



Management Science

Publication details, including instructions for authors and subscription information:
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To cite this article:

Pino G. Audia, Jack A. Goncalo, (2007) Past Success and Creativity over Time: A Study of Inventors in the Hard Disk Drive Industry. Management Science 53(1):1-15. <https://doi.org/10.1287/mnsc.1060.0593>

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Past Success and Creativity over Time: A Study of Inventors in the Hard Disk Drive Industry

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We integrate psychological theories of individual creativity with organizational theories of exploration versus exploitation to examine the relationship between past success and creativity over time. A key prediction derived from this theoretical integration is that successful people should be more likely to generate new ideas, but these ideas will tend to be less divergent as they favor the exploitation of familiar knowledge at the expense of the exploration of new domains. This prediction departs from the often-held view that people who generate more ideas will also generate ideas that are more divergent. Analyses of patenting in the hard disk drive industry support our prediction and indicate that collaboration with other inventors and organizational norms for exploration attenuate the tendency for successful individuals to generate increasingly incremental ideas.

Key words: creativity; exploration; exploitation; adaptor; innovator; incremental; divergent

History: Accepted by Scott Shane, technological innovation, product development, and entrepreneurship; received August 25, 2005. This paper was with the authors 4 months for 2 revisions.

Creative ideas are the raw material necessary for innovation, and a strong competitive advantage is conferred on organizations that are adept at eliciting creativity from their employees (Kanter 1988). Under the right circumstances, a single creative idea may be wildly profitable. Take, for example, one employee's idea for a "failed" adhesive that gave rise to the ubiquitous Post-it Note by the 3M Corporation (Collins and Porras 1994). One insight gave rise to three new product lines and a complete change in the company's strategic approach to innovation (von Hippel et al. 1999).

Creativity is most often defined as an idea that is both novel and useful (Amabile 1983). While most people associate creativity with dramatic breakthroughs that take a firm in an entirely new direction, like the Post-it Note, a growing body of research suggests that creativity may also reflect incremental advances on existing ideas (Mumford and Gustafson 1988, Basadur 1992, Herbig and Jacobs 1996, Houtz et al. 2003, Proctor et al. 2004). An idea may be both novel, useful, and therefore creative, even if it reflects continuity with existing solutions (Kirton 1976, Sternberg et al. 2003). This distinction may have considerable implications for managing creativity in organizations because extremely divergent ideas may be disruptive or risky (Christensen 1997). In fact, when an organization's environment is relatively stable, it may be useful to encourage the generation of

more incremental ideas that build on existing knowledge and skill (Sorensen 2002, Sternberg et al. 2003). Therefore, to effectively manage creativity in organizations, it is necessary to be able to understand the conditions under which people will tend to generate ideas that are divergent as opposed to incremental.

We propose that the experience of past success may be a critical but underexplored factor that may lead people to generate ideas that become increasingly incremental over time. The literature on the effect of performance on organizational behavior defines success as performance above an aspiration level (e.g., Cyert and March 1963, Greve 2003). According to March (1991), the experience of success contributes to a shift from the exploration of new ideas to the exploitation of existing solutions. These two types of behavior closely parallel the distinction made in the psychological literature between incremental versus divergent creativity (Taylor 1959, Kirton 1976, Torrance 1988, Sternberg et al. 2003). It is unfortunate that the two literatures, while complementary, do not speak to each other. On the one hand, researchers have applied theories of exploration-exploitation to the study of strategic alliances (Beckman et al. 2004, Rothaermel and Deeds 2004), product development (Holmqvist 2004), organizational innovation (Sorensen and Stuart 2000, Benner and Tushman 2002), and organizational performance (Lee et al. 2003, He and Wong 2004). However, theories

of exploration-exploitation have not yet been applied to the individual level. On the other hand, theories of incremental versus divergent creativity have conceptualized the distinction in terms of a stable cognitive style (Kirton 1994) without considering how past performance might impact creativity. Therefore, in this paper, we test a key prediction derived from the integration of the two streams of research: Successful people will be more likely to generate new ideas, but these ideas will tend to be more incremental over time.

This prediction departs from research on scientific creativity, which suggests that people who generate more ideas will also generate ideas that are more divergent and have more impact on their field (Simonton 2004). An underlying assumption of that alternative view is that the sheer number of ideas generated by an individual is positively correlated with the novelty or divergence of those ideas (Dennis 1966, Simonton 1977). For instance, some scientists have been found to produce their most highly-cited work during periods of peak productivity (Simonton 1984, 1985), leading to the argument that “Quality is a probabilistic consequence of quantity” (Simonton 1997, p. 73). In contrast, we argue that the generation of divergent ideas is not merely a statistical outcome. It may also be associated with the experience of success, which should in turn have a pervasive and predictable influence on the nature of subsequent ideas.

Divergent vs. Incremental Creativity

Creativity is typically defined as an idea that is both novel and useful (Amabile 1983, Stein 1974). For example, the Post-it Note was a creative idea in part because it offered a useful solution to a nagging problem experienced by a great many people. Notes that were taped to a desk or computer with a conventional adhesive were impossible to remove without either tearing the note to pieces or leaving a stain. However, the Post-it Note was creative not merely because it was useful; it also satisfied the second criteria of *novelty*. Art Fry recognized a novel use for an adhesive that everyone regarded as useless because it did not really stick. By diverging from everyone’s assumptions about adhesives, Fry was able to generate a truly creative idea (Collins and Porras 1994).

It is this second element of divergence from past solutions that people normally associate with creativity. Highly creative people tend to have personality traits such as independence of judgement, autonomy, and self-confidence (Barron and Harrington 1981) that allow them to break with the status quo and to diverge from their peers to suggest something “radically novel” (Barron 1969). Creativity, especially in Western cultures (Lubart 1999), is assumed to emerge from an atmosphere of deviance (Moscovici 1976) and

dissent (Nemeth and Wachtler 1983). This conception of creativity is also prevalent in organizations where employees are often instructed to “think outside the box” to come up with ideas that no one has yet suggested (Nemeth 1997).

The emphasis on divergence as an indicator of creativity can be traced to Guilford’s influential divergent thinking test (Guilford 1956, Mumford 2003). Using this test, creativity is measured by the extent to which people are able to generate a large number of ideas (fluency) that are different from one another (flexibility) (Guilford 1956, Mayer 1992). Following Guilford (1956), divergence in idea generation is central to most modern theories of creativity (e.g., Amabile 1988, Kanter 1988, Brophy 1998). However, there is increasing evidence that this focus on divergence as a critical component of creativity may only capture one side of a continuum because creative ideas may range from incremental to divergent, and not all creative ideas diverge significantly from an existing paradigm (Kuhn 1970, Houtz et al. 2003).

As early as 1959, Taylor suggested that there are many levels of creativity that differ in their emphasis on originality as opposed to the incremental improvement of an existing idea. He distinguished between *emergentive* creativity involving the generation of a completely new principle and *innovative* creativity involving improvements through modification (Taylor 1959, Torrance 1988). The distinction between divergent and incremental improvement is also prominent in more recent theories of creativity. For instance, Sternberg and his colleagues (2003) propose a propulsion model of creative leadership that differentiates between the concept of *forward incrementation*, in which progress is achieved through continuity with existing solutions and the concept of *redirective leadership*, in which a leader pursues an idea that diverges from the group’s current direction. New models of cars and new breakfast cereals are examples of forward incrementation because new versions of these products usually differ from the old versions in a predictable way (Sternberg et al. 2003). In contrast, when Mattel (a toy company) decided to invest in the Mickey Mouse Club television show to advertise directly to children, it was diverging significantly from any strategy it had used in the past (Sternberg et al. 2003).

Kirton (1976) proposed that the tendency to generate ideas that are divergent as opposed to incremental is rooted in a stable personality trait. According to Kirton (1976, p. 623), adaptors tend to “do things better” by generating new ideas within an established framework, while innovators “do things differently” by breaking with accepted modes of thought. He stressed that, “Although adaptors and innovators both create in their own way, the literature on

creativity has concentrated on describing innovators" (Kirton 1976, p. 623). In other words, the propensity to generate ideas that are incremental as opposed to divergent largely reflects a stable cognitive "style" defined as "peoples' characteristic and typically preferred modes of processing information" (Sternberg and Grigorenko 1997, p. 700) which is assessed by a widely used personality test (Kirton 1987, 1994).

Although it is certainly useful to have reliable measures of personality that can distinguish people based on their tendencies to adapt or innovate (Kirton 1994), it would also be useful to understand the situational factors that impact this tendency (Amabile 1983). For instance, are there certain conditions under which people are more likely to generate ideas that are divergent than to generate ideas that are incremental? We propose that the answer to such a question exists at the intersection of psychological theories of creativity and organizational theories of the exploration-exploitation trade-off (March 1991).

Past Success and the Exploration-Exploitation Trade-Off

Levinthal and March (1993, p. 105) define exploration as "the pursuit of new knowledge, of things that might come to be known" and exploitation as "the use and development of things already known." The distinction between these two broad types of behaviors parallels the distinction between divergent and incremental creativity made in the creativity literature (e.g., Kirton 1976, Sternberg et al. 2003). Like divergent creativity, exploration involves the search for knowledge that departs from an established direction, the potential generation of a completely new principle, and breaking with accepted modes of thought. Like incremental creativity, exploitation involves continuity with existing solutions, improvement through modification, and generating ideas within an established framework.

The theory of exploration-exploitation is potentially useful for understanding the creative process because it incorporates past success as a factor that impacts the propensity to explore new ideas. According to March (1991) and Levinthal and March (1993), individuals and organizations are sensitive to the risks inherent to exploration and exploitation. They will be especially inclined to take the risks inherent to exploration when they are still searching for adequate solutions. However, following success in their endeavors, they are likely to prefer exploitation over exploration because exploitation of knowledge that has proven to be effective guarantees more certain results and therefore reduces the risk that their efforts will lead to dead ends.

Applying this argument to creativity leads to the prediction that successful people should favor creativity that results from exploitation, that is, from refining

previously used combinations of familiar knowledge. A first implication of the tendency of successful people to generate new ideas by exploiting things they already know is that these individuals should have a higher creative output. The reason is that, to the extent that people draw from familiar knowledge, they should be not only faster in the execution of the creative idea, but also less likely to encounter unforeseen obstacles that can stifle the creative process because ideas that diverge from the status quo may not only turn out to be wrong, as March (1991) emphasizes, but they may also encounter resistance (Moscovici 1976).

A second implication emerging from the exploration-exploitation framework is that although people who experience success are more likely to generate new creative ideas, these ideas should be increasingly incremental over time and therefore less divergent. Applied to the individual level, research on the exploration-exploitation trade-off suggests that past success may operate as a constraint on the process of generating divergent ideas by focusing an inventor's attention excessively on knowledge that has already been used in the past. According to Amabile (1988), knowledge is "the raw material" of the creative process. She gives the example of the likely impact of knowledge in the realm of financial strategy: "Certainly, it is impossible to be creative in planning financial strategy unless one knows something (and probably a great deal) about the stock market, money markets, and current economic trends" (Amabile 1988, p. 131). The larger and the more diverse the knowledge base, the greater and the more diverse the number of possible combinations. For example, in an in-depth study of the process underlying the discovery of novel entrepreneurial opportunities, Shane (2000) found that individuals with broad prior knowledge were more likely than individuals with limited prior knowledge to conceive novel ways of representing the market, how to serve the market, and how to solve customers' problems.

While knowledge may well be "the raw material" in the creativity process, heuristics are equally important because they represent the way in which knowledge is combined. Creative people facilitate the combinatorial process by taking new perspectives on problems and applying new heuristics for the exploration of solutions (Amabile 1988, Simonton 2004, Miller 2000). The larger and the more diverse the set of heuristics used, the more diverse the possible combinations of the available knowledge. However, research on the exploitation-exploration trade-off suggests that success may constrain this component of the creative process by inducing individuals to focus narrowly on heuristics that worked in the past, encouraging them to refine well-known ways to combine knowledge

as opposed to exploring new approaches. This prediction is supported by considerable psychological research on cognitive framing, which suggests that when people have experienced success with a particular strategy, they often become narrowly focused on implementing that particular strategy to solve new problems (Duncker 1945, Luchins 1942). This type of mental block is called *negative transfer* (Bartlett 1958) and it has been found to deter the generation of novel solutions in a variety of situations such as negotiations over time (Bareby-Meyer et al. 2004), factory operation after a change in accident-monitoring devices (Besnard and Cacitti 2005), and firms acquiring targets from different industries (Finkelstein and Halebian 2002).

Perhaps the best illustration of this mental block comes from Duncker's (1945) series of classic experiments on functional fixedness. Duncker gave his subjects three cardboard boxes, matches, thumbtacks, and candles and asked his subjects to mount the candle vertically on a screen to serve as a lamp. However, half the subjects received the objects inside the cardboard boxes while the other half received the objects and the boxes separately. The correct solution to the problem was to tack the box to the screen, use the matches to melt the wax and attach the candle to the box and then light the candle. The problem was much more difficult to solve for those who received the objects in the boxes because they fixated on the boxes as merely containers and were unable to rethink the purpose of the box as a support instead of just a container. In other words, the past experience of seeing a situation in a certain way constrained the heuristics used in the creative process by limiting subjects from generating novel solutions.

The classic work on cognitive framing is foundational to modern theories of creative cognition. According to Ward (2004), creativity results from the application of mental operations such as analogies to existing knowledge structures. People store a wealth of information in the form of ideas or concepts and creative solutions emerge when pieces of prior knowledge stored in memory are combined in a novel way (Smith et al. 1995). Ward (1994) demonstrated the constraining effects of experience on creativity in a study in which he asked participants to draw an alien from another planet that was "beyond their wildest imagination." Instead of drawing radically different creatures, participants drew figures that conformed to the basic features of earth animals, such as bilateral symmetry (Ward 1994). The constraining effect of past experience was also demonstrated in a brainstorming study in which subjects were asked to generate new ideas; half the subjects were given an example to get them started and the other half were given no examples (Smith et al. 1993). This study found

that the groups who were given examples generated less creative ideas than the groups who were given no examples because their "new" ideas followed the examples too closely (Smith et al. 1993). These blocking effects may have considerable negative consequences for creative idea generation because people will suggest ideas that follow existing solutions too closely (Smith 2003).

In sum, success in generating an idea that is new and useful decreases exposure to new ideas and encourages the use of heuristics that worked in the past. These effects of success on two building blocks of the creative process facilitate the generation of ideas that are incrementally related to their initial idea. This argument comports with March's (1991) prediction that past success should lead to exploitation instead of exploration, but it suggests how the process might occur at the individual, instead of organizational, level of analysis. Thus, the experience of past success should have two very distinct effects on subsequent creativity. First, past success should influence creative output in terms of the sheer number of creative ideas an individual will generate over time, thus giving rise to the following hypothesis.

HYPOTHESIS 1. *An individual's past success in creative endeavors is positively related to the subsequent likelihood of generating creative ideas.*

In addition to the sheer number of ideas generated, however, past success should also influence an individual's subsequent tendency to generate ideas that are incremental extensions of his or her past work.

HYPOTHESIS 2. *An individual's past success in creative endeavors is negatively related to the subsequent propensity of generating creative ideas that diverge from his/her previous solutions.*

Moderators of the Relationship Between Past Success and Subsequent Creativity

The effect of success on creativity discussed above highlights how individuals learn from their own experience. It is clear, however, that learning and creativity may also be affected by features of the social context in which individuals operate (Amabile 1988). Here we extend our analysis by focusing on two characteristics of the social context that are likely to attenuate or exacerbate the relationship between success and creativity. If it is true that successful individuals generate increasingly incremental ideas because they frame creative efforts from the perspective of their initial ideas, then this tendency should be especially pronounced among people who work alone as opposed to collaborating with others. Divergent responses require people to question premises (Duncker 1945), to focus their attention on a broad range of information (Kasof 1997), and ultimately

to search for new solutions that extend beyond an existing train of thought (Mednick 1962). One way this exposure is achieved is by working and collaborating with others because different people might have different perspectives (Nemeth and Goncalo 2005). Groups of people working together can stimulate each other to arrive at more creative solutions (Osborne 1957, Torrance 1971) because they might have different and unique sets of knowledge and experiences that can be brought to bear on the problem (Stasser and Titus 1985). Also, simply being exposed to an alternative viewpoint can lead people to completely reappraise a problem from many different angles (Nemeth 1995). For instance, Choi and Thompson (2005) found that membership changes enhance the creativity of groups. This kind of stimulation is unlikely to occur when people work alone, thus allowing cognitive frames to persist and remain unquestioned for a longer period of time. March (1991) made a similar argument, but at the organizational level. He suggested that organizations can sustain exploration by acquiring new knowledge through personnel turnover. At the individual level, we suggest that exploration may be sustained through exposure to the ideas and viewpoints of collaborators. Therefore, we predict the following:

HYPOTHESIS 3. *The negative relationship between past success and the generation of divergent ideas will be moderated by whether individuals work alone or collaborate with others such that this relationship will be stronger when individuals work alone than when they collaborate with others.*

The link between past success and subsequent creativity may also be moderated by the extent to which the firm in which an individual works emphasizes the value of exploration. A norm is described as "...what most people do, and it motivates by providing evidence as to what will likely be effective and adaptive action" (Cialdini et al. 1990, p. 1015). Social psychologists have repeatedly demonstrated the power of norms for inducing a wide range of behaviors (Cialdini et al. 1990). In organizational settings, norms about which behaviors are more or less appropriate help individuals anticipate how other members are likely to react to their own attitudes and behaviors (Feldman 1984). Individuals then adjust their behaviors on the basis of these expectations. They increase the frequency of behaviors viewed by other members as desirable and reduce the frequency of behaviors perceived by other members as undesirable (Chatman and Barsade 1995, O'Reilly and Chatman 1996). In particular, norms may also influence the extent to which individuals engage in divergent creative efforts (Flynn and Chatman 2001). A well-known case in point is the product design IDEO,

which makes salient the importance of playful exploration through its hiring practices, core values, and brainstorming sessions (Sutton and Hargadon 1996). IDEO's emphasis on exploratory behaviors has made it one of the most successful and innovative product design firms of its kind. Successful individuals working in firms with a norm for exploration may therefore be less likely to generate incremental ideas as compared to successful individuals who work in firms that lack such norms.

HYPOTHESIS 4. *The negative relationship between past success and the generation of divergent ideas will be moderated by organizational norms encouraging exploration, such that it will be stronger for individuals belonging to organizations with a weak norm for exploration than for individuals belonging to organizations with a strong norm for exploration.*

Having an Impact: Divergent Ideas as a Foundation for Subsequent Creative Efforts

A final implication of the exploration-exploitation distinction concerns the extent to which creative ideas are path breaking. Studies of innovation suggest that a key distinguishing feature of a path-breaking idea is the impact it has on the direction of subsequent creative efforts (e.g., Podolny and Stuart 1995, Rosenkopf and Nerkar 2001). Much like academic articles whose importance is often measured by the extent to which they inspire future work within the scientific community (Feist 1994), path-breaking ideas open new avenues of inquiry and serve as the foundation for many subsequent developments. Creative ideas arising from exploration should be more path breaking because they reflect efforts that diverge from accepted modes of thought and from established directions (March 1991). This suggests that the extent to which ideas reflect diverging creative efforts should be positively associated with the impact they have on subsequent creative efforts (Ahuja and Lampert 2001). This logic is consistent with the view that creativity is a kind of investment (Sternberg and Lubart 1995). Creative ideas arising from exploration require a high level of investment up-front, but they are more likely to yield long-term dividends in the form of impact.

HYPOTHESIS 5. *The more an individual's creative solution diverges from his/her previous creative solutions, the greater the impact that a creative solution will have on others' subsequent creative efforts.*

Patenting History as a Measure of Creative Output

One of the biggest challenges in studying creativity is deciding what is "creative" in the first place (Amabile 1982). Although the measurement of creativity has been approached from a variety of angles, including personality traits (Helson 1996) and cognitive processes (Sternberg and Grigorenko 1997), we focus on

creativity as a product that can be assessed by people who are experts in a particular field (Amabile 1982). Patented inventions are one form of creativity in which creative outputs are both carefully scrutinized and publicly available. Therefore, following past research on creativity (Huber 1998, Ford and Harris 1992, Gilman 1992, Torrance 1988, Altshuller 1984, Albaum 1976, McPherson 1963, Rossman 1931), we use the frequency of patenting to indicate creative output, and patent characteristics to examine the degree to which creative output is divergent (or incremental). Of course, creative output can take many forms, including trade secrets and copyrighted material. Thus, it is important to keep in mind that the conclusions that can be drawn from our analyses are limited by the fact that we focus on one indicator of creative output. We return to this point in the discussion section.

According to the U.S. Patent Office, any person who “invents or discovers any new and useful process, machine, article of manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent” (U.S. Patent and Trademark Office). The basic requirement of a patent parallels the most widely used definition of creativity in the research literature: an idea that is both novel and useful (Amabile 1983). Invention as a type of creativity is probably subject to the most careful scrutiny, both in terms of defining what creativity means and elucidating the criteria used to identify a “creative” idea (Torrance 1988).

In addition to the fact that the definition of a patent so closely parallels the academic definition of a creative idea, the Patent Office itself actively promotes the idea that patenting is an activity that simultaneously stimulates creativity and requires creative thinking skills. According to Article I, Section 8, Clause 8 of the U.S. Constitution, the purpose of the patent itself is to “promote the progress of science and the useful arts.” It is widely acknowledged that the lawmakers who wrote this article were guided by the belief that people generate more creative ideas if they have the economic incentive to do so. Historians of creativity, for example, have noted that the modern idea of creativity itself can be traced to the emergence of patents: “It is clear that the idea of a patent is direct and strong testimony to the significance of creation in the modern sense of the word: It values innovation, prohibits imitation and gives economic advantage to the recipient” (Weiner 2000, p. 68). Even today, the U.S. Patent Office sponsors a major program to teach high school students creative thinking skills in an effort to stimulate the generation of new patents (<http://www.uspto.gov/web/offices/pac/doc/general/index.html#patent>). This is in line with its stated vision, which is “providing customer-valued intellectual property (IP)

rights that spark innovation, create consumer confidence, and promote creativity.”

The process through which an idea must go to be patented is also remarkably similar to one of the most influential methods of assessing creativity, the *consensual assessment technique* (Amabile 1982). This technique is based on the premise that a panel of expert observers can say, at an acceptable level of agreement, that some products are more creative than others (Amabile 1982). Following this logic, the actual work of deciding whether to grant or not to grant a patent is divided among a number of examining technology centers, each center having jurisdiction over a certain assigned field of technology. In other words, the technicians employed at these centers have both technical and legal training that qualifies them to make expert judgments about the usefulness and novelty of the inventions under review. Each year, more than 6,000 technicians decide on tens of thousands of patent applications. For instance, in 2003 there were approximately 360,000 patent applications, almost half of which were rejected. The considerable failure rate of patent applications suggests that the objection often raised by critics of the current patenting system that almost anything can be patented is either incorrect or applies only to some specific technological domains. It also supports the assumption made in studies of R&D management that obtaining a patent is generally considered an important creative achievement by both individual inventors and organizations (Hagedoorn and Cloudt 2003, Hauser 1998, Keller and Holland 1982).

An additional advantage of using patents is that they are carefully sorted into categories based on how similar they are to each other. Patents are classified according to classes and subclasses. Classes reflect broad technological areas, whereas subclasses reflect specific technological components within a given technological area. This categorization scheme allows us to measure the extent to which people generate patents that are similar to or different from their prior research efforts. It also mirrors the categorization scheme that is typically used to measure divergent thinking. In this scheme, ideas are categorized based on how similar they are to each other, and people who generate ideas that fall into fewer categories are considered less creative than people who generate ideas that fall into many categories (see Guilford 1956 and, more recently, Choi and Thompson 2005).

Method

Sample and Procedure

We study the patenting histories of inventors of hard disk drives, a computer component that stores programs and data. We chose this setting because in-depth studies of this industry reveal a high rate of tech-

nological innovation reflecting both incremental and divergent creative efforts (Christensen 1997). Focusing on a specific technological area allows us to control for industry-level effects. Industries are known to vary in their propensity to patent, and such variations would complicate comparisons of inventors' creative output across industry boundaries. Furthermore, technological areas are subject to evolution processes that may influence the rate and type of innovation (Tushman and Anderson 1986). By studying only one industry, we can control for such processes by including a time variable in the analyses.

Because we are interested in examining the patenting histories of inventors of hard disk drives and because the focus of the study is on creativity over time, the sample includes inventors who applied for at least one patent and were employed by U.S. firms specializing in this computer component. Inventors in diversified firms such as IBM, Digital Equipment, or Hewlett-Packard are excluded because it was difficult to identify a priori whether they specialized in hard disk drives.

Information about patents was obtained from the U.S. Patent Office databases and Derwent Information, a firm specializing in patent searches. The firms specializing in hard disk drives were identified using *Disk Trend*, a comprehensive industry publication that lists hard disk drive manufacturers. Fourteen of the U.S. firms listed were considered to be specialists because they derived 75% or more of their revenues from sales of hard disk drives. The observation window goes from 1978, the year in which the first patent application was made by a specialist firm, to 1998. In 1998 there were still four firms in existence—Maxtor, Quantum, Seagate Technologies, and Western Digital.

To assemble complete patenting histories of inventors in the sample, we incorporate information about patents they obtained before 1978 and during employment spells at nonspecialist firms. Inventors' patenting histories are terminated (or right censored) either in 1998, if their firm was still in existence at that time, or the year in which the company they last patented with ceased operations. When a patent has multiple inventors, we attribute it to each inventor listed as coauthor (cf. Ernst et al. 2000) and include in our analyses a control variable that captures inventors' propensity to patent alone or with other inventors to take into account the effect of collaboration on the creative output. Our sample includes 372 inventors to whom were assigned 2,037 patents. Of these inventors, approximately 7% had more than 10 patents. Because the analyses are conditional on inventors already having one patent, 1,665 patents enter the models.

Measures

Success. Consistent with research on the effect of performance on organizational behaviors (Cyert and

March 1963, Greve 2003), our measure of success is based on the assumption that individuals determine whether they are performing well or poorly by comparing themselves to similar others. Here, we assume that inventors specializing in hard disk drives compare themselves to peers in similar firms. Specifically, we compute the number of patents generated by each inventor in the previous two years minus the average number of patents generated by all the inventors specializing in the hard disk drive industry over the same period. Past studies consistently suggest that the number of patents is a key indicator of innovative performance. Hagedoorn and Cloodt (2003), in a recent study of 1,200 companies in four high-tech industries, concluded that the number of patents is an indicator that captures the innovative performance of companies (see also Hauser 1998). At the individual level, Keller and Holland (1982), in a study of 258 R&D professionals, found that an inventor's number of patents was positively and significantly correlated to both superior's ratings of performance and self-ratings of performance. The yearly average number of patents generated by inventors specializing in hard disk drives varied between 0.71 and 1.33 over the period of the study. We focus on the previous two years because time has to elapse for performance to influence an inventor's creativity, and past studies have shown that R&D lags between 10 and 18 months from project inception to completion in the computer industry (Iansiti 1997, Pakes and Shankerman 1984). Nonetheless, exploratory analyses in which we used three-year and four-year time windows showed that the success measure was not sensitive to the length of the period used.

Divergence from Previous Patented Ideas. We use two measures to detect the extent to which a patent diverges from an inventor's previous patents. Both measures are derived from information contained in patent documents. The first is the *number of new subclasses* in which a patent is classified that are new to the inventor. Patents are classified according to classes and subclasses. Classes reflect broad technological areas, whereas subclasses reflect specific technological components within a given technological area (e.g., Fleming 2001). Patents about hard disk drives and their components fall into three classes—360, 369, and 428—which together comprise more than 1,000 subclasses. For example, between 1988 and 1990, Frederick Stefansky generated five patents that fall into class 360—dynamic magnetic information storage or retrieval—the main class for hard disk drive technology. His patents also fall into a total of 10 subclasses corresponding to the following technological components: head control (75), track changing (78), disk record (97 and 264), plural disks (98),

latch (256), storage density (902), physical parameter (903), weight (904), and miscellaneous (137). Three of these patents fall into subclasses in which he had not previously patented, which suggests that these patents were developed using components that were new to the inventor. However, two of the patents—5,029,026 and 4,979,062—fall into subclasses in which the inventor had previously patented, which indicates that they were developed using components with which the inventor was already familiar.

The second measure is *the number of new citations made*. When a patent is granted, a document is created containing information about the invention, including references to patents on which the invention builds—i.e., citations, also known as *prior art*. Studies of patenting at the organizational level detect the use of new knowledge on which patents build by identifying citations that were not previously made in the organization's own patents (Benner and Tushman 2002). Drawing from this work, we define new citations at the level of the individual inventor as citations to patents that were not previously cited in the inventor's patents. We exclude from this measure citations to the inventor's own patents even when these are made for the first time. We also exclude from this measure citations to the organization's own patents because inventors are likely to be familiar with their colleagues' creative output due to social contacts eased by propinquity, intraorganizational collaborative relationships, and information sharing motivated by the pursuit of departmental goals.

Working Alone. We measure the extent to which an inventor works alone by computing the inventor's *proportion of patents in which he/she is the sole inventor*. This is a necessary control variable because inventors who collaborate less should be less likely to patent. However, we also expect an interaction with success, such that those who collaborate less should be more susceptible to the positive effect that success has on the propensity to generate incremental creative output than those who collaborate more.

Organizational Norm for Exploration. Past studies suggest that an organization's emphasis on the importance of exploratory behavior is reflected in the kinds of patents that it generates in aggregate (Sorensen and Stuart 2000, Benner and Tushman 2002). Drawing on that work, we measure the extent to which organizations embrace norms for exploration by computing an organization's *proportion of patents that enter new subclasses* and an organization's *proportion of patents that make new citations* over the past two years.

Impact. Studies of patenting (Ahuja and Lampert 2001, Fleming 2001, Rosenkopf and Nerkar 2001, Sorensen and Stuart 2000) also suggest that the impact of a patented idea is evidenced by the *number of*

citations that a patent receives after it is granted. The more a patent is cited, the more it is used as a foundation for subsequent creative efforts. This variable excludes self-citations, which would reflect inventors' tendency to build on their own work rather than other inventors' recognition of the importance of a patent. Note that in contrast to the number of citations made, which is constructed from the citations made by a patent to earlier patents, our measure of impact utilizes citations received from subsequent patents. Because patents granted in earlier years are likely to have more citations than patents granted in later years, the model predicting impact controls for the number of years elapsed between the patent application year and 1998 (i.e., 1998—calendar year). This variable is expected to have a positive effect on the number of citations a patent receives.

Control Variables. Inventors' timing of entry in the sample is recorded using three cohort variables that identify whether inventors had their first patent on or before 1980, between 1981 and 1990, or between 1991 and 1998. These variables control for any effect of aging on creativity. The cohort with the first patent on or before 1980 is the comparison group and therefore is not included in the models. We also control for the effect of the size of an organization's R&D activities by including in the models the total number of patents granted to the organization employing the inventor, and for organizational differences that remain constant over time by including firm-level fixed effects.

Results

Means, standard deviations, and intercorrelations for the study are reported in Table 1. We test Hypothesis 1, that people who experience success in a creative domain are more likely to generate a new creative idea, with event history analysis rather than logistic or Poisson regression. The primary reason for this choice is that event history analysis incorporates more extensive information about the relative likelihood of generating a new creative idea, and therefore provides more accurate estimates of predictor effects (Blossfeld and Rohwer 1995). Using logistic or Poisson regression would require examining the extent to which success in creative endeavors at time T1 (e.g., number of patents between January 1980 and January 1982 minus industry average) influences creativity at T2 (e.g., number of patents between January 1982 and January 1983). By compressing the generation of creative ideas in one point over the course of a year, this approach would discard useful information about the precise interval of time between the generation of creative ideas. Instead, an event history analysis allows us to model with precision the length of time in days

Table 1 Descriptive Statistics and Correlations

	Mean	SD	Min.	Max.	Correlations											
					1	2	3	4	5	6	7	8	9	10	11	12
1. Inventor's success	−0.018	0.415	−1.311	0.995												
2. Inventor's proportion of sole-inventor patents	0.177	0.307	0	1	−0.042											
3. Organization's stock of patents	78.206	94.3	0	321	−0.048	0.026										
4. Cohort 1981–1990	0.477	0.499	0	1	−0.084	0.127	−0.114									
5. Cohort 1991–1998	0.401	0.49	0	1	0.128	−0.127	0.27	−0.781								
6. New subclasses	1.981	1.849	0	24	−0.11	−0.115	−0.152	0.006	−0.006							
7. New citations made	4.176	5.241	0	51	−0.037	−0.012	−0.144	0.081	−0.142	0.136						
8. Citations received	12.655	17.514	0	149	−0.01	−0.045	−0.325	0.152	−0.223	0.252	0.149					
9. Organization's proportion of patents entering new subclasses	0.848	0.133	0	1	−0.07	−0.08	−0.24	0.01	0.01	0.24	0.03	0.20				
10. Organization's proportion of patents making new citations	0.796	0.246	0	1	−0.01	−0.05	0.06	0.21	−0.25	0.09	0.34	0.14	−0.02			
11. Number of subclasses	2.66	1.84	1	29	−0.04	−0.10	−0.13	0.04	−0.05	0.83	0.11	0.24	−0.24	0.01		
12. Number of citations made	10.60	12.23	0	117	0.08	−0.02	−0.02	−0.06	−0.01	−0.09	0.35	−0.07	−0.24	0.01	−0.01	
13. Year	1992.44	4.353	1971	1998	−0.027	0.06	0.531	−0.183	0.476	−0.424	−0.187	−0.424	−0.21	−0.24	−0.15	0.12

Note. Correlations with absolute values >0.045 are significant at the 0.05 level; $N = 1,665$.

until a new creative idea is generated. Another advantage of event history models is that they allow us to record right-censored observations that occur when information about the occurrence of the event, in this case patenting, is incomplete because the sample ends at a certain point in time (Blossfeld and Rohwer 1995). Unlike logistic or Poisson regressions, event history methods produce estimates that take into account the difference between censored and uncensored cases.

Within event history models (Blossfeld and Rohwer 1995), we use the proportional hazard rate model, also known as the Cox model, because (1) the study does not include hypotheses examining how the passage of time influences the probability of patenting; and (2) Hypothesis 1 focuses on indentifying the effect of creative success on the probability of generating a new creative idea at any point in time. Note that, as in other studies of patenting behavior (e.g., Fleming 2001, Sorensen and Stuart 2000), we focus on patent application dates rather than patent issue dates because the time employed by the U.S. Patent Office to process an application is largely outside inventors' control. We use robust standard errors adjusted for clustering at the inventor level to allow for non-independence of the observations belonging to the same inventor. We also control for firm-level effects by allowing the baseline hazard function to vary across firms, using stratified estimation. Exploratory analyses showed that stratified models fit significantly better than unstratified ones. The estimates were obtained using the `stcox` command in Stata.

The results of the event history analyses are reported in Table 2. The coefficients in Model 1 reveal several significant effects of the control variables.

Inventors with a greater fraction of sole inventor patents are less likely to patent. Inventors employed by organizations with a greater stock of patents are also less likely to patent. Inventors who enter the sample after 1980 are more likely to patent than inventors who had their first patent before 1980, an effect that may reflect the consequences of aging. Finally, Model 1 also includes a control variable specific to event history methods, the cumulative event occurrence (Blossfeld and Rohwer 1995), which in this case is the cumulative number of patents belonging to an inventor. This variable allows us to control for unobserved factors that may drive the probability of

Table 2 Cox Models Stratified by Firms of the Probability of Patenting

	Model 1	Model 2	Model 3 Inventor-specific fixed effects
Inventor's proportion of sole-inventor patents	−0.315* (0.094)	−0.311* (0.091)	−1.128* (0.136)
Cohort with first patent in 1981–1990	0.566* (0.111)	0.545* (0.111)	0.595 (0.866)
Cohort with first patent in 1991–1998	1.217* (0.131)	1.175* (0.136)	−0.445 (0.766)
Organization's stock of patents	−0.002* (0.001)	−0.002* (0.001)	−0.003* (0.000)
Cumulative inventor patents	0.080* (0.013)	0.076* (0.014)	0.064* (0.008)
Inventor's success		0.139* (0.068)	0.220* (0.070)
Log likelihood	−6,453.03	−6,450.92	−10,345.64
Spells	3,592	3,592	3,592
Events	1,665	1,665	1,665

* <0.05 significance level.

patenting (e.g., talent) and shows that the probability of patenting increases as the cumulative number of patents increases. After controlling for these variables, Model 2 shows that inventors with a successful record over the previous two years are more likely to patent, that is, to generate creative ideas, as predicted by Hypothesis 1. Focusing on inventors who display extreme values on the success variable, the coefficient implies that the least successful inventors are 31% less likely to patent than the most successful inventors ($e^{(-1.31 \times 0.139)} - e^{(0.99 \times 0.139)} = -0.314$).

A skeptic could argue that successful inventors patent more simply because they choose to make small increments in a limited domain. In other words, success may be a consequence of an inventor's research strategy rather than a factor that influences subsequent patenting behavior. To account for this potential effect, we conducted an event history model with inventor-fixed effects. These effects control for any unobserved inventor's characteristic that remains constant over time. The results reported in Model 3 indicate that the pattern of results remains unchanged. Therefore, to the extent that a hypothetical inven-

tor's research strategy does not change over time, our results rule out this alternative explanation.

While this evidence indicates that successful inventors are more likely to generate creative ideas, the results in Table 3 help us understand the extent to which these ideas are incremental or divergent. To test Hypotheses 2, 3, and 4, we conduct Poisson regressions because the dependent variables (number of new subclasses and number of new citations) are count variables that take only nonnegative values. We estimate Poisson regressions with random effects to control for unobserved inventor-specific effects that may be a source of serial correlation. The random effect specification includes an inventor-specific effect that permits observations of the same inventor to be correlated. Because the dependent variables in these models may simply reflect a tendency to generate patents that fall into many subclasses or patents that make many citations, we also control for the number of subclasses into which a patent falls and the number of citations that a patent makes. Model 1 shows that the proportion of sole-inventor patents

Table 3 Poisson Regressions of Patent Characteristics Indicative of Diverging Creative Efforts

	Number of new subclasses			Number of new citations made		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Inventor's proportion of sole-inventor patents	-0.106* (0.071)	-0.119* (0.071)	-0.18* (0.075)	0.071 (0.058)	0.039 (0.058)	0.114 (0.06)
Cohort with first patent in 1981–1990	0.001 (0.08)	0.016 (0.079)	0.017 (0.078)	-0.008 (0.125)	0.026 (0.124)	0.015 (0.125)
Cohort with first patent in 1991–1998	0.071 (0.082)	0.101 (0.082)	0.094 (0.082)	-0.017 (0.126)	0.055 (0.126)	0.059 (0.127)
Number of subclasses	0.236* (0.01)	0.234* (0.01)	0.232* (0.01)			
Number of citations made				0.022* (0.001)	0.022* (0.001)	0.022* (0.001)
Organization's stock of patents	-0.001* (0.000)	-0.001* (0.000)	-0.001* (0.000)	-0.001* (0.000)	-0.001* (0.000)	-0.001* (0.000)
Organization's proportion of patents with new subclasses	1.63* (0.21)	1.597* (0.209)	1.622* (0.209)			
Organization's proportion of patents with new citations				3.827* (0.159)	3.869* (0.158)	3.981* (0.166)
Inventor's success		-0.131* (0.050)	-0.141* (0.051)		-0.264* (0.37)	-0.299* (0.044)
Success \times proportion sole-inventor patents			-0.408* (0.160)			0.637* (0.120)
Success \times proportion patents with new subclasses			0.913* (0.414)			
Success \times proportion patents with new citations						0.601* (0.299)
Constant	-0.014 (0.082)	-0.025 (0.082)	-0.007 (0.081)	0.958* (0.118)	0.906* (0.117)	0.891* (0.118)
Log likelihood	-2,502.57	-2,499.25	-2,493.41	-4,714.99	-4,690.19	-4,673.88
<i>N</i>	1,665	1,665	1,665	1,665	1,665	1,665

* <0.05 significance level.

and the organization's stock of patents decrease the probability that a patent falls into new subclasses, whereas an organization's proportion of patents with new subclasses increases it. Furthermore, the number of subclasses into which a patent falls is positively associated to the probability that a patent enters new subclasses. After controlling for these variables, Model 2 shows that success over the previous two years decreases the probability that a patent falls into new subclasses. Comparing inventors who display extreme values on the success variable, we find that the coefficient implies that the most successful inventors are 30% less likely to generate patents that fall into new subclasses than the least successful inventors ($e^{(0.99*-0.131)} - e^{(-1.31*-0.131)} = -0.308$). This finding therefore supports Hypothesis 2. Model 3 adds interaction terms to test Hypotheses 3 and 4. The interaction between success and the proportion of sole-inventor patents is negative and significant. Focusing on the most successful inventors, we find that those who always patented alone compared to those who never patented alone are 38% less likely to generate patents that enter new subclasses ($e^{[(0.995*-0.141)+(1*-0.18)+(0.995*1*-0.408)]} - e^{[(0.995*-0.141)+(0*-0.18)+(0.995*0*-0.408)]} = -0.385$). This finding therefore supports Hypothesis 3, that the negative effect of past success on the tendency to generate divergent ideas will be more pronounced among people who work alone than among people who collaborate with others. Furthermore, the interaction between success and the organization's proportion of patents that enter new subclasses is positive and significant. Again, focusing on the most successful inventors, the coefficients imply that those who belonged to organizations that had a proportion of patents that entered new subclasses one standard deviation below the mean (i.e., weaker norm for exploration) compared to those who belonged to organizations that had a proportion of patents that entered new subclasses one standard deviation above the mean (i.e., stronger norm for exploration) are more than five times less likely to generate patents that enter new subclasses ($e^{[(0.995*-0.141)+(0.751*1.622)+(0.995*0.751*0.913)]} - e^{[(0.995*-0.141)+(0.981*1.622)+(0.995*0.981*0.913)]} = -5.095$). This finding therefore supports Hypothesis 4, that the negative effect of past success on the tendency to generate divergent ideas will be more pronounced among people who work in organizations with weaker norms for exploration than among people who work in organizations with stronger norms for exploration.

Additional support for our hypotheses comes from the results regarding the number of new citations reported in Models 4 through 6. Model 5 shows that the patents of inventors who experienced success over the previous two years are less likely to make new citations, in line with Hypothesis 2. Furthermore,

Table 4 Ordinary Least Squares Regression of Citations Received

Number of new subclasses	1.537* (0.212)
Number of new citations made	0.189* (0.074)
1998—patent application year	1.5235* (0.091)
Constant	0.356 (0.717)
R-square	0.21
N	1,665

* <0.05 significance level.

Model 6 shows that the interaction between success and an organization's proportion of patents is positive and significant. This means that in organizations in which the proportion of patents that make new citations is greater, the probability that a patent generated by a successful individual makes new citations is higher, as predicted in Hypothesis 4. However, contrary to Hypothesis 3, the interaction between success and the proportion of sole-inventor patents is positive and significant, which indicates that an inventor's proportion of sole patents increases the probability that successful individuals make new citations. Perhaps this unexpected finding is due to the fact that citations are often added by patent lawyers. It may be that their propensity to add citations that were not originally included in patent applications is higher when inventions are generated by sole inventors due to a belief that sole inventors engage in narrow searches.

Finally, Table 4 reports regression analyses conducted to test Hypothesis 5. Both the number of new subclasses and the number of new citations made are positively associated to the number of citations received by subsequent patents. Therefore, this evidence supports Hypothesis 5, that the extent to which a creative idea diverges from previous creative ideas will be positively related to the impact it has on subsequent creative efforts. The effect of new subclasses is more pronounced. The coefficient implies that a standard deviation increase in the number of new subclasses is associated with an increase of approximately three citations received (1.85×1.53).

Discussion

By integrating the psychological research on incremental versus divergent creativity (Kirton 1976) with organizational theories of exploration versus exploitation (March 1991), we identified success in creative endeavors as an important condition influencing whether people will generate ideas that are divergent

as opposed to incremental. Empirical analyses of the patenting histories of individual inventors in the hard disk drive industry provide support for our hypotheses. Successful inventors were more likely to generate new patents (Hypothesis 1), but these patents tended to be less divergent from their previous work (Hypothesis 2) on two important indicators, entry into new subclasses and number of new citations made. Furthermore, the tendency of successful inventors to generate incremental ideas was more pronounced among inventors who work alone (Hypothesis 3) and among inventors who work in organizations with weaker norms for exploration (Hypothesis 4). The moderating effect of collaboration, however, was found only in our analysis of whether patents enter new subclasses. These results are especially significant in light of the fact that more incremental ideas were less likely to have an impact on their field as measured by the number of times they were cited by other inventors (Hypothesis 5). In other words, the distinction between incremental and divergent creativity is not merely theoretical, but also has practical significance.

Our results are counterintuitive in light of creativity research suggesting that the way to generate divergent ideas is to generate a lot of ideas (Amabile 1988, Dennis 1966, Osborne 1957, Simonton 1977). From a purely statistically perspective, this premise makes a great deal of sense (Dennis 1966). However, as the results suggest, the experience of success may be an important boundary condition to consider. If people's thinking is narrowly focused on the refinement of existing ideas, then more ideas may not necessarily result in more divergent ideas. The creative process may actually be path dependent: Once an individual generates a creative idea, future creative efforts may be framed from the perspective of the initial idea. Our results therefore suggest that it is important to observe not only an individual's creative output over time, but also the underlying qualities of the ideas generated, such as their divergence from past solutions and the extent to which they draw from existing knowledge.

Our findings also contribute to the small but growing psychological literature on incremental versus divergent creativity (Kirton 1976, Houtz et al. 2003). Current research suggests that the tendency to generate incremental ideas is driven by an underlying cognitive style (Kirton 1994) that is essentially stable across different situations over time. From this perspective, it is necessary to develop personality tests that will separate divergent thinkers from their incremental counterparts and select people based on their underlying tendencies. In contrast, our research suggests that people who are adept at divergent creativity may actually become more incremental in their

thinking over time and as a result of past experiences of success. Therefore, the distinction between divergent and incremental creativity may be more situationally determined than is currently assumed (Kirton 1987).

This paper also extends existing research on the exploration-exploitation trade-off, which thus far has been focused on organizational-level processes. For instance, Sorensen and Stuart (2000) found that as organizations age they show a greater tendency to build on their previous innovative activity than to explore new domains. They attributed this finding to the bureaucratization that accompanies organizational aging. Consistent with their interpretation, Benner and Tushman (2002) found that the adoption of process management activities increases firms' propensity to favor exploitation of familiar knowledge at the expense of exploration of new technological areas. Although this empirical work helps explain why organizations differ in their exploratory and exploitative behaviors, little is known about the conditions that may explain intraorganizational variation. By examining the exploitation-exploration trade-off at the individual level, our study takes a step toward filling that gap.

Our results support March's (1991) suggestion that success is a key reason why exploitation often drives out exploration. However, whereas March places special emphasis on the importance of success at the level of the organization, our results indicate that the experience of personal success is also an important influence on how individuals balance the tension between exploratory and exploitative behaviors and that this influence is moderated by characteristics of the social context within which individuals operate. Differences in individual performance within an organization, then, should be considered a source of intraorganizational variation in exploratory versus exploitative behaviors, and greater attention should be directed to the link between individual-level processes and organizational-level processes.

This study suggests several interesting parallels between theories of organizational learning (March 1991) and theories of individual creativity (Kirton 1976) that can be used to guide future research in this area. For instance, the concepts of exploration versus exploitation are directly comparable to the distinction between divergent versus incremental creativity. The notion that past success leads to an excessive focus on the exploitation of previous solutions is parallel to the research on cognitive framing at the individual level. Also, the idea that people can break these cognitive frames by collaborating with others is closely related to March's (1991) proposition that exploration can be stimulated through increased turnover. These

logical parallels suggest that exploration at the organizational and individual levels may be isomorphic (House et al. 1995). A classical example of isomorphism is the threat rigidity hypothesis that stress leads individuals, groups, and organizations to rely on a narrow set of well-learned behaviors (Staw et al. 1981). In a similar vein, it is possible that the effects of success may also be isomorphic across levels: Past success may lead individuals as well as organizations to become more narrowly focused on the exploitation of old ideas. Although the exact mechanisms may differ across levels, the overall pattern is similar, thus presenting the possibility of integrating two important streams of research that have previously been considered in isolation.

By extending March's (1991) theory to the individual level, it is also possible to consider several implications for managing creativity in organizations. First, our results dovetail with Lotka's (1926) inverse square law of productivity, which indicates that scientific performance is concentrated within a small fraction of researchers, but they add an important qualification: As the quantity of inventive output concentrated in a few individuals increases, the extent to which new inventions diverge from past ones may decrease. This qualification may have an important practical implication for R&D managers interested in increasing the creative output of their departments. Allocating more resources to the most prolific inventors may increase the creative output of their department, but it may diminish the extent to which the creative output reflects exploratory efforts. The risk of that strategy may then be technological obsolescence. Managers may therefore want to consider the counterintuitive strategy of relying less frequently on their most successful inventors.

A second implication of our study is the importance of collaboration in counteracting the negative effects of success on creativity. It is possible that collaboration stimulates people to consider new perspectives and gives them the opportunity to break the cognitive frames that arise as a consequence of past success. Although the idea of collaboration may go against the stereotype of the scientist as a "lone" genius, it may be a key ingredient in promoting creativity in organizations (Perry-Smith and Shalley 2003, Burt 2004). Our results also suggest that the negative effects of success can be attenuated by leveraging the organization's norms for exploration versus exploitation (Flynn and Chatman 2001). Successful inventors can be stimulated to continue exploring new areas if they are surrounded by people who also emphasize exploration in their research. This strategy may be more effective than relying less frequently on successful inventors because successful inventors can remain with the firm, continue to explore, and act as a resource for

other scientists who have not yet achieved their level of success.

Although a strength of our empirical analysis is that it examines the creative output of inventors in real settings and over an extended period of time, a limitation of our results is that we were not able to observe creative ideas that were not patented. Many of these unpatented ideas probably did not exceed the threshold of novelty necessary to obtain a patent. However, firms are also known to protect important inventions by using trade secrets and copyright. This feature of the data should suggest caution in the interpretation of the results. However, unless there is a systematic bias, the results should be unaffected. Further, although we used two distinct indicators of the extent to which patented ideas diverged from past ones, the number of new subclasses and the number of new citations, future research may benefit from considering other indicators.

We began by citing the Post-it Note as an example of a wildly creative idea that transformed an organization. What do you think became of Art Fry, the brilliant coinventor of the Post-it Note? He had a long and distinguished career as a corporate scientist at 3M and is rightly considered to be a pioneer in his field. And, according to the company website, he is proud of the innovative products that emerged from the original idea: the Post-it Pop-up Note Dispenser and the Post-it Flag (the whole story: A NOTE-able achievement). A brilliant idea is apparently inescapable.

Acknowledgments

The authors thank Olga Khessina, Barry Staw, Mark Runco, Kevyn Yong, Scott Shane, and the anonymous referees for their helpful suggestions. The first author gratefully acknowledges the Committee on Research of the University of California, Berkeley for supporting this research.

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