Journal of High Technology Management Research 19 (2008) 83–93

Contents lists available at ScienceDirect

Journal of High Technology Management Research

journal homepage: www.elsevier.com/locate/hitech

# Exploratory learning and new product performance: The moderating role of cognitive skills and environmental uncertainty

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ARTICLE INFO

Available online 8 November 2008

*Keywords:*
Exploration
A-shaped skills
T-shaped skills
Cognition
Team learning

ABSTRACT

This study advances research on organizational learning and new product development (NPD) by examining the relationship between exploration and NPD performance while considering the moderating effects of cognitive skills and environmental uncertainty. Drawing on the cognitive perspective, we posited that A-shaped and T-shaped skills enhance NPD performance by hastening exploratory learning in NPD teams. Furthermore, we argued that exploration is advantageous in conditions of high technological and market uncertainty. Based on a survey of 198 NPD projects from IT firms located in Taiwan, we found that exploration is positively related to NPD performance, and that both A-shaped skills of team leaders a well as technological uncertainty significantly moderated this focal relationship.

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## 1. Introduction

Intense competition coupled with volatile markets engenders a drastically shortened product life cycle. Clearly, only those firms that can constantly introduce new products to keep abreast of changing market trends will survive in today's competitive arena. Researchers observe that a firm's new product success is largely ascribed to a systemic focus upon managing the new product development (NPD) process as a continuous learning process (Kusonaki, Nonaka, & Nagata, 1998; Söderquist, 2006). Hence, NPD is portrayed as a process of learning to acquire and exploit new knowledge as well as market opportunities (Adams, Day, & Dougherty, 1998; Atuahene-Gima & Murry, 2007; Shane, 2000). Two primary types of learning imbued into the NPD process are exploitation and exploration (Geiger & Makri, 2006; He & Wong, 2004; March, 1991; Rothaermel & Deeds, 2004). The form of learning determines the pattern by which a firm devotes effort and attention to NPD activities, which in turns influences its ultimate performance (Hurley & Hult, 1998; Kessler, Bierly, & Gopalakrishnan, 2000). In an industry such as information technology (IT), where the product life cycles are very short and environmental uncertainty is high, firms must continuously discover potentially useful innovations for their markets to sustain competitive advantages (Oliver, Dostaler, & Dewberry, 2004). Exploration is obviously more important than exploitation for firms seeking to create variety, to adapt, and hence to exploit ever decreasing windows of opportunity (McGrath, 2001). In practice, the bulk of successful innovations are developed through the collective efforts of NPD team members (Akgün, Lynn, & Yilmaz, 2006; Kessler et al., 2000). Accordingly, this study focuses on how the NPD teams in IT firms undertake exploration to enhance their NPD performance.

Recent work has begun to empirically analyze the effect of exploration on organizational performance. Although such effects are theoretically assumed to be positive in general, the results show that they are not always significant or monotonic (Auh & Menguc, 2005; Atuahene-Gima & Murry, 2007; Özsomer & Gençtürk, 2003). Such inconsistent findings imply that exploration may require specific conditions to ensure a positive influence on organizational performance. Also lacking are empirical studies that

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1047-8310/$ – see front matter © 2008 Published by Elsevier Inc.
doi:10.1016/j.hitech.2008.10.001

investigate the factors that moderate the exploration–performance relationship. In light of contingency theory, considering organizational conditions under which exploratory learning takes place may clarify this focal relationship (Atuahene-Gima, Slater, & Olson, 2005; Gresov, 1989). Within the NPD context, noteworthy is the cognitive perspective. This view highlights that one of the major success factors for NPD is that a NPD team functions as an integrated whole engaged in the process of learning (Akgün et al., 2006; Madhaven & Grover, 1998). Given the interactive nature of the learning process, cognitive skills that amalgamate disparate views and knowledge are essential (Akgün et al., 2006; Kusonaki et al., 1998; Madhaven & Grover, 1998). Madhaven and Grover (1998) identify two types of cognitive skills: T-shaped skills denote the capability of individual specialists to maintain meaningful and synergistic conversations with others; A-shaped skills refer to the unique ability of team leaders to integrate insights synergistically from multiple sets of knowledge (Madhaven & Grover, 1998). Both cognitive skills are crucial for a NPD team to perform exploration because they allow the new knowledge manipulated by individuals within the team to transcend beyond individual minds and become a collective entity that facilitates achieving its mission of innovation (Akgün et al., 2006; Madhaven & Grover, 1998; Johannessen, Olsen, & Olaisen, 1999). Thereby, A-shaped and T-shaped skills may act as moderators that improve NPD performance by hastening exploratory learning in NPD teams. Notwithstanding the apparent importance of these skills, researchers have rarely delved into the relevant issues.

On the other hand, organizational learning theory views learning as an organizational adaptation pattern that responds to perceived changes in environments (Burgelman, 2002; Levinthal & March, 1993). In this respect, Song and Montoya-Weiss (2001) assert that "uncertainty should be studied in relation to specific components of the environment in order to properly attribute its effects." Likewise, Shenar (2001) suggests that it is prudent for NPD research to incorporate market and technological uncertainty as external contingency variables. Indeed, the moderating impact of environmental uncertainty exists because learning processes involve lags in adjustment to environmental changes (Akgün, Byrne, Lynn, & Keskin, 2007; Özsomer & Gençtürk, 2003). To our knowledge, there are no previous studies that have systematically examined the moderating effects of the different dimensions of environmental uncertainty on the relationships between exploration and NPD outcomes.

In this article, we aim to address these issues by proposing a conceptual model and formulating research hypotheses (Fig. 1). Using organizational learning theory and cognitive perspective, we first elaborate on the relationship between exploration and NPD performance. Secondly, we investigate the moderating roles of cognitive skills and environmental uncertainty. Afterwards, these hypotheses are subjected to empirical testing based upon a sample of 198 NPD projects from Taiwanese IT firms. The paper closes with a discussion of the findings and implications, followed by the limitations and future research directions.

## 2. Theoretical background and research hypotheses

Organizational learning theory serves as a theoretical underpinning for the association of exploration with NPD performance. Organizational learning is defined as the development of knowledge or insights that facilitate behavioral change (Hurley & Hult, 1998). According to the knowledge-based view, knowledge is an intangible resource that is difficult for competitors to replicate, and can thus provide a foundation for superior performance (Grant, 1996). Within this perspective, organizational learning has a great potential for affecting organizational outcomes (Auh & Menguc, 2005; Levinthal & March, 1993). Organizational learning has thus been seen as a means to generate capabilities that are valued by customers and difficult to imitate, hence bestowing competitive advantage (Crossan & Berdrow, 2003). For this reason, organizational learning may be the main determinant of the differences in firm performance.

As a manifestation of organizational learning, exploration refers to experimentation with new, nontraditional, and radically different alternatives (March, 1991). It entails activities such as search, variation, risk-taking, discovery, innovation, and research and development (Lewin & Volberda, 1999; March, 1991). The essence of exploration has been characterized as the pursuit of new

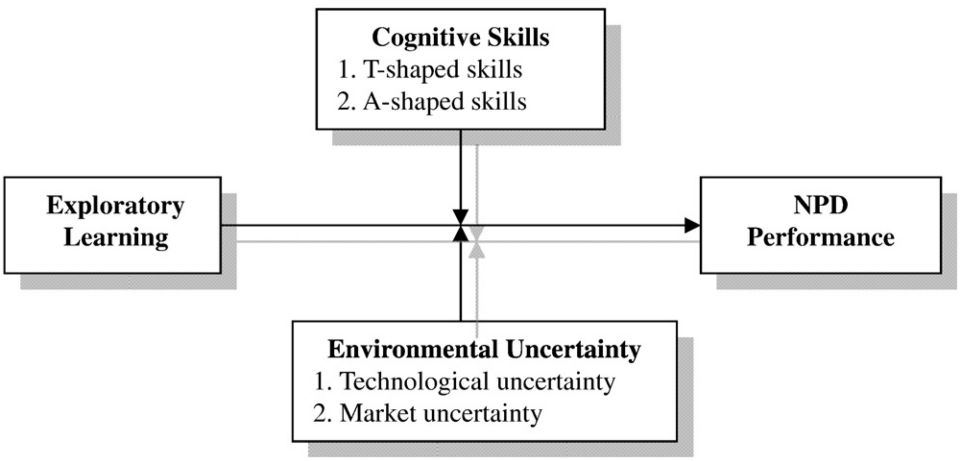


**Fig. 1.** Conceptual model.

knowledge and a boundary-spanning search for the discovery of new approaches to technologies, businesses, processes or products (Levinthal & March, 1993; McGrath, 2001; Sidhu, Volberda, & Commandeur, 2004). Simply put, exploration that focuses on changes, flexibility, and innovation allows for the creation of new organizational missions, forms, and practices.

March (1991) noted that organizational returns from exploration are systematically less certain, less clear, and more distant in time compared with returns from exploitation. In other words, the pursuit of new knowledge (e.g., radically new products, new markets, or new marketing programs) has more uncertain outcomes, longer time horizons, and more diffuse effects than does the exploitation of existing knowledge in the markets (Özsomer & Gençtürk, 2003). Therefore, exploration may be effective but inefficient at the same time due to its long-term nature (Levinthal & March, 1993). Scholars suggest that exploration has a positive impact on effectiveness, a longer-term aspect of performance (Auh & Menguc, 2005; He & Wong, 2004).

As mentioned above, burgeoning research has examined the relationship between exploration and performance. Nevertheless, the reported results are not conclusive. While several studies find a positive and linear relationship, others find a non-significant or U-shaped relationship (Auh & Menguc, 2005; Atuahene-Gima & Murry, 2007; He & Wong, 2004). This has been interpreted by Gupta, Smith, and Shalley's (2006) argument that exploration and exploitation might be orthogonal rather than the two ends of a continuum given that the analysis is at the group or organization level. The resources and routines necessary for exploration and exploitation are different, and must be delegated within a group or organization, so that both can be achieved simultaneously. For instance, while a cross-functional NPD team engages in a high degree of exploration in product R&D, they can simultaneously carry out a high rate of exploitation in complementary downstream activities such as manufacturing and sales. Along this vein, given the NPD context, exploration and exploitation can be regarded as two separate constructs. Thus, we concur with the view that proposes a linear relationship inasmuch as a high-high combination may exist.

Prior research has drawn on the concept of cognition to elucidate learning in groups and organizations (Anderson & Ausubel, 1965; Cook & Yanow, 1993). The term "cognition" is defined as the mechanism of information-processing (Reed, 1982) or data processing and storing in the human nervous system (Anderson & Ausubel, 1965). While investigating the learning phenomenon at group level, scholars suggest that the cognitive perspective is a good theoretical angle for capturing the aspects of human information-processing within groups (Akgün et al., 2006). Using the cognitive perspective, learning has been recognized as a combination of information-processing activities that includes the acquisition, interpretation, transmission, storing, retrieving, and using of information (Adams et al., 1998; Akgün et al., 2006). Since the entire NPD process is seen as a process of embodying new knowledge in a product (Madhaven & Grover, 1998), it entails a series of information-processing activities (Akgün et al., 2006; Yang, 2005). The ability to perform these activities is reflected in the cognitive skills (Akgün et al., 2006; Madhaven & Grover, 1998). Building on the cognition notion, we assert that the cognitive skills expedite the exploratory learning process, in turn enhancing NPD performance.

### *2.1. Exploratory learning and NPD performance*

Exploration involves the search for new and diverse information and knowledge that takes a firm beyond the scope of its experience and experimentation that yields variations in organizational activities (March, 1991). While a firm's primary interests are to probe for new market opportunities and latent market needs, exploration is relatively important. As Katila and Ahuja (2002) state, only a limited number of new ideas may be created using existing knowledge. NPD teams thus rely on exploration to increase their ability to add new elements to their knowledge repertoire because it facilitates and promotes the generation of new knowledge (Atuahene-Gima et al., 2005; Levinthal & March, 1993). In this way, team members can improve the possibilities for finding a new and useful combination, as well as for developing non-conventional problem solving during the NPD project.

In other words, exploration enables NPD teams to continually uncover new markets and develop technology and ideas that challenge the existing cause–effect relationships, thereby resulting in innovative products with unique benefits (Atuahene-Gima et al., 2005). By providing new insights into the design of new features and benefits in a product, exploration ensures that the new product will contain emergent ideas. These may differentiate the product from what competitors offer and thus be judged superior by customers (Katila & Ahuja, 2002). Thereby, it is postulated:

**Hypothesis 1.** Exploration is positively related to NPD performance.

### *2.2. The moderating role of cognitive skills*

A team's cognitive capability is manifested in the T-shaped skills of its members and A-shaped skills of the leader (Madhaven & Grover, 1998). According to Madhaven and Grover (1998), T-shaped skills connote both deepness factors (the vertical part of the "T") and broadness (the horizontal part of the "T") factors. People with T-shaped skills not only possess a deep knowledge of a discipline (like ceramic materials engineering), but they also understand how their branch of knowledge interacts with others to function as a whole (such as polymer processing).

As mentioned earlier, exploration concentrates on the pursuit of new knowledge aimed at innovation (Levinthal & March, 1993). Because knowledge derived from exploration is defined as novel, complex, diverse, and ambiguous (Atuahene-Gima & Murry, 2007), it is likely to be synergistic with T-shaped skills. Effectively interpreting and utilizing novel and unfamiliar knowledge requires T-shaped skills. People with these skills have the ability to combine theoretical and practical knowledge and to sustain meaningful conversations with others (Madhaven & Grover, 1998). They can expand their competence across several functional branch areas, and thereby develop systemic thinking skills (Johannessen et al., 1999; Lee & Choi, 2003). Accordingly, they can help their team organize market and technical knowledge in a systemic way (Johannessen et al., 1999). That is, such T-shaped skills provide a NPD team with a greater ability to comprehend a wide variety of new information and to integrating newly created knowledge with previous existing knowledge. As a result, NPD teams are better able to correctly interpret extensive new knowledge and further apply it effectively to a new product and process. Hence, it is posited:

**Hypothesis 2a.** The presence of team members with T-shaped skills positively moderates the relationship between exploration and NPD performance.

Likewise, the value of exploration to a firm is contingent on the knowledge creation process within NPD teams which is motivated and managed by team leaders (Sarin & McDermott, 2003; Söderquist, 2006). A-shaped skills refer to the team leaders with expertise in at least two disciplines (Madhaven & Grover, 1998). Team leaders with A-shaped skills will be more effective at knowledge development tasks than those without them, inasmuch as A-shaped skills allow them to combine insights synergistically from multiple knowledge sources (Madhaven & Grover, 1998). Particularly in a cross-functional context, team leaders with A-shaped skills are able to integrate multiple perspectives and manage conflicting technical trade-offs well (Madhaven & Grover, 1998). Synthesizing disparate views increases the variety and richness of available knowledge, which can be a catalyst for the creative ideas in NPD (Kessler et al., 2000; Kusonaki et al., 1998; Woodman, Sawyer, & Griffin, 1993; Yang, 2005).

Additionally, team leaders can craft a unified vision through the process of integrating and reconciling diverse ideas and views (Brown & Eisenhardt, 1995; Madhaven & Grover, 1998). This vision is one critical way by which leaders manage the tension between the exploration and exploitation paths to effective learning (Slater & Narver, 1995). As argued by Johannessen et al. (1999), vision steers the manner by which individuals manipulate new information and knowledge. For example, vision provides guidance regarding the type of knowledge to be pursued for innovation (Johannessen et al., 1999). Therefore, NPD teams can devote greater effort to developing the explicit and tacit knowledge sets most useful for generating innovations. In brief, leaders possessing A-shaped skills create a favorable condition that supports exploration.

Given that exploration relies heavily on novel knowledge and ideas, leaders with A-shaped skills can contribute by accelerating the knowledge creation process in order to boost product innovation. Hence, it is proposed:

**Hypothesis 2b.** The presence of a team leader with A-shaped skills positively moderates the relationship between exploration and NPD performance.

### *2.3. The moderating role of environmental uncertainty*

Galbraith (1973) defines uncertainty as the difference between the amount of information required to perform a task, and the amount of information already possessed by the organization. Milliken (1987) further defines uncertainty as the unpredictability of an environment, the inability to predict the impact of environmental change, and the inability to predict the consequence of a response choice.

Numerous researchers (e.g., Sutcliffe & Zaheer, 1998) have stressed that uncertainty is a complex construct in that it may be derived from different sources that include customers, suppliers, competitors, distributors, regulatory factors, union issues, technology, and so forth. Among these sources, technology and markets are the two best-known sources of uncertainty for organizations (Chen, Reilly, & Lynn, 2005).

Technological uncertainty denotes the perceived complexity of the technology, thus making it difficult for firms to make accurate predictions (Song & Montoya-Weiss, 2001). It is due to a lack of knowledge about the state of technological advances (Sutcliffe & Zaheer, 1998). Technological uncertainty is high where technology is new or rapidly changing (Chen et al., 2005). Market uncertainty refers to the instability or unpredictability of markets, changes in the market structure, or in the degree of competition (Bestieler, 2005). Generally, high market uncertainty results from a fast-changing market or an emerging, new market (Chen et al., 2005). Research on NPD indicates that environmental uncertainty originating in markets and technologies may have an impact on product development and ultimately on product performance (Bestieler, 2005; Jaworski & Kohli, 1993; Song & Montoya-Weiss, 2001). Following Shenar's (2001) suggestion, we explore the technological and market uncertainty as external dimensions of the NPD contingency.

In volatile markets, success relies more on creating new knowledge than on the ability to reconfigure and harness existing knowledge (Herrmann, Gassmann, & Eisert, 2007; Özsomer & Gençtürk, 2003). This is primarily because rapidly changing environments require firms to develop products fast enough to keep pace with changing customer demands and technological advances (Chen et al., 2005). Thus, a firm's rate of exploration and the rate of change in the environment must be in sync for a competitive advantage to be developed and be sustained.

If an environment is characterized by a high level of uncertainty, much technical and market information will emerge during typical timeline for project development thus requiring a reaction to newly discovered information (Bestieler, 2005; Iansiti, 1995). As Moorman and Miner (1998) report, product development performance is influenced by the real-time organizational information with regards to environmental changes throughout the NPD process. Exploration may be more suitable under conditions of high uncertainty as it places a greater significance on innovation and marketing research activities (Auh & Menguc, 2005; McDaniel & Kolari, 1987). NPD teams engaged in exploration will spend more time scanning their external environment and evaluating opportunities and threats. Subsequently, this will prompt them to implement formal procedures and systems for disseminating and assimilating knowledge in order to diminish the perceived uncertainty (Liao et al., 2003). By focusing organizational resources on monitoring, interpreting, analyzing, and predicting market needs and technological evolution, exploration augments a team's ability to add new variants of insights and novel information into NPD while increasing its problem-solving and innovative capacity (Atuahene-Gima & Murry, 2007; Levinthal & March, 1993; Lu & Yang, 2004; McGrath, 2001). Overall, exploration alerts NPD teams to latent and emerging market needs as well as technological developments that challenge current ideas and result in radical products with unique benefits.

Environments that are perceived to be highly uncertain appear to increase the value of search, flexibility, and experimentation. We therefore contend that exploration may have more advantages under conditions of high uncertainty. This discussion leads to the following hypotheses:

**Hypothesis 3a.** The positive effect of exploration on NPD performance is stronger when technological uncertainty is high rather than low.

**Hypothesis 3b.** The positive effect of exploration on NPD performance is stronger when market uncertainty is high rather than low.

## 3. Research method

### *3.1. Sampling*

Data for this study were collected from a survey of Taiwanese IT firms. We utilized a systematic random sampling procedure to draw a sample of 500 firms from the Taiwan Manufacturing Business Directory, published by the Chinese Credit Information Service, Ltd. We studied Taiwan's IT industry for two reasons. First, the IT industry is characterized by extremely short product life cycles and rapidly changing technologies. This compels firms to involve themselves heavily in exploration and NPD activities in response to the changes (Geiger & Makri, 2006). Second, Taiwan-made IT products dominate the global marketplace in many categories, and most of them share over 50% of the worldwide market (Lu & Yang, 2004). As representatives of the IT industry, Taiwanese companies can provide good insight into exploration and NPD.

The unit of analysis was the NPD project. We firstly contacted the preliminary informant in each firm (i.e., R&D, engineering, marketing, or new product managers) to solicit cooperation, and to identify the key informants. They were asked to help identify appropriate projects, project leaders, and one person directly involved in each project. The NPD projects were screened based on the following two criteria. First, all projects included in the study had been completed and launched within the previous three years. Since the data collected was primarily retrospective in nature, the recall time was restricted to three years in an attempt to improve the accuracy of retrospective reports (Miller, Cardinal, & Glick, 1997). Second, products must have been commercialized and launched into the marketplace at least six months prior to the assessment to ensure NPD performance could be assessed more accurately. Finally, 324 eligible projects were identified from 157 companies.

The conventional method of back-translation was used to translate the measures from English to Chinese. Two professional translators independently translated the English questionnaires into Chinese versions and the Chinese versions were back into English. The latter English versions were compared with the originals to assure that their meanings were consistent with the original concepts. The questionnaires were then pre-tested with 15 managers involved in NPD projects from six Taiwanese IT firms. Based upon the feedback, we refined the measures and ensured their relevance to the Chinese context. Subsequently, two structured questionnaires were developed and mailed separately to the project leaders and members. Project members were asked to provide information only about the A-shaped skills, while project leaders were asked to provide information about the exploratory learning, T-shaped skills, environmental uncertainty, and NPD performance. Project leaders were asked to answer the bulk of the items because they have a broader view of each member's behavior than other team members (Akgün et al., 2007), and were expected to offer more reliable and objective data (Kumar, Stern, & Anderson, 1993). By contrast, since it is A-shaped skills that are exhibited by project leaders, this scale was better evaluated by the members in order to minimize any ego-involved bias. To encourage participation, all informants were assured that their responses would be kept confidential and presented in an aggregated form only. We also promised to provide a summary of the study results to each respondent.

Altogether, we gathered 396 useable questionnaires on 198 NPD projects (117firms) after excluding 20 questionnaires due to missing data. This represents an effective response rate of 61%. The informants' average experience in NPD was 8.2 years, indicating that our informants were knowledgeable about the issues under study. Approximately 12% of the firms had more than 10,000 employees, 48% had between 1001 and 10,000, 21% had between 501 and 1000, and 19% had 500 or fewer employees.

We addressed the potential for non-response bias by comparing respondent firms and a group of 60 randomly selected nonparticipating firms, in terms of sales and employee numbers. The information was obtained from the Taiwan Economic Journal Data Bank. The results of the *t*-test demonstrate no significant between-group mean differences, suggesting that a non-response bias poses no problem in this research. The tests provided some assurance that the sample of responding firms was closely representative of the broader population surveyed (Armstrong & Overton, 1977).

### *3.2. Measures*

Table 1 presents the measures for the key variables. We measured all multi-item variables with seven-point scales (1 = "do not agree" to 7 = "completely agree"). Table 2 summarizes the correlation matrix and descriptive statistics for the variables.

**Table 1**
Confirmatory factor analysis results

| Measures | Standardized loading | *Z*-statistic |
|---|---|---|
| *Exploration (CR=0.90, AVE=0.74)* | | |
| 1. In information search, we focused on acquiring knowledge of project strategies that involved experimentation and high market risks. | 0.88 [a] | |
| 2. We collected novel information and ideas that went beyond our current market and technological experiences. | 0.89 | 17.78 |
| 3. Our aim was to acquire knowledge to develop a project that led us into new areas of learning such as new markets and technological areas. | 0.87 | 17.05 |
| 4. Our aim was to collect new information that forced us to learn new things in the product development project. | 0.82 | 15.15 |
| 5. We preferred to collect information with no identifiable strategic market needs to ensure experimentation in the project. | 0.85 | 16.40 |
| *T-shaped skills (CR=0.81, AVE=0.59)* | | |
| 1. Our project members can understand not only their own tasks but also others' tasks. | 0.61 [a] | |
| 2. Our project members can not only perform their own task effectively, but also make suggestions about others' task. | 0.87 | 8.31 |
| 3. Our project members can communicate well not only with their department members but also with other department members. | 0.80 | 8.28 |
| 4. Our project members are specialists in their own part. [b] | | |
| *A-shaped skills (CR=0.82, AVE=0.60)* | | |
| 1. Our project leader has specialized knowledge in more than one discipline. | 0.84 [a] | |
| 2. Our project leader is an expert in two or more fields. | 0.75 | 9.91 |
| 3. Our project leader is able to integrate different perspectives and ideas well. | 0.72 | 9.55 |
| 4. Our project leader can arbitrate and negotiate the conflict between the members from different departments. [b] | | |
| *Technological uncertainty (CR=0.82, AVE=0.53)* | | |
| 1. The technology in our industry is changing rapidly. | 0.84 [a] | |
| 2. It is very difficult to forecast where the technology in our industry will be in the next two to three years. | 0.76 | 11.09 |
| 3. Technological developments in our industry are rather minor (reverse coded). | 0.75 | 10.95 |
| 4. Technological changes provide big opportunities in our industry. | 0.53 | 7.37 |
| 5. A large number of new product ideas have been made possible through technological breakthroughs. [b] | | |
| *Market uncertainty (CR=0.86, AVE=0.62)* | | |
| 1. In our business, the customers' product preferences change quite rapidly. | 0.75 [a] | |
| 2. Our customers tend to look for new products all the time. | 0.84 | 12.05 |
| 3. Customer tastes and demands are fairly easy to forecast (reverse coded). | 0.81 | 11.50 |
| 4. New customers tend to have product needs that are different from existing customers. | 0.75 | 10.63 |
| 5. We cater to many of the same customers as in the past (reverse coded). [b] | | |
| *NPD performance (CR=0.78, AVE=0.55)* | | |
| 1. Our project successfully attained product sales relative to the objective | 0.76 [a] | |
| 2. Our project successfully attained market share relative to the objective | 0.79 | 9.51 |
| 3. Our project successfully attained profit margin relative to the objective | 0.66 | 8.30 |
| *Model fit indices* | | |
| $X^2$=309.69 ($p$<0.001), *df*=194, RMSEA=0.05, IFI=0.95, NNFI=0.94, CFI=0.95, GFI=0.87 | | |

[a] The *Z*-statistic is not available because the regression weight of the first item loading on each construct is fixed at 1.
[b] Item dropped as a result of scale purification.

### *3.2.1. Exploration*

Exploration was measured using a five-item scale developed and validated by Atuahene-Gima and Murry (2007). This measure gauged the extent to which the team members had acquired and used new knowledge during the NPD process for the purpose of experimentation.

**Table 2**
Descriptive statistics and correlation matrix

| Variable | Mean | S.D. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. NPD performance | 4.13 | 1.22 | | | | | | | | |
| 2. Exploration | 5.12 | 1.46 | 0.56** | | | | | | | |
| 3. T-shaped skills | 4.75 | 1.04 | 0.51** | 0.48** | | | | | | |
| 4. A-shaped skills | 5.10 | 1.73 | 0.20 | 0.05 | −0.26* | | | | | |
| 5. Market uncertainty | 4.36 | 1.12 | 0.08 | 0.12 | 0.06 | −0.12 | | | | |
| 6. Technological uncertainty | 4.85 | 1.34 | −0.31* | −0.01 | −0.07 | 0.11 | 0.14 | | | |
| 7. Firm size [a] | 7.36 | 1.55 | 0.19 | 0.16 | 0.06 | −0.07 | −0.12 | 0.14 | | |
| 8. Firm age | 10.01 | 7.40 | 0.06 | 0.20 | 0.14 | 0.10 | 0.11 | −0.17 | 0.07 | |
| 9. Team size | 25.05 | 24.69 | 0.08 | 0.16 | 0.19 | 0.34** | −0.13 | −0.24* | 0.18 | 0.06 |

* $p$<0.05 ** $p$<0.01 $N$=198.
[a] Natural logarithm of the number of employees.

#### 3.2.2. T-shaped skills

T-shaped skills were measured by using the instrument developed by Lee and Choi (2003). Respondents were asked to rate the extent to which the team members exhibited the T-shaped skills.

#### 3.2.3. A-shaped skills

There is no A-shaped skills scale in the academic literature. Following the procedure recommended by Churchill (1979), we created a four-item scale based upon Madhaven and Grover's (1998) conceptualization. Respondents were asked to indicate the extent to which their team leaders demonstrated the A-shaped skills.

#### 3.2.4. Technological and market uncertainty

These two measures were adapted from Jaworski and Kohli (1993). We measured technological uncertainty with five items that captured the perceived speed and magnitude of change and uncertainty in technology and the variety of new product introductions afforded by changing technology in the industry. The five items measuring market uncertainty reflected the speed of change in customer demand, product preferences, and emergence of new customer segments in the industry.

#### 3.2.5. NPD performance

As discussed earlier, exploration is associated with effective performance. Thus, we measured NPD performance with three items derived from Calantone, and Dröge (2003) by asking informants to assess the degree of a new product's success relative to expected objectives on sales, market share, and profit margin.

#### 3.2.6. Control variables

Three variables were controlled for in testing the hypotheses. Team size was measured by the number of project team members. Previous research suggests that the size of an NPD team can significantly affect a team's information processing and performance (Ancona & Caldwell, 1992). Firm size was measured as the natural logarithm of the number of fulltime employees. Similarly, large firms tend to have greater slack resources with which to enhance their innovation and NPD efforts (Geiger & Makri, 2006; Nohria & Gulati, 1996). Firm age is measured by the number of years elapsed after founding until the year 2007. It would predict performance according to Stinchcombe's (1965) argument of "liability of newness".

In order to address the common method variance issue, we took the following steps. First, we reverse coded some items in the questionnaire (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Second, as stated earlier, we collected the construct measures from both the project leaders and members. Third, we conducted a *post hoc* test, viz., the Harman's one-factor test in which all the variable measures were entered into a single factor analysis (Podsakoff & Organ, 1986). The analysis extracted 5 factors with eigenvalues greater than 1, accounting for 67% of the total variance. Neither a single factor nor a general factor accounted for the majority of the covariance in the measures, suggesting that common method variance was not a serious concern. In particular, considering that nearly all of our hypotheses were based on interaction effects rather than main effects, it is unlikely that common method bias would have produced our results. As scholars and methodologists have observed (e.g., Doty, Glick, & Huber, 1993; Evans, 1985), the complex data relationships shown by predicted interaction effects are not explained by common method bias because respondents are unable to guess the researchers' interaction hypotheses so as to respond in a socially desirable manner.

### 3.3. Measurement model

Adapting Anderson and Gerbing's (1988) two-step procedures, we developed a measurement model to perform a confirmatory factor analysis (CFA) before testing the hypotheses. The measurement model containing 22 items measuring the six first-order constructs. Each item was restricted to load on its *a priori* specified factor, with the underlying factors permitted to correlate (Gerbing & Anderson, 1988). In CFA, item measures that cross-loaded on different factors or had standardized factor loadings (SFL) less than 0.5 were eliminated from the model. Following purification, model fit indices ($\chi^2$=309.69, $p$<0.001, $df$=194, RMSEA=0.05, IFI=0.95, NNFI=0.94, CFI=0.95, GFI=0.87) indicate that the measurement model fits the data reasonably well.

We assessed the reliability and validity of the measures using Fornell and Larcker's (1981) stringent criterion. In the Table 1, the CFA showed that the composite reliabilities (CR) were all above the widely accepted threshold of 0.7, demonstrating strong reliability. Each of the 22 indicators loaded significantly onto its intended constructs ($p$<0.01) and the average variance extracted values (AVE) exceeded the level of 0.5 (Fornell & Larcker, 1981). Thus, all of the constructs exhibited convergent validity. Discriminant validity was established by verifying that the shared variances between the pairs of constructs were lower than the AVE estimates for the individual constructs (Fornell & Larcker, 1981). The shared variances between pairs of all possible scale combinations ranged from 0% to 31%, which is below the AVE estimates for each construct ranging between 53% and 74%. This satisfies the criterion for discriminant validity.

## 4. Analyses and results

The hypotheses were tested using hierarchical moderated regression analyses. As recommended by Aiken and West (1991), both independent and moderator variables were mean-centered to minimize the threat of multicollinearity in equations wherein we created interaction terms. The values of the variance inflation factor associated with each coefficient showed a range from 1.20 to 3.68, suggesting no serious problems with multicollinearity.

**Table 3**
Regression analysis of exploration and interactions on NPD performance

| Variables | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| *Controls* | | | |
| Firm size | 0.22† | 0.07 | 0.03 |
| Firm age | 0.07 | 0.09 | 0.15† |
| Team size | 0.11 | 0.16 | 0.17 |
| *Main effects* | | | |
| Exploration | | 0.45*** | 0.42** |
| T-shaped skills | | 0.27* | 0.20* |
| A-shaped skills | | 0.17† | 0.16† |
| Market uncertainty | | 0.02 | 0.01 |
| Technological uncertainty | | −0.31** | −0.30** |
| *Interactions* | | | |
| Exploration × T-shaped skills | | | 0.04 |
| Exploration × A-shaped skills | | | 0.31** |
| Exploration × Market uncertainty | | | 0.06 |
| Exploration × Technological uncertainty | | | 0.28* |
| $R^2$ | 0.05 | 0.52 | 0.62 |
| Adj. $R^2$ | 0.02 | 0.47 | 0.55 |
| $F$ | 1.40 | 9.29*** | 8.73*** |
| $\Delta R^2$ | | 0.47 | 0.10 |
| $F$ for $\Delta R^2$ | | 13.30*** | 4.16** |

† $p<0.1$ * $p<0.05$ ** $p<0.01$ *** $p<0.001$ $N=198$.

Our results are presented in Table 3. There are three models: a base model, a reduced model and a full model. The based model (Models 1) includes only the control variables. The reduced model (Models 2) incorporates both the control and main variables. The full model (Models 3) consists of all variables and tests the interaction effects. The change in $R^2$ between the reduced and full models is significantly different ($p<0.01$), suggesting the existence of moderating effects.

H1 posits that exploration is positively related to NPD performance. As shown in Model 1, exploration was found to be positively and significantly related to NPD performance ($b=0.45$, $p<0.001$). Hence, H1 was supported.

H2a and H2b explore the moderating effects of T-shaped and A-shaped skills, respectively, on the relationship between exploration and NPD performance. We found that the interaction between exploration and A-shaped skills was positively significant ($b=0.31$, $p<0.01$), but the interaction between exploration and T-shaped skills was insignificant ($b=0.04$, $p>0.05$). Therefore, only H2b was supported.

Finally, H3a and H3b postulate that technological and market uncertainty moderate the relationships between exploration and NPD performance, respectively. We found that the interaction between exploration and technological uncertainty was positively significant ($b=0.28$, $p<0.05$), but the interaction between exploration and market uncertainty was insignificant ($b=0.06$, $p>0.05$). In other words, only H3a was supported.

Nevertheless, Schoonhoven (1981) cautioned that merely inspecting the signs and magnitudes of regression coefficients is insufficient analysis for contingency hypotheses. To reconfirm the moderation effects, we conducted further analyses to identify any differences in the form of the relationship between the predictor variable (exploration) and the dependent variable (NPD performance) over the range of the moderator variables (A-shaped skills and technological uncertainty).

As per Aiken and West (1991), the analyses were performed by computing the partial derivative of NPD performance in the regression equation for exploration using the following partial differentiation equation: $\partial Y/\partial X=0.42+0.31\times$(A-shaped skills), where $X$=exploration and $Y$=NPD performance. The value of $\partial Y/\partial X$ is $\geq 0$ when the mean-centered value of A-shaped skills is $\geq -1.35$. Since the mean value of A-shaped skills is 5.10, the value of $\partial Y/\partial X$ is $>0$ when the uncentered value of A-shaped skills is $\geq 3.75$. It means that the effect of exploration on NPD performance is positive when A-shaped skills is $>3.75$ (i.e., measured to be somewhat higher than average), but it becomes negative when A-shaped skills is $<3.75$. Therefore, H2b was supported.

With respect to H3a, the partial differentiation equation is: $\partial Y/\partial X=0.42+0.28\times$(technological uncertainty), where $X$=exploration and $Y$=NPD performance. The value of $\partial Y/\partial X$ is $\geq 0$ when the mean-centered value of technological uncertainty is $\geq -1.50$. Since the mean value of technological uncertainty is 4.85, the value of $\partial Y/\partial X$ is $>0$ when the uncentered value of technological uncertainty is $\geq 3.35$. That is, the effect of exploration on NPD performance is positive when technological uncertainty is $>3.35$, but it is negative when technological uncertainty is $<3.35$. Hence, H3a was supported.

## 5. Discussion

By examining NPD teams in Taiwan's IT firms, this study dealt with the relationship between exploration and NPD performance while taking into account two aspects of moderating effects. We believe that our study makes a contribution to the literature of NPD and organizational learning.

Firstly, our empirical results show unequivocally that exploration is associated with NPD performance. The positive linear relationship not only reconfirms the findings of Auh and Menguc (2005), bus also resonates with Gupta et al.'s (2006) theoretical conjecture that exploration and exploitation may be orthogonal at the group and organization levels. Such findings suggests that, if firms are eager to succeed in highly volatile IT industry, their NPD teams may be well advised to put emphasis on exploration such as radical product innovation and competing product designs. Even though the returns from exploration are uncertain and remote in time, and the exploration *per se* is costly, it will eventually be rewarding. This is an especially important implication for IT firms that attempt to transfer themselves from original equipment manufacturing (OEM) businesses into original design manufacturing (ODM) or original brand manufacturing (OBM) businesses.

Furthermore, traditional technological life cycle (TLC) theory (e.g., Abernathy & Utterback, 1978) proposes that product innovation may have the highest payoff in the early stage of TLC and that process innovation may provide a greater payoff in the later post-dominant design stage, when incremental process innovation to reduce costs becomes more important. Although exploitation resulting in process innovation is widely recognized, an exploratory innovation may also lead to process innovation through the discovery of entirely new process technologies (e.g., in the semiconductor industry) (He & Wong, 2004). To assure long-term performance, firms can not forsake exploration at every stage. Otherwise, long-term performance will ultimately fall off as the accompanying costs surpass the rents attributable to product innovation.

Another contribution of this paper lies in the investigation of moderators. To the best of our knowledge, this study is the first to empirically examine the effects of T- and A-shaped skills on NPD. As predicted, exploration is more conducive to NPD performance when team leaders with A-shaped skills are presented in NPD teams. This finding bolsters the cognition perspective that individuals' cognitive attributes play an essential role in NPD team learning because they enable the team to organize market and technical knowledge into a meaningful pattern (Akgün et al., 2006; Madhaven & Grover, 1998). For instance, an NPD project manager who holds both a bachelor's degree in engineering and an MBA degree is better able to integrate insights synergistically from the two disparate knowledge areas. As such, he can help the team assess a new product design by synthesizing both engineering and market perspectives and thereby gauge its likelihood of successful launch more accurately. This importance has been recognized by practitioners, so that in Taiwan's IT industry, more and more senior engineering managers go back to universities to obtain an Executive MBA (EMBA) degree.

Yet, surprisingly, the T-shaped skills did not have a moderating effect, but rather a positive effect upon NPD performance ($b=0.20$, $p<0.05$). A plausible explanation could be that T-shaped skills may be a precursor to exploration in NPD teams. Sharma et al. (1981) suggested that a hypothesized moderator is perhaps an antecedent of other variables as the absence of interacting effect. We thus regressed T-shaped skills on exploration and found that it was indeed statistically significant ($b=0.48$, $p<0.001$), indicating that exploration may mediate the relationship between T-shaped skills and NPD performance. Specifically, team members endowed with T-shaped skills can understand the language of the several functional branches, allowing for the effective interpretation and use of novel knowledge (Johannessen et al., 1999; Kusonaki et al., 1998). This in turn fosters the kind of exploration that contributes to NPD performance. Consequently, firms should increase a team's cognitive capability by keeping the two types of skills in place. In this way, firms are well positioned to benefit from exploratory innovation. This also implies that IT firms focusing on exploration are encouraged to nurture the T- and A-shaped skills of personnel or employ people possessing them.

As expected, we found that technological uncertainty had a positive moderating effect. This result confirms that exploration is beneficial to NPD performance under conditions of high technological uncertainty. Our finding echoes Bourgeois' argument that "firms should only reduce uncertainty under stable environmental conditions and that uncertainty may be functional in volatile environments" (Bourgeois, 1985: 570, emphasis in original). Notably, although not hypothesized, technological uncertainty was found to be negatively and significantly related to NPD performance ($b=-0.30$, $p<0.01$). Hence, IT firms that confront technological uncertainty where it exists, via exploration, typically outperform those that disregard its presence.

Unexpectedly, market uncertainty did not moderate the relationship between exploration and NPD performance. This surprising result can be interpreted in the light of the nature of Taiwan's IT industry. Here, the main type of business is OEM/ODM. These OEM/ODM firms are not directly involved in their OEM/ODM clients' sales or marketing activities. Isolated from the ultimate customer (i.e., end user) base, Taiwanese IT firms tend to be less aware of the changes in the market demands or customer preference. This renders them incapable of making accurate interpretations and predictions. Stated differently, if they intend to transform their current businesses into OBM in the future, they should devote greater effort to understanding the market environments, and learn to ameliorate related uncertainties.

### *5.1. Limitations and future research directions*

In conclusion, we list two caveats that could limit the generalizability of our findings. First, as our sample firms were solicited from the IT industry, the findings should be interpreted in the strictest sense as applying only to this industry. Second, we used data from Taiwanese companies to test our hypotheses. It might be the case that the nature of these relationships varies between national cultures. Subsequent research can explore these issues using a broader research sample. Moreover, our investigation of T- and A-shaped skills also poses an interesting question: How are T- and A-shaped skills cultivated inside an organization? This merits further investigation inasmuch as prior theoretical works as well as our empirical efforts have suggested and demonstrated that the two cognitive skills occupy prominent roles in NPD.

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