade designs left, leaving the company behind with limited documentation about the technologies applied in the blade designs.

> *"We did not document the technologies in enough detail so that we could just throw it over the wall to the production facilities in Asia. In the documentation we had, hardly any tolerances were mentioned." (COF)*

The lack of an effective documentation system for blade designs, made problem solving even more time consuming because production workers in Asia were hardly trained. In particular new workers in the production facilities had great difficulty interpreting the manuals and translating them into the desired specifications of the blades. On a regular basis, a team from the blade company visited the production facilities to train the employees:

> *"We acted like an educational institute for Asia." (SEN)*

However, once employees in production had improved their skills, they left and went to other Asian manufacturers because they paid better salaries. So training activities never stopped:

> *"We had the feeling we could start all over from scratch, again and again." (SEN)*

In order to deal with the load of problem solving requests and improvement of the documentation system, more employees were hired. Along with the complexity of activities, the organizational structure became more complex. The flat organizational chart from the beginning evolved into a structure with separated departments for each technical core competence and additional layers of management. Also, a project management department was created. In order to increase control over adherence to speed, quality and budget, standard processes were introduced for every project, led by one or more project managers. Some of the respondents were rather skeptical about this approach:

> *"Have you seen our project-list? It's ridiculous! And now they also want to pour some stage-gating on top of that. That will never work. (PMT)*

Many respondents complained about the walls that were created between the disciplines. Not only in terms of coordination an supervision, but also physically. All functional areas became separated in dedicated rooms, spread over two floors. The following statement illustrated how the entrepreneurial firm of the beginning had turned into a bureaucracy:

> *"People who visit us all react the same: the club is numb, everyone sits behind their desks. Where's the spirit, the real debate; what is really going on here? Everyone is just writing procedures." (MT)*

Although the new procedures were considered necessary to take control over the workload of problem solving requests, some employees were convinced that research and development became over formalized.

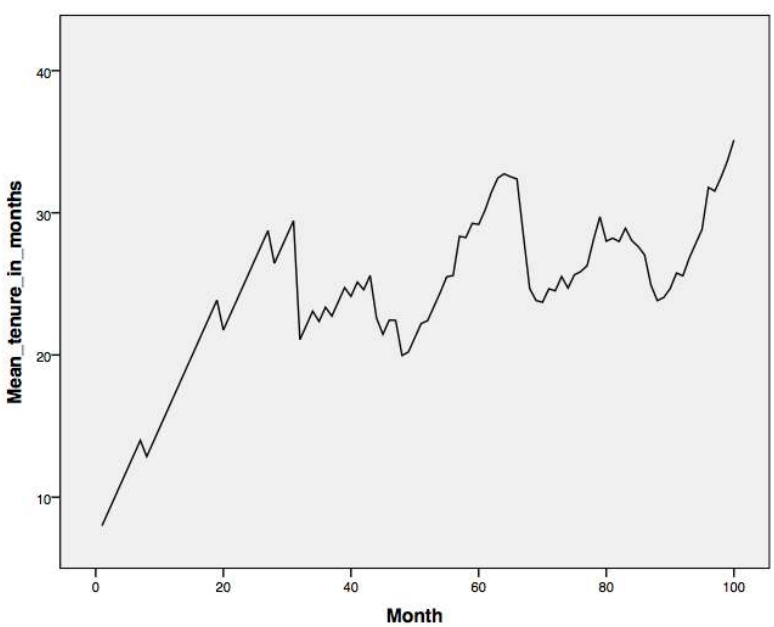
> *"It's not a high tech product. It consists of just a few components that happen to be big. That's it." (MT)*

> *"They installed a whole army of administrators, but I am convinced that with just a bunch of specialists, you could do better than them" (COF)*

Again, some of the founders and senior engineers left the company. According to the interviewees, these entrepreneurial and highly creative engineers couldn't adjust to the high degree of formalization and the way they had to account for every new initiative. In order to deal with the growing amount of support activities and the leave of experienced personnel, new employees were attracted to become problem-solving specialists.

In Europe, people with experience in the field of wind blade technology were scarce and the new engineers who joined the company came straight from university. New employees that had more experience mainly came from other industries, such as ship building and aviation. This implied that a lot of time had to be invested to train them for the job, which again could not be invested in exploration. It also became clear that it was very difficult to train new people for problem-solving activities, as the knowledge about the step-by-step history of products iterations was hard to transfer. This history was hardly documented and mainly tacit knowledge of the experienced people who left. Figure 4, which illustrates the development of company experience within the 100-month timeframe, shows some big drops in mean tenure as a result of the leave of experienced personnel and the hiring of new employees.

Figure 4: mean tenure



In order to attract more blade technology expertise, a separate research unit was created in another European country to tap into a local highly developed knowledge infrastructure in which skilled engineers were more readily available. Its mission was to work on technology development that could not be done in The Netherlands as most of the new employees were more oriented toward exploitative activities. Also, a joint venture with another blade company was initiated to increase fundamental research on new blade technologies. Knowledge transfer between these new initiatives and our focal company, however, was very limited. All of our respondents experienced the actions of the mother company to build multiple centers of blade technology knowledge as “divide et impera” tactics; all of the units aspiring to be in the lead of new technologies not trusting each other because the mother company perceives them as “many horses in the race”, not treating them as a whole system to build up to future blade development.

When exploitative activities had become dominant, engineers realized that new technologies had to be developed to stay competitive. They also felt stimulated to boost explorative activities by the increasing competition from the newfound unit in the other European country. It then was stated at board meetings that more fundamental research was needed to catch up with the competition and new visions on innovation were developed in a project called “turning blades”. A lot of time had been invested in improving the documentation system including manuals, tolerances, time control systems and training and new attempts were made to boost exploration:

> *“We labeled engineers “R&D” to make them focus on research projects”*

However, these attempts failed because of a lack of redundancy of expertise. Engineers that were supposed to focus on research could not detach themselves from day-to-day problem-solving activities because they were needed for running business. In the materials group, two persons were appointed as “champions”. They had to analyze the stream of support requests, and then direct them to the group members in a way that those who had to do research did not become overwhelmed by new problem-solving activities. This initiative did also not work out well:

> *“We came to the conclusion that we needed all of our resources to handle the support requests. Actually, we even needed more”.*

The capacity of available workforce did not grow in the same pace as the production of blades and the problems stemming from it. Interviewees emphasized that the huge amount of problems that had to be solved, worsened the working atmosphere. Some even had to call in sick, burned-out.

> *"If you take a look at how bad the atmosphere is, it is surprising so few people leave. Dealing with a web of problems without having a standardized problem solving approach is very stressful."*

Interviewees explained that based on workload calculations, there was time available for explorative activities, such as writing research reports on new materials. However, in practice these slack hours could hardly be employed for those activities as they were scattered over the whole week. This fragmented way of working gave employees a lot of stress and made them less productive. As one informant illustrates:

> *"Sometimes I just stared at my computer screen for hours, doing nothing."*

Exploration recovery

Around week 80, the level of detail in manuals and reliability of knowledge transfer processes to the production facilities had significantly been improved. The organization had become more efficient in dealing with non-conformity and root cause analysis requests by designing strict procedures about how to deal with them. This made it easier for engineers to plan their activities as tasks became more defined and better coordinated by project managers that took care of the flow of activities between departments involved. Whereas engineers first were drowning in replying flooding e-mailboxes, they now could plan a part of the day to work on longer-term projects. As a result, slack resources that at first were absorbed by inefficient processing of problem-solving activities that were scattered over a working day now became more streamlined, unabsorbed and available for exploration.

Also the amount of these requests decreased as the mother company's sales dropped and customers reported fewer problems. The company had learned that a lot of time had been invested in searching for causes of unique problems that in the end could not be solved. They also found new bays to deal more efficiently with support requests and in addition they decided not to hunt for solutions to every little problem anymore and focus on problems that occurred on larger scale and for which problem solving efforts would be well invested.

The new separate unit in another European country, where engineers could experiment with new technologies, without the constraints of running business activities, had grown steadily up to 20 FTE. This unit was primarily built up in order to attract wind energy know-how to the company. In comparison with the unit in the Netherlands, they had the unique opportunity to solely explore and work on new ideas for the future. However, soon the R&D director of the new unit wanted to make their expertise more relevant by implementing it. They then became involved in a growing number of running projects that ran in The Netherlands. As one of our interviewees illustrated:

> *"I think the R&D director wanted a complete blade design site for his own".*

This way, the R&D unit in another European country acted as an expansion vessel for the overheated problem solving activities of the focal company. They released the pressure by taking over some of the day-today-activities. This created some slack in the engineering departments of our focal company.

The sense of urgency to start developments for a new type of wind blade increased. The mother company then concurred with start-up of development activities for a new generation of sleeker wind blades with a different aerodynamic profile. These developments pursued a sophistication level comparable to more technology leading competitors and would include the implementation of ideas about new blade structures and approaches to aerodynamics that they had not dared to work on before.

ANALYSIS

To further analyze the decline and recovery of exploration in this organization we focus on the four antecedents identified in literature, viz. slack resources, organizational structure, tenure, and cognitive style. The first factor is the availability of slack resources. In our case, we observed that the organization gained more slack resources while growing. Initially this did not have a positive effect on exploration as the increase of slack was not ready to be deployed for exploratory activities, as it was tied to current operations. Only when exploitative activities became more formal and efficient, by implementing strict procedures and guidelines, slack was deployed for exploration. So not slack as such, but only un-absorbed slack has a shown positive influence on exploration levels. The process of de-absorbing is related to the second antecedent, organizational structure.

The organizational structure of our case seemed to evolve with the stages of the main product's life cycle. In the initiation stage, which showed high levels of explorative activity, the organizational structure was quite organic, characterized by a lack of job and task descriptions, low formalization and no centralization of autonomy. When sales of the mother company began to grow rapidly, the R&D organization was encouraged to build further on existing products along already known technological trajectories. This was facilitated by a somewhat halfhearted shift from an organic to a more mechanistic mode of organizing. Specialized departments were built around core disciplines, levels of hierarchy and job descriptions were introduced, as well as standard operating procedures and guidelines. However, these were not implemented well enough to increase efficiency and create unabsorbed slack. After a period of implementing and exploiting existing products and technologies, management intended to recover explorative activities. The mechanistic mode, however, seemed to be a hampering factor for exploration because it created boundaries between the departments hindering cross-functional flow of information.

The introduction of parallel project structures then helped to increase communication between the separate disciplines and stimulated the recovery of explorative activities. Next to our focal unit, a physically separated unit for explorative activities had been developed. It was first intended that the initial unit continued its main focus on exploitation, whereas the new unit should focus on explorative activities exclusively. However, this structural approach had an unexpected effect on exploration and exploitation in both units. The new explorative unit gradually moved from exploring technologies to developing products and implementing them as its local management wanted to create stronger dependencies and produce visible results for the mother company. Also, in our focal unit, this new unit was regarded as internal competition and threatening its own business. Although the structure was created to facilitate the Dutch organization to mainly focus on exploitative activities, exploration received increasing attention. Our study shows that structuration and formalization, which seems inherent to organizational growth, has a negative, but also a positive impact on the level of exploration as it de-absorbs slack that can be redeployed for explorative activities. Furthermore, this case demonstrates that in situations of fairly autonomous R&D organizations, the creation of a separate unit for exploration may lead to increased internal competition, and to a recovery of exploration in the unit focusing on exploitation.

The individual antecedents we studied are the cognitive style and tenure of the employees. In growing organizations that skew toward efficiency and increased formalization, work environments might become less motivating for individuals that tend to prefer an intuitive thinking style. In our case we observed that many of the intuitive, entrepreneurial engineers that initiated the first product lines in the organic phase of the organization, left the company when the organizational mode became more mechanistic and formalized. The effect was twofold. First, an important driving force for innovation went away which could have been deployed for exploration. Second, their tacit knowledge about the products they developed left the company, which made exploitation less efficient and requiring resources that were intended for exploration.

In our case of a fast growing company, we observed negative effects of low levels of mean tenure and company experience. Our results suggest that when an organization transitions from a phase of exploration and initiation of new products to a phase where focus lies on developing along existing trajectories, experienced employees are needed for efficient exploitation of existing knowledge. In our case, as a result of the leave of experienced engineers, mean tenure and experience among employees was insufficient to deal with exploitative tasks in an effective way. Engineers who were supposed to focus on exploration therefore had to help out others focusing on exploitation, which negatively impacted exploration levels.

CONCLUSION AND DISCUSSION

The aim of this study was to explore a company's evolution of exploration levels and the relationships between structural and individual factors that influence these dynamics. In order to provide such a longitudinal perspective, we developed a novel method based on project descriptions and time-accounting data to assess the relative importance of exploration and exploitation over time. This method proved to create an accurate reconstruction of how exploration levels varied over time. The evolution of exploration levels that were measured indicated that the focal company, after a period of high levels of exploration, experienced a decline of exploration afterwards. It also showed that, facing the danger of a competence trap, the company succeeded at recovering exploration activities. We identified several structural and individual attributes that contributed to the emergence of these exploration dynamics.

In this section we discuss the main theoretical contributions of our findings and point to the main managerial implications. In particular, we provide suggestions to managers of R&D organizations and growing R&D organizations in specific on how to evaluate and influence exploration levels. Finally we discuss the main limitations of this study and point out to interesting avenues for future research.

Interaction between formalization and slack resources for exploration

Formalization is expected to constrain exploration and facilitate exploitation via incremental improvements in processes and products (Lavie et al., 2010). It refers to the degree to which jobs are codified (Hage and Aiken, 1970) and like bureaucracy (Thompson, 1965), it is usually predicted to be inversely related to innovation (Slappendel, 1996). Worse, there is evidence that exploitation-oriented problem solving practices diminish an individual's ability to explore (Adler et al., 2009).

Challenging this research, we find that focusing on process improvement may not always harm exploration. The results of the present study paradoxically indicate that developing efficient formalized procedures for exploitation also has a positive effect on exploration. This is related to the interaction between formalization and the availability of unabsorbed slack human resources.

As companies grow, they often attain access to resources that are in excess of the minimum necessary to produce a certain level of output (Nohria and Gulati, 1996). Slack facilitates risk-taking and innovation by buffering organizations from environmental fluctuations and downside risk, and thus legitimize experimentation (Greve, 2007; Sharfman et al., 1988; Singh, 1986).

According to Voss et al. (2008), more human resource slack does not necessarily lead to more exploration. It might depend on the degree to which human slack is absorbed or unabsorbed in nature. Human resource slack refers to specialized and skilled human resources that are rare and absorbed (Mishina et al., 2004). Human resource slack is absorbed because the resources are tied up in the organization's current operations. The absorbed nature of human resource slack therefore has a negative influence on exploration and a positive influence on exploitation.

Our study shows that human resource slack can be de-absorbed by having efficient formalized procedures in place. Slack human resources, which are non-redundant and absorbed can only be de-absorbed and employed for exploration when individuals are not continuously challenged to shift between both types of activities, especially when exploration is not constantly interrupted by exploitative tasks asking for prioritization. Only when exploitative activities can be isolated, for instance by confining them to specific days or working hours, individuals will be able to shift their attention to exploration and work on long term projects on the other days. Efficient procedures, like standard procedures for prioritization of problem solving requests can help to achieve this. Procedures for running business and problem solving activities should be designed in a way that individuals do not constantly have to switch between exploration and exploitation (which they can't) but switch fewer times and with longer intervals. Given the continuous relationship between the amount of exploration and exploitation activities within single business units (Gupta et al., 2006), efficient exploitation creates time for exploration.

Interaction between formalization and individual antecedents

Furthermore this study illuminates the interaction between formalization and individual antecedents for exploration. Individual attributes that are time related have an impact on exploration. Age and tenure, for instance, have been found to negatively impact individual explorative behavior (Scott and Bruce, 1994). Also in groups, the time factor seems to have a negative impact on exploration among individuals (Katz, 1982).

According to the contingency theory developed by Zaltman et al. (1973), structural variables will be contingent upon the two main stages of the innovation process. An organic structure seems to be required for the initiation of innovations, whereas implementation may be best supported by a mechanistic structure (Zaltman et al. 1973). The tendency of aging personnel to stick to trajectories already known, fits with the stages of the innovation process shifting from an organic to a more mechanistic organizational mode over time. However, when the organization attempts to transition to a new initiation phase of a new innovation life cycle, the human resources available might not be the ones required for exploration.

Our study showed that people that were the idea generators at the beginning, who built the fundaments for the product that would be exploited in the following years, did not develop alongside the phases of the product life cycle and did not match with the organizational mode which became more mechanistic, and left the company to start their own new businesses. The engineers who intuitively built the initial designs should have been kept to transfer their tacit, sticky knowledge for efficient exploitation and for the next round, the next product life cycle. Our study indicates that not only should mechanistic and organic organizational modes be aligned with the product life cycle phase, but also human resources should be aligned with the product life cycle and pro-actively be managed when a new product life cycle is to be initiated. This implies that the real innovators at the beginning of the cycle should be treasured as chances are high they might be intrinsically motivated and skilled to ignite subsequent life cycles of new products.

Limitations and future research

As our study was based on one single case, no general conclusions can be drawn about the relationships between structural and individual factors that we explored. Future studies might adopt our method to measure exploration dynamics in multiple organizations and compare results in order to find out whether the relationships we identified can be generalized to a larger population. These studies may also include a broader set of organizational factors. Although we have investigated important structural and individual factors that influence exploration within organizational boundaries, the role of other factors such as the strategic intent of the mother company deserves further investigation.

In addition, we see three important ways in which our method can be improved for future research. First, inter-rating scores and interviews demonstrated that our word-counting method was quite accurate in re-creating the evolution of exploration and exploitation. However, the project descriptions we used were made at the very beginning of the project; they did not necessarily reflect the actual content of the projects as the projects' scope can change over time and deviate from the initial project description. Future studies on exploration fluctuations within firms might consider incorporating multiple sources of project documentation, such as minutes of meetings and evaluation reports.

Second, the project descriptions that were used in our analysis served various purposes. In the first place they were written for internal communication about projects and in order to receive budget for new plans. However, some of them were also made to acquire government subsidy. This might have had impact on the wording and the extent to which they describe the actual content of the project. In order to obtain technology subsidies, for example, project descriptions might have had a stronger innovative character than the projects actually had when they were conducted. Following studies that adopt our method of text analysis might pay attention to the uniformity of project description purposes in order to improve the accurateness of project classification into explorative and exploitative projects.

Third, the underlying motivation of the exploration and exploitation debate is that they are of critical importance to sustained performance of the firm. March's belief is that firms that have a single-sided focus on either exploration or exploitation will suffer from never gaining the returns of new knowledge, or from offering obsolete products in the market. In this study we examined changes of exploration and exploitation activity levels, neglecting the impact of these activity levels on the firm's financial performance. This was not possible because our focal company engineers only a part of a product that is sold in the market, which makes the relationship between the firm's products and profit and sales rather difficult to investigate. Future research may investigate the relationship between exploration and exploitation activity levels and financial performance generated by these efforts.

6
CONCLUSION

In this thesis we investigated the effects of cognitive and structural factors in NPD on multiple levels, taking into account the multi-dimensionality of innovation. Below, we summarize the main findings and contributions of each study (also see table 1) and conclude with interesting avenues for future research.

Ch. 2: To what extent do cognitive styles of CEOs influence exploration and exploitation?

In this study we explored the link between CEOs' cognitive style and firms' ability to explore new products and technologies as well as to exploit existing ones. We provided a richer understanding of exploration and exploitation within firms, acknowledging the relevance of the cognitive style of senior executives in explaining differences in innovation behavior and their effects on choices between investing in explorative and exploitative innovation and firms' incremental and radical innovation performance. With this study, we contribute to integrating insights from upper-echelon theory in research on new product innovation. The upper echelon approach views strategic choice as a function of the demographic and psychological composition of top managers and suggests several factors that impact the strategic direction and performance levels of a firm, such as age, functional backgrounds, other career experiences, education, socioeconomic roots and financial position (Hambrick and Mason, 1984). Because of the difficulties in studying the mental representations and other psychological characteristics of the organization's executive members, Hambrick and Mason (1984) advocated indirect methods of cognitive assessment, whereby executives' background characteristics (e.g. education, functional specialization) are used as proxies for cognitive variables in the prediction of organizational outcomes (Hodgkinson and Healey, 2008). Using a direct method to assess cognitive style of CEOs, our study supports the view that strategic decision-making is influenced by the cognitive base of top managers. In particular, our findings show how cognitive characteristics and individual inclinations for explorative and exploitative activities influence strategic decision-making on allocating resources to exploration and exploitation and firms' product innovation performance. Previous studies already pointed to the important role of senior managers in organizations' decisions between investing in exploration and exploitation. Our study emphasizes the relevance of upper echelon theory in explaining some of the antecedents of these strategic decisions.

Ch. 3: To what extent do cognitive styles in teams influence exploration and exploitation?

In this study, we explored relationships between cognitive styles in NPD teams and project performance in different innovation settings. The results of our analyses point at the relevance of psychological factors that have received little attention in the NPD literature. In particular, our data suggest that team cognitive styles have significant predictive value in explaining project performance. Our analyses of the impact of analytical and intuitive thinking styles on performance indicate that organizations might benefit from composing teams not only based on functional backgrounds, but also based on thinking styles of team members. These findings are relevant to management of NPD as we found evidence that the effectiveness of thinking styles in teams is contingent on the explorative degree of project activities. This implies that teams can be configured in terms of thinking styles for optimal performance of different types of projects. We observed that high levels of intuitive processing in NPD teams have significant positive impact on overall performance in explorative projects, whereas this thinking style has a significant negative impact on project performance in less explorative settings. At the same time, we observed that team analytical processing has a positive impact on project performance, independent of the explorative degree of the project activities. Our results indicate that the effectiveness of NPD teams seems to be contingent on the fit between thinking styles and the task of the team. Our findings confirm the points earlier made by Burns and Stalker (1994), who argued that different thinking styles might be required to optimize overall performance when interacting in organic and mechanistic work environments (Burns and Stalker, 1994). Based on our findings and insights, we argue that for optimal overall project performance, managers should compose NPD teams with mostly analytical thinkers for their incremental, less explorative projects, and compose teams with high-level intuitive and high-level analytical thinking for more radical, explorative NPD projects.

Ch. 4: To what extent do organizational integration structures influence exploration and exploitation?

With this study, we contributed to a firm-level perspective on the management of NPD processes, acknowledging the relevance of structural ambidexterity in organizing NPD. Although the structural ambidexterity argument has become increasingly popular in the academic literature, our data reveal that the popularity of this strategy among practitioners is rather low. Our data show that the majority of our firms preferred a standardized approach concerning their integration structure. At the same time, though, our analyses indicate that organizations might benefit from adopting structural ambidexterity. We found evidence that the effectiveness of integration is different for different kinds of NPD processes. In particular, we observed that, adopting a cross-functional integration structure - instead of a functional integration structure - in radical NPD processes has a significant positive impact on breakthrough innovation performance, whereas the implementation of a cross-functional integration structure in incremental NPD processes has a significant negative impact on incremental innovation performance. Based on these findings, we argue that firms that manage to apply a cross-functional integration structure for their radical NPD processes and a functional integration structure for their incremental NPD processes will be the most successful in terms of balancing derivative and breakthrough innovation performance. As such we derived evidence in favor of structural ambidexterity in terms of organizing both types of innovative activity differently.

Ch. 5: How do structural and cognitive factors influence the evolution of exploration and exploitation over time?

In this case study, we started identifying interactions and connections between structural and individual factors. First, this study illuminates the interaction between formalized structures and individual antecedents for exploration. In previous studies age and tenure have been found to negatively impact individual explorative behavior (Scott and Bruce, 1994). Also in groups, the time factor seems to have a negative impact on exploration among individuals (Katz, 1982). According to the contingency theory developed by Zaltman et al. (1973), structural variables will be contingent upon the two main stages of the innovation process. An organic structure seems to be required for the initiation of innovations, whereas implementation may be best supported by a mechanistic structure (Zaltman et al. 1973). The tendency of aging personnel to stick to trajectories already known, fits with the stages of the innovation process shifting from an organic to a more mechanistic organizational mode over time. However, when the organization attempts to transition to a new initiation phase of a new innovation life cycle, the human resources available might not be the ones required for exploration. Our study showed that people that were the idea generators at the beginning, who built the fundaments for the product that would be exploited in the following years, did not develop alongside the phases of the product life cycle and did not match with the organizational mode which became more mechanistic, and left the company to start their own new businesses. The engineers who intuitively built the initial designs should have been kept to transfer their tacit, sticky knowledge for efficient exploitation and for the next round, the next product life cycle. Our study indicates that not only should mechanistic and organic organizational modes be aligned with the product life cycle phase, but also human resources should be aligned with the product life cycle and pro-actively be managed when a new product life cycle is to be initiated. Secondly, this study illuminates the interaction between formalization and the availability of unabsorbed slack human resources for exploration. As companies grow, they often attain access to resources that are in excess of the minimum necessary to produce a certain level of output (Nohria and Gulati, 1996). Slack facilitates risk-taking and innovation by buffering organizations from environmental fluctuations and downside risk, and thus legitimizes experimentation (Greve, 2007; Sharfman et al., 1988; Singh, 1986). According to Voss et al. (2008), more human resource slack does not necessarily lead to more exploration. It might depend on the degree to which human slack is absorbed or unabsorbed in nature. Our study shows that human slack can be de-absorbed by having efficient formalized procedures in place. Slack human resources, which are non-redundant and absorbed can only be de-absorbed and employed for exploration when individuals are not continuously challenged to shift between both types of activities, especially when exploration is not constantly interrupted by exploitative tasks asking for prioritization. Only when exploitative activities can be isolated, for instance by confining them to specific days or working hours, individuals will be able to shift their attention to exploration and work on long term projects on the other days. Efficient procedures, like standard procedures for prioritization of problem solving requests can help to achieve this. Procedures for running business and problem solving activities should be designed in a way that individuals do not constantly have to switch between exploration and exploitation (which they can't) but switch fewer times and with longer intervals. Given the continuous relationship between the amount of exploration and exploitation activities within single business units (Gupta et al., 2006), efficient exploitation creates time for exploration.

Our studies have several limitations, which are displayed per chapter in table 2. The most interesting avenues for future research that these limitations provide will be briefly discussed. Research on the effects of CEOs' cognitive style on exploration and exploitation within firms might consider assessing long-term effects of changes in CEOs' innovation behavior. By adopting a longitudinal approach, insight into how changes in CEOs' innovation behavior, allocation of R&D resources and innovation performance causally relate to each other, could be improved. Future studies on the effects of cognitive style in NPD teams might also adopt a time lens. Although we were able to examine the degree to which thinking styles were present in NPD teams, we have not paid attention to the effects of cognitive style throughout the stages of a project. Previous research, however, suggests that the effects of thinking styles may differ depending on the stage in the NPD process. It would therefore be relevant for future research to provide more fine-grained insights into the performance implications of interactions between team members from different functional backgrounds and their thinking styles in different phases of the project. Finally, our longitudinal study on the effects of interactions between structural and cognitive factors on exploration was based on one single case, which implies that no general conclusions can be drawn about the relationships between the structural and individual factors that we explored. Future studies might be inspired by our novel method to measure exploration dynamics in multiple organizations and compare results in order to further study interactions between cognitive and structural factors.

Table 1: main findings per chapter

Chapter	Title and topic	Findings	Related articles
2	"Exploration and exploitation within firms: the impact of CEOs' cognitive style on incremental and radical innovation performance" The impact of thinking styles of CEOs on the balance between exploration and exploitation.	The more analytical (intuitive) the cognitive style of CEOs, the stronger their focus on exploitative (explorative) activities. The degree to which CEOs focus on exploitative (explorative) activities is positively related to the percentage of R&D resources that are allocated to exploitative (explorative) activities within the firm. Higher allocation of R&D resources to exploitative activities increases firms' incremental product innovation performance; Higher allocation of R&D resources to exploitative activities decreases a firms' radical product innovation performance.	De Visser, M., Faems, D., Van den Top, P., 2011. Exploration and exploitation within SMEs: connecting the CEO's cognitive style to product innovation performance. In proceedings of the International Product Development Management Conference, Delft, The Netherlands, June 5-7. De Visser, M., Faems, D., Van den Top, P., 2011. Exploration and exploitation within SMEs: connecting the CEO's cognitive style to product innovation performance. Presented at the INSCOPE Conference, Enschede, The Netherlands, October 12.
3	"Team composition and NPD project performance: do cognitive styles matter?" The impact of cognitive styles in teams on NPD project performance.	NPD team intuitive processing has a significant positive impact on overall project performance in highly explorative settings. NPD team intuitive processing has a significant negative impact on overall project performance in less explorative settings. Team analytical processing has a significant positive impact on project performance, independent of the explorative degree of the project activities.	De Visser, M., Faems, D., Visscher, K., De Weerd-Nederhof, P.C., 2013. Team composition and NPD performance: do cognitive styles matter? To be presented at the International Product Development Management Conference, Paris, France, June 23-25.

Chapter	Title and topic	Findings	Related articles
4	"Structural ambidexterity: a firm-level assessment of the impact of differentiated integration structures on innovation performance" The impact of (cross-) functional structures in incremental and radical NPD processes on innovation performance.	The effectiveness of integration is different among different kinds of NPD processes. Adopting a cross-functional integration structure in radical NPD processes has a significant positive impact on breakthrough innovation performance. The implementation of a cross-functional integration structure in incremental NPD processes has a significant negative impact on incremental innovation performance.	De Visser, M., de Weerd-Nederhof, P., Faems, D., Song, M., van Looy, B., Visscher, K., 2008. Ambidexterity in NPD processes: an exploration of performance effects of - differentiated - organizational practices. Presented at the R&D Management conference, Ottawa, Canada, June 17-20. De Visser, M., de Weerd-Nederhof, P., Faems, D., Song, M., Van Looy, B., Visscher, K., 2009. Structural ambidexterity in NPD processes: the impact of differentiated integration structures on innovation performance. In Best Paper Proceedings of the Academy of Management Conference, Chicago, USA, August 7-11. De Visser, M., De Weerd-Nederhof, P., Faems, D., Song, M., Van Looy, Visscher, K., 2010. Structural ambidexterity in NPD processes: The impact of - differentiated - structures on firm-level innovation performance. Technovation, 30, 5-6, 291-299.
5	"Gone with the wind? A longitudinal study of explorative innovation in a growing wind turbine blade technology company" Relationships between structural and individual factors and their impact on the evolution of a firm's balance between exploration and exploitation.	Formalization of exploitative activities can de-absorb human slack resources, which can be redeployed for explorative activities. This way, efficient exploitation can have a positive effect on the level of exploration. When an organization evolves from an organic to a more mechanistic mode of organizing along the stages of the product life cycle, the work environment might become less motivating for individuals that tend to prefer an intuitive thinking style. When these individuals leave the company, an important driving force for innovation may go away as well as their tacit knowledge making exploitation less efficient.	De Visser, M., Faems, D., Visscher, K., De Weerd-Nederhof, P.C., 2010. Toward a dynamic perspective on explorative and exploitative innovation activities: a longitudinal study in the wind blade industry. In proceedings of the International Product Development Management Conference, Murcia, Spain, June 13-15.

Table 2: limitations per chapter

Chapter	Title	Limitations
2	Exploration and exploitation within firms: the impact of CEOs' cognitive style on incremental and radical innovation performance	Limited generizability: compared to SMEs, innovation outcomes at larger firms are often influenced by a broader set of factors besides the CEO's innovation behavior, such as more complex organizational systems, which make strategic decision-making less straightforward. The statistical relationships we found between CEOs' Cognitive Style, CEOs' Innovation Behavior, Allocation of R&D Resources and Innovation Performance may not be as strong as what we found with our sample of SMEs. Cross-sectional data: although we built in time lags between some of our variables, we were not able to assess long-term effects of changes in CEOs' innovation behavior. Future studies may adopt a longitudinal approach to increase insight into how changes in CEOs' innovation behavior, allocation of R&D resources and innovation performance causally relate to each other.
3	Team composition and NPD project performance: do cognitive styles matter?	Unidimensional performance measure: in this study we only examined effects on overall project performance. However, project performance is a multi-dimensional construct. For a product development team charged with designing a specific part of a larger product, several properties may be important, such as including functionality, manufacturability and dimensional integrity. As analytical and intuitive processing may have different effects on these different dimensions of performance, we suggest that future studies on thinking styles in NPD teams distinguish between more dimensions of project performance. Cross-sectional data: although we were able to examine the degree to which thinking styles were present in NPD teams, we have not paid attention to their effects on performance throughout the stages of a project. Previous research, however, suggests that the effects of thinking styles may differ depending on the stage in the NPD process. For instance, individuals with a more intuitive cognitive style may be more effective in the initiation phase, whereas those with a more analytical style may be better in the implementation phase where ideas come into practice. Also, the effects of cognitive style may be dependent on the functional background of team members. It would therefore be relevant for future research to provide more fine-grained insights into the implications of thinking styles of team members with different functional backgrounds in different phases of the project.

Chapter	Title	Limitations
4	Structural ambidexterity: a firm-level assessment of the impact of differentiated integration structures on innovation performance	US-only data: previous project-level research already indicated that the relationship between integration structures, product innovativeness and project performance is influenced by the national culture in which the firm is embedded. We therefore encourage researchers to conduct an international comparison of the impact of integration structures in different kinds of NPD processes on different kinds of innovation performance. Binary distinction between functional and cross-functional integration structures: previous research on individual NPD projects indicates that firms can implement different kinds of cross-functional integration structures. These studies provide indications that the particular composition of cross-functional integration teams might influence project performance. Future firm-level research on the relationship between integration structures and innovation performance may use more fine-grained measures for the applied integration structure.
5	Gone with the wind? A longitudinal study of explorative innovation in a growing wind turbine blade technology company	Single case study: from this study no general conclusions can be drawn about the relationships between the structural and individual factors that we explored. Future studies might be inspired by our method to measure exploration dynamics in multiple organizations and compare results in order to find out whether the relationships we identified can be generalized to a larger population. These studies may also include a broader set of organizational factors. No link with financial performance: we examined changes of exploration and exploitation activity levels, neglecting the impact of these activity levels on the firm's financial performance. This was not possible because our focal company engineers only a part of a product that is sold in the market, which makes the relationship between the firm's output end profit and sales rather difficult to investigate. Future research may investigate the relationship between exploration and exploitation activity levels and financial performance generated by these efforts.

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8

ACADEMIC OUTPUT

Conference papers

De Visser, M., de Weerd-Nederhof, P., Faems, D., Song, M., van Looy, B., Visscher, K., 2008. Ambidexterity in NPD processes: an exploration of performance effects of - differentiated - organizational practices. Presented at the R&D Management conference, Ottawa, Canada, June 17-20.

De Visser, M., de Weerd-Nederhof, P., Faems, D., Song, M., Van Looy, B., Visscher, K., 2009. Structural ambidexterity in NPD processes: the impact of differentiated integration structures on innovation performance. In Best Paper Proceedings of the Academy of Management Conference, Chicago, USA, August 7-11.

De Visser, M., Faems, D., Visscher, K., De Weerd-Nederhof, P.C.. Toward a dynamic perspective on explorative and exploitative innovation activities: a longitudinal study in the wind blade industry. In proceedings of the International Product Development Management Conference, Murcia, Spain, June 13-15.

De Visser, M., Faems, D., Van den Top, P., 2011. Exploration and exploitation within SMEs: connecting the CEO's cognitive style to product innovation performance. In proceedings of the International Product Development Management Conference, Delft, The Netherlands, June 5-7.

De Visser, M., Faems, D., Van den Top, P., 2011. Exploration and exploitation within SMEs: connecting the CEO's cognitive style to product innovation performance. Presented at the INSCOPE Conference, Enschede, The Netherlands, October 12.

De Visser, M., Faems, D., Visscher, K., De Weerd-Nederhof, P.C., 2013. Team composition and NPD performance: do cognitive styles matter? To be presented at the International Product Development Management Conference, Paris, France, June 23-25.

Publications

De Visser, M., De Weerd-Nederhof, P., Faems, D., Song, M., Van Looy, Visscher, K., 2010. Structural ambidexterity in NPD processes: The impact of - differentiated - structures on firm-level innovation performance. Technovation, 30, 5-6, 291-299.

Awards

Runner Up Best Paper Award 18th International Product Development Management Conference 2011, Delft.

9
ABOUT THE AUTHOR

Matthias de Visser ('s-Hertogenbosch, 1981) studied Business Administration and Public Administration at the University of Twente, where he also received his MSc. degree in Innovation Management. Currently Matthias holds a position as assistant professor at the department of Innovation Management and Strategy at the University of Groningen. His research interests are in individual innovative behavior, NPD team composition and NPD project portfolio management. During his PhD research Matthias focused on the influence of structural and cognitive factors on exploration and exploitation in new product development. His early research findings have been published in Technovation (2010) and the Journal of Product Innovation Management (2010). His work has been presented at various international conferences such as the Academy of Management Conference, R&D Management Conference, and the International Product Development Management Conference where he was rewarded with the Christer Karlsson Best Paper Award (2009) and the Runner Up Award (2011). At the University of Groningen Matthias is responsible for teaching Bachelor's and Master's courses related to strategy, innovation management and marketing.

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