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Mentorship and creativity: Effects of mentor creativity and mentoring style

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A R T I C L E I N F O

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A B S T R A C T

This paper examines mentorship as a mechanism for individuals to acquire and develop creativity. More specifically, we study the effect of mentor creativity on protégé creativity and how this effect is moderated by the mentoring styles of autonomy and exploration. Our empirical analysis focuses on formal PhD supervision and training, drawing on survey and bibliometric data for 143 life-science professors (mentors) and their 685 PhD students (protégés). We find that the effect of mentor creativity on protégé creativity is insignificant during protégés' PhD studies but becomes significantly positive after protégés hold faculty positions, suggesting that the mentorship effect takes time to manifest but is enduring. Furthermore, the effect of mentor creativity on protégé creativity is significant only when protégés have high levels of autonomy and exploration during PhD studies. This suggests the importance of autonomy and exploration in the effective transfer of creativity from mentors to protégés.

If I ask myself how it came about that one day I found myself in Stockholm, I have not the slightest doubt that I owe this good fortunate to the circumstance that I had an outstanding teacher at the critical stage in my scientific career… (Krebs, 1967) Hans Krebs (The Nobel Prize in Physiology or Medicine 1953)

1. Introduction

In modern organizations and society, knowledge is the source of competitiveness and the engine of growth, so it is crucial that knowledge workers are sustainably developed for the continual production of new knowledge (Argote and Ingram, 2000; Grant, 1996; Hatch and Dyer, 2004; Teece et al., 1997). Under the rapidly changing knowledge landscape, knowledge workers must go beyond learning existing knowledge to develop and exploit their *creativity* for producing novel and useful ideas and solutions (Crossan et al., 1999; Huber, 1991; March, 1991). The source of creativity has been long studied in the previous literature on creativity (Amabile, 1983; Drazin et al., 1999; Ford, 1996; Woodman et al., 1993). This paper contributes to this literature by exploring mentorship as a mechanism for individuals to acquire and develop creativity at the personal level.

In knowledge-intensive work, the ingredients of creativity tend to be internalized in experienced workers, and it is critical that organizations effectively transfer such ingredients to newcomers (Bryant, 2005; Nonaka, 1994; Singh et al., 2002). Mentorship plays an important role in transferring creativity from experienced workers to novices (Chao et al., 1992; Feldman, 1981; Kram, 1985; Ragins and Cotton, 1999; Scandura, 1992). There are many anecdotes supporting the importance of mentoring in transmitting creativity (Clynes et al., 2019). For example, Nobel laureates are often protégés of Nobel laureates (Zuckerman, 1977). However, the role of mentorship in nurturing creativity has not yet been systematically examined. It has been elusive how inexperienced workers acquire various skills from experienced workers and how it feeds into their own creativity (Hatch and Dyer, 2004; Shipton et al., 2005; Tharenou et al., 2007).

Building on the creativity literature, in particular the componential model of creativity (Amabile, 1988), and the mentorship literature, in particular the model of mentor functions (Kram, 1985), we argue that key skills necessary for creative work can be transferred from mentors to their protégés through mentoring. Furthermore, we argue that the effective transfer of creativity from the mentor to the protégé depends on mentoring styles that allow the protégé *autonomy* in planning and executing research activities and *exploration* in terms of choosing research topics beyond the mentor's main expertise. Autonomy and

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exploration are viewed as features of work organization that are conductive to creative work (March, 1991; Merton, 1973; Pelz and Andrews, 1976; Whitley, 2000). This is also the case in the context of mentorship, where depriving protégés of autonomy and exploration may impede their personal growth (Fox, 1992; Hackett, 1990; Laudel and Glaser, 2008; Shibayama, 2019; Walsh and Lee, 2015). However, there is an inherent tension between mentorship and autonomy/exploration. From the mentor side, being an active mentor calls for control and supervision. From the protégé side, being mentored means no absolute autonomy or exploration. We contribute to better understanding of this tension by exploiting the variance in autonomy and exploration within mentorships and analyzing how it affects the transfer of creativity.

We conducted our empirical analysis in the setting of academia, where mentors are university professors, protégés are PhD students, and mentoring is the formal academic training during protégés' PhD studies. We drew on a sample of 143 professors and their 685 PhD students in life sciences in Japan. The primary data were collected with a questionnaire survey of the mentors, in particular about their mentoring relationship with the protégés. We also retrieved 20,100 publications by the mentors and 10,800 publications by the protégés, and measured their creativity in terms of the inclination towards novel research, i.e., the share of novel publications. We measured mentor creativity using their publications before the focal protégés started PhD studies. We traced the creativity of protégés both during their PhD studies, and more importantly, after they had become independent scientists holding a faculty position of assistant, associate, or full professor.

Empirical results suggest that mentor creativity has an insignificant effect on protégés' short-term creativity during their PhD studies, but a significantly positive long-term effect after they hold faculty positions. Furthermore, we find positive moderating effects of both autonomy and exploration: the long-term effect of mentor creativity on protégé creativity is significantly positive only if protégés had a high level of autonomy or exploration during their PhD studies.

This paper makes several theoretical contributions. First, it contributes to the creativity literature by exploring mentorship as a channel for individuals to acquire and develop creativity at the personal level. It suggests a new research avenue for understanding the source of individual creativity in addition to various personal traits or social contextual factors associated with creativity (Anderson et al., 2014; Shalley et al., 2004). It also builds on the network perspective of creativity. We do not study networks of peers or collaborators but focus exclusively on a particular kind of interpersonal relation as a source of creativity: the asymmetric mentor-protégé relation, which adds to prior studies focusing on network structure, peer relations, and leader-employee relations (Perry-Smith and Shalley, 2003). Second, our findings make important contributions to the mentorship literature, which has focused extensively on how mentorship affects protégé outcomes, such as job performance, compensation, promotion, and satisfaction (Allen et al., 2004; Noe Raymond et al., 2002; Wanberg et al., 2003). Scholars have called for investigating more diverse protégé outcomes, in particular those related to personal learning, development, and growth (Kram and Ragins, 2007). This paper answers to this call by exploring protégé creativity as an outcome for investigation. The mentorship literature has also called for going beyond comparing individuals with and without mentors and examining differences in mentors and mentoring relationships (Allen and Eby, 2010; Dougherty and Dreher, 2007). This paper responds to this call by examining the effects of mentor creativity and mentoring style in terms of autonomy and exploration. Third, this paper contributes to the academic training and higher education literature, in which concern is growing as to the increasing bureaucratization of science. It has been cautioned that reducing PhD training to performing some subordinate and dependent tasks rather than training them to become fully autonomous scientists may endanger the long-term progress of science (Fox, 1992; Hackett, 1990; Laudel and Glaser, 2008; Shibayama, 2019; Walsh and Lee, 2015). This paper illustrates how the level of autonomy and exploration during PhD studies influences the transfer of creativity from mentors to PhD students.

2. Theory and hypotheses

2.1. Interpersonal relations and individual creativity

Before presenting our conceptual model and hypotheses, we first discuss the grounding of this paper in relevant streams of creativity research. Creativity has been a long-standing research interest in many disciplines, and the sources of creativity have been studied extensively. While earlier studies focused on the innate abilities and traits of creative individuals (Barron, 1955; MacKinnon, 1965), more recent studies have taken a social turn and investigated social determinants of creativity in the organizational and social environment (Amabile, 1983; Drazin et al., 1999; Ford, 1996; Woodman et al., 1993). Most studies have viewed individuals as the locus of the creative process and considered that social factors influence creativity through individuals' affect, behavior, and cognition. Other studies have further center-staged groups or dyads and developed theories for the collective and interactive co-creation process that takes place among individuals (Hargadon and Bechky, 2006; Harvey, 2014; Rouse, 2020). These studies may have different views on whether the individual, dyad, or group is the locus of the creative process, but they agree that individual creativity is a critical input at all levels for performing creative work. Therefore, understanding individual creativity remains important.

Individual creativity depends not only on personal characteristics but also on a host of contextual factors at group and organizational levels and external environment (see Shalley et al. (2004) and Anderson et al. (2014) for literature reviews on these factors). In this study we focus on factors that pertain to interpersonal relations, drawing on three streams of research. This paper builds on these literatures to make a distinct contribution to the relational perspective in studying creativity at the individual level.

The first stream of literature studies how individuals' creativity is affected by characteristics of their social networks, such as tie strength, structural holes, and centrality (Li et al., 2013; McFadyen and Cannella, 2004; McFadyen et al., 2009; Uzzi and Spiro, 2005; Wang, 2016). These studies adopt a structuralist approach and views certain network properties as advantageous to creative work because they provide better access to intellectual or social capitals (Nahapiet and Ghoshal, 1998; Perry-Smith and Mannucci, 2017; Perry-Smith and Shalley, 2003), while other attributes of the social network contacts are deemed irrelevant or inessential to the conceptual framework. Our study differs from this stream of research in that it focuses on the characteristics of the social network contact (i.e., mentor creativity) and the relationship (i.e., mentoring style) but not on the network's structural factors.

The second stream of literature investigates how individuals' creativity is affected by the attributes of their coworkers or collaborators. More specifically, it posits that creative peers increase an individual's own creativity by providing more diverse, novel, and useful information (Borgatti and Cross, 2003; Grigoriou and Rothaermel, 2014; Li et al., 2020; Liu et al., 2018) or by serving as a creative role model for observational learning (Grosser et al., 2017; Tierney and Farmer, 2011; Zhou, 2003). Our conceptual discussion of how mentorship affects protégé creativity is heavily influenced by this stream of literature. However, in this paper we focus on asymmetric mentor-protégé relations rather than symmetric peer-peer relations, which allows us to explore more nuanced properties of this relation (i.e., mentoring style) and how mentoring style may moderate the transfer of creativity from mentors to protégés.

The third stream of literature examines how employee creativity is affected by leadership style or supervisor behavior. It views characteristics of the leader or leadership as a contextual factor that affects employee creativity through employees' emotions, self-efficacy, or motivation (Gong et al., 2009; Oldham and Cummings, 1996; Zhang and Bartol, 2010; Zhou, 2003). In this literature, some leader attributes or behaviors may interact with employees' personal characteristics, which results in creative work, but this does not change employees' skills or abilities to conduct creative work (Shalley et al., 2004; van Knippenberg and Hirst, 2020; Woodman et al., 1993). There are important differences between this stream of literature and our paper. First, different types of relations are studied (leader-employee vs. mentor-protégé). Second, our paper focuses on mentorship as a channel for protégés to develop individual creativity rather than leadership as a contextual factor that facilitates creative performance. Third, this paper investigates the long-term effect of the relation after its termination rather than focusing solely on the immediate effect of the relationship while it is active.

2.2. Mentorship and protégé creativity

In this section, we develop our theory and hypothesis regarding the mentorship effect on protégé creativity. Mentorship plays an important role in transferring knowledge, skills, and attitudes from experienced workers to novices and has gained popularity in the increasingly volatile knowledge landscape (Chao et al., 1992; Kram, 1985; Ragins and Cotton, 1999; Scandura, 1992; Shibayama, 2019). Mentorship offers a critical means for organizations to share knowledge (Bryant, 2005; Carraher et al., 2008; Swap et al., 2001), socializes newcomers into a desirable set of organizational behavior (Donaldson et al., 2000; Feldman, 1981; Payne and Huffman, 2005), and forms a basis for the functioning of organizations (Kram, 1985; Scandura, 1992). Although the role of mentorship in nurturing individual creativity has been understudied, anecdotal evidence seems to suggest that mentorship can effectively transfer creativity from the mentor to the protégé (Clynes et al., 2019; Zuckerman, 1977).

Building on the componential model of creativity (Amabile, 1988) and the model of mentor functions (Kram, 1985), we argue that creativity is driven by two sets of skills: *skills in the task domain* and *skills in creative thinking*[1], and that the mentor transfers these skills to the protégé through coaching, challenging assignments, and role-modeling. *Skills in the task domain* are the raw material of creative work and include factual knowledge, technical skills, and special talents relevant for work in the selected domain (Amabile, 1983, 1988; Amabile and Pratt, 2016). *Skills in creative thinking* allow individuals to combine raw materials in new ways for creative work. They include cognitive styles, perceptual styles, and thinking skills that are conducive to taking new perspectives on problems, thinking outside the box and breaking from existing pathways, and taking risks and being persistent in the creative pursuit (Amabile, 1983, 1988; Amabile and Pratt, 2016).

These two types of skills can be effectively transferred from creative mentors to their protégés through mentoring. Mentors are generally viewed as instilling two types of functions to their protégés: *career functions* aimed at preparing and promoting protégés for career advancement and *psychosocial functions* that enhance protégés' senses of competence, identity, and effectiveness in a professional role (Kram, 1985). Mentor functions cover a variety of sometimes intertwined activities. We argue that the career functions of coaching and challenging assignments and the psychosocial function of role modeling are important channels for transferring creativity from mentors to protégés.

First, through coaching, the mentor imparts information and knowledge that are critical to performing the work, helps protégés to acquire and develop necessary skills, and guides them to build and accumulate human capital (Chao et al., 1994; Kram, 1985; Ramaswami and Dreher, 2010). A large part of the skills in the task domain and skills in creative thinking is tacit and internalized in individuals. Factual knowledge of the domain is only partially documented for formal education or self-education, and a large body of knowledge remains tacit, such as taken-for-granted assumptions, legitimate epistemology and methodology, understanding of knowledge gaps and frontier, problems that are important and "ripe" for solution (Kuhn, 1962; Leahey et al., 2016; Merton, 1973; Zuckerman, 1977). Compared with factual knowledge, technical skills, special talents, and skills in creative thinking are even more tacit. Transferring such tacit knowledge requires intense and fine-grained information exchanges as well as a high level of intimacy and commitment (Reagans and McEvily, 2003; Tortoriello and Krackhardt, 2010; Uzzi, 1996), which mentorship offers through close personal coaching.

Second, a more creative mentor may offer challenging assignments requiring a higher level of creativity than a less creative mentor (Kram, 1985). These challenges are better suited for the protégé to learn and practice creativity in complex real-world settings (Nonaka and Takeuchi, 1995; Polanyi, 1958; Swap et al., 2001; von Hippel and Tyre, 1995). In addition to challenging assignments, creative mentors may provide a series of performance feedback, which guides the learning process by revealing the subtle and hidden specifics of skills and directs protégés towards the important elements to be learned (Covaleski et al., 1998; Kim and Kim, 2020; Morrison, 1993). Furthermore, through engaging with these challenging assignments, the protégé learns about what assignments and problems are worthy of effort and inherits creative mentors' tastes and standards conductive to creative work (Kram, 1985; Zuckerman, 1977).

Third, the mentor serves consciously and unconsciously as a role model; the protégé identifies with this role model and emulates the mentor's working style and professional identity (Covaleski et al., 1998; Humberd and Rouse, 2016; Kram, 1985). The social learning theory has highlighted that through learning by observation, the protégé can acquire complex skills and patterns of behavior without having to go through a long process of trial and error (Bandura, 1977). Through closely observing how the mentor works, the protégé gains insights into skills in the task domain such as knowledge about the paradigm and performance scripts, and skills in creative thinking such as heuristics for breaking mental set and working styles favorable to creative work (Amabile, 1988; Zuckerman, 1977).

In summary, mentorship plays an important role for protégés to acquire and develop skills in both the task domain and creative thinking. Through the mentoring process, creativity of the mentors passes down to the protégés. More creative mentors have more skills in the task domain and skills in creative thinking to impart to the protégés through coaching. More creative mentors also offer challenging assignments that are suited to helping protégés develop their own creativity and serve as a role model inclined towards creative work. Therefore, we hypothesize that,

Hypothesis 1 (H1): *Mentor creativity has a positive effect on protégé creativity.*

2.3. Mentoring style and protégé creativity

The effectiveness of creativity transfer from the mentor to the protégé likely depends on the mentoring style. We focus on two important aspects of mentoring style: (1) *autonomy*, defined as giving the protégé freedom to plan and execute their own research activities, and (2) *exploration*, defined as allowing the protégé to work on areas that are

[1] Amabile's componential model of creativity consists of three components: task-domain skills, creative-thinking skills, and motivation. We exclude motivation from our conceptual model for two reasons. First, our study focuses on skills or capabilities, which motivation is not. Amabile (1988) stated that what an individual *can do* depends on their levels of task-domain skills and creative-thinking skills, while task motivation determines what an individual *will do*. In other words, motivation determines the extent to which an individual will actively use task-domain and creative-thinking skills for creative work. More importantly, among the three components, motivation is the most dynamic and the most easily subject to change. Motivation may change from one task to another within the same domain, and in very short time span, from one moment to another (Amabile, 1988; Amabile & Pratt, 2016). Considering that motivation is task-specific and unstable, it is less relevant for studying the effect of mentorship on protégé creativity at the personal level in the long term.

distant from the existing expertise of the mentor. These two characteristics of mentoring style have received much attention in science studies and higher education literatures (Kam, 1997; Mainhard et al., 2009; Yoshioka-Kobayashi and Shibayama, 2020). To some extent, the abilities to conduct research autonomously and to explore new areas are recognized as important goals of academic training (Lee et al., 2007). Although the effect of mentoring styles on creativity in the academic training context has been understudied, Shibayama (2019) suggested that autonomy and exploration affect the protégé's scientific productivity. In this paper, we add to this line of research by exploring autonomy and exploration as moderators, i.e., investigating whether and how autonomy and exploration affect the effectiveness of creativity transfer from the mentor to the protégé.

Autonomy. Autonomy is generally viewed as a salient feature of the work organization for tasks that require creativity and face a high level of uncertainty (Freidson, 1984; Hackman and Oldham, 1976; Wallace, 1995), in particular scientific research (Aghion et al., 2008; Pelz and Andrews, 1976; Whitley, 2000). Theories have outlined many advantages of autonomy for creative work. It allows creative workers to make independent decisions that serve the best interest of their task (Abbott, 1981; Hall, 1968; Sharma, 1997). Autonomy gives creative workers more responsibility for their work and can therefore elicit more effort (Hackman and Oldham, 1976). It is highly valued by creative workers (Perkmann et al., 2019; Sauermann and Cohen, 2010; Sauermann and Stephan, 2013) and often recognized as an indication of high status (Alvesson et al., 2008; Mazmanian et al., 2013), which also motivates creative workers.

However, the positive effects of autonomy are more elusive in practice than the theory suggests, and empirical findings are mixed and inconclusive (Cohen and Bailey, 1997; Langfred, 2004; Langfred and Moye, 2004). More recent studies have also explored the potential negative effects of autonomy. Stern et al. (2008) highlight that the effect of autonomy depends on the ability or experience of the individual. Hospital residents (i.e., postgraduate trainees practicing medicine under the supervision of senior clinicians, often referred to as attendings) often lack the necessary knowledge or skills to properly handle a situation, so too much autonomy for them would lead to medical errors. In this sense, autonomy may provide insufficient guidance for protégés. Haas (2010) argues that autonomy may also lead to isolation and lower access to valuable external information. This isolation risk is particularly detrimental for complex and novel tasks that require a diverse range of information. Shibayama (2019) argues that autonomy reduces the efficient division of labor (where experienced mentors take up upstream tasks while less experienced protégés focus on downstream tasks) and therefore harms the short-term productivity of the protégé, although it facilitates protégés' learning and enhances their long-term productivity.

In the context of mentorship, there is an inherent tension between mentoring and autonomy. To some extent, being mentored means having limited autonomy. However, within a mentoring relation, there can still be varying degrees of autonomy, ranging from a low level where the mentor takes the leading role in various research tasks (e.g., choosing the topic, planning experiment, analyzing data) to a high level where the protégé plays the leading role.

Autonomy may also moderate the effectiveness of creativity transfer in opposite directions. On the one hand, autonomy may negatively moderate creativity transfer from the mentor to the protégé. A low level of autonomy might be conductive to transferring skills in the task domain, which are by definition contextual and domain-specific (Amabile, 1988). Much of the factual knowledge, technical skills, and special talents required for work in a particular domain is tacit and specific to the field or even specialty. The transmission of such skills prefers a controlled, less autonomous, and hand-over-hand mentoring approach, in which the mentor makes decisions about various steps in the work process. Through observing these fine-grained decisions, the protégé can directly experience the field knowledge embodied in the mentor's actions. In a mentoring relationship where the protégé has a high level of autonomy, however, the mentor does not make all the detailed decisions about work design or operation, thereby not providing sufficient exemplars for the protégé to observe and learn from, compared with a mentoring relationship with a low level of autonomy.

On the other hand, autonomy may positively moderate creativity transfer. A high level of autonomy may help protégés learn skills in creative thinking from the mentor. When the protégé has a high level of autonomy, the mentor does not make specific decisions but instead focuses on guiding the protégé to make such decisions him/herself independently. For example, the mentor does not choose the exact work design but guides the protégé to develop a proper one. The mentor does not decide the operational procedure but only provides advice on fruitful directions. In this way, the protégé's learning journey focuses more on general skills in creative thinking to combine raw materials in new ways for creative problem solving.

In light of these two opposite directions about how autonomy may moderate creativity transfer, we propose two competing hypotheses:

Hypothesis 2a (H2a): *Autonomy decreases the effect of mentor creativity on protégé creativity.*

Hypothesis 2b (H2b): *Autonomy increases the effect of mentor creativity on protégé creativity.*

Exploration. In his seminal work, March (1991) distinguished between exploration and exploitation: Exploration pursues knowledge that is not yet known and "includes things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, innovation," while exploitation uses and develops knowledge that is already known and "includes such things as refinement, choice, production, efficiency, selection, implementation, execution." Scholars have studied the tradeoff between exploration and exploitation at different levels. At the global level, exploration searches for possibilities unknown to humankind, including the individual engaged in the learning process. At the individual level, exploration seeks new possibilities unknown to the individual but not necessarily unknown to others. In the creativity literature, the conceptualization of exploration at the global level is inherently associated with concepts of novelty and divergence, which stresses creating new ideas and solutions that diverge from and challenge the existing cognitive framework (Audia and Goncalo, 2007; Guilford, 1967; Mumford, 2003).

At the individual level, however, the association between exploration and creativity is less straightforward. It is unclear who is more likely to deliver an idea or solution that is new to the whole field or human kind: an individual exploring areas outside his/her field of expertise or an individual exploiting their existing expertise. On the one hand, exploiting one's existing expertise has advantages for delivering creative outcomes. The creativity literature has long recognized skills in the task domain as a critical input for creativity (Amabile, 1983; Ford, 1996; Woodman et al., 1993). Clearly, it is impossible to make a ground-breaking discovery in biomedicine if one does not know much about biomedicine. With a strong knowledge base in the field, an individual can better understand the problem and solution spaces and therefore have a higher chance to identify new and useful combinations (Gruber et al., 2013; Kaplan and Vakili, 2015; Liu et al., 2018). This individual can also avoid unfruitful directions, or remain persistent when confronted with failed attempts (Fleming and Sorenson, 2004; Levinthal and March, 1993).

On the other hand, exploration provides special conditions that stimulate creativity. Outsiders and newcomers are viewed as crucial carriers of creativity in both the sociology and social psychology literatures, as they are not constrained by dominant conventions and cognition frameworks (Cattani et al., 2017; Greenwood and Suddaby, 2006; Gupta et al., 2006; Perretti and Negro, 2006). Individuals exploiting their existing expertise may become narrowly focused on previously successful epistemology and methodology and less sensitive to abnormalities and opportunities to revolutionize the existing paradigm (Audia and Goncalo, 2007; March, 1991; Skilton and Dooley, 2010). Merton (1973) coined the term, *focused naïveté*, "a useful ignorance of prevailing assumptions and theories that allows them to attack problems generally regarded as impossible or uninteresting by specialists."

Exploration may also moderate the transfer of creativity from mentors to protégés in opposite directions. On the one hand, a low level of exploration might benefit the transfer of skills in the task domain. When the degree of exploration is high, the mentor may simply not bring sufficient skills in the task domain, and the protégé cannot learn much from the mentor. In contrast, when the degree of exploration is low, the protégé has access to the mentor's rich set of skills in the task domain.

On the other hand, a higher level of exploration might be desirable for transferring skills in creative thinking. When the degree of exploration is high, the creative process relies heavily on skills in creative thinking. Without existing specific concepts and propositions to fall back on to, the mentor and the protégé have to use more general principles and heuristics that crosscut different fields. Such skills may include skills for making sense of complex problems (Drazin et al., 1999) and synthesizing different perspectives and knowledge components (Harvey, 2014). Such skills are particularly complex and tacit, and it is only through observing creative mentors that protégés can acquire and develop such skills (Dougherty, 1992; Liu et al., 2018; von Hippel and Tyre, 1995). Therefore, exploration is more effective than exploitation in transmitting skills in creative thinking from mentors to protégés.

Following the above discussion about the opposite moderating effects, we propose two competing hypotheses:

Hypothesis 3a (H3a): *Exploration decreases the effect of mentor creativity on protégé creativity.*

Hypothesis 3b (H3b): *Exploration increases the effect of mentor creativity on protégé creativity.*

3. Method and data

3.1. Empirical setting

To test our hypotheses, we draw on a sample of professors and their PhD students in life sciences in Japanese universities. Mentors in this study are supervising professors, protégés are their PhD students, and mentoring is the academic training during protégés' PhD study.

Before presenting our empirical strategy, we outline the postgraduate education system in Japan. Japan has approximately 700 universities, 400 of which offer PhD programs. Universities are categorized into three groups based on their governing bodies: 86 are national, 92 are regional (of prefectures or cities), and 603 are private universities. Among the three groups, national universities are the main providers of both academic training and research, while most private universities are oriented to undergraduate education. Most postgraduate programs consist of a two-year master's program and a three-year PhD program. Students usually decide whether to pursue a PhD degree during their master's program (Yoshioka-Kobayashi and Shibayama, 2021). As in many other countries, a PhD degree is usually required for academic employment. PhD graduates typically have a postdoctoral position before finding a faculty position (Misu et al., 2010).

The academic system in Japan has a few characteristics that are pertinent to our empirical strategy.[2] First, it is traditionally based on the so-called "chair system," modelled on the German system (Kneller, 2010; Shibayama, 2019; Wang et al., 2018). A chair, also often called a laboratory, is led by a lab head (usually, a full professor) and consists of lab members including younger faculty members, postdocs, and students. A chair has strong authority in every aspect of university operation including postgraduate education. This creates a great variation in how students are trained (Shibayama, 2019), which helps us analyze the moderating effect of mentoring styles. The strong authority of the chairs implies decentralization of postgraduate education, with a chair somewhat insulated from the external environment (Shibayama, 2021). This helps us observe the mentorship effect on protégés' development with limited noise.

Second, it is common for students to join a lab already during their undergraduate studies and continue working in the same lab through their master's and PhD programs. We expect that this mitigates the selection bias of creative supervisors tending to match with (potentially) creative PhD candidates. Before students join a lab, they usually have no research experience, and thus, supervisors have little information about students' research abilities. In addition, this matching process is often driven by undergraduate students choosing supervisors. Our additional survey found that 86% of students chose their labs based on the lab's research areas and 23% on the lab's research performance. This suggests that students' selection of supervisors is influenced by the creativity or mentoring styles of professors to only a limited degree.

Third, financial support for PhD students is rather limited. PhD students are often self-funded. Some students are funded through fellowships but infrequently hired as research assistants on project grants. This allows students to have a certain level of independence from the supervisors, and the supervisor-student relationship involves substantial mentoring rather than simply giving and taking orders. This also allows us to examine the students' performance during their PhD studies as an indication of the students' own creativity rather than an inseparable component of the lab's performance.

Fourth, the career preference of PhD students is strongly inclined toward academia (NISTEP, 2005). This mitigates a potential bias when we disregard those who exit from academic careers in analyzing the long-term mentorship effect.

3.2. Data

This study draws on a sample of mentors (professors) and their protégés (PhD students) and data collected from a survey, publications, dissertations, and curricula vitae (CVs) sources.

Survey of mentors. To design the survey, we conducted interviews with 30 life scientists in Japanese universities.[3] Our survey respondents were selected as follows. First, we selected 20 universities that provide public dissertation databases, through which we identified supervisors.[4] Second, we focused on the field of life sciences. Third, we selected grantees of national research funds to identify researchers active at the time of the survey.[5] We mailed the survey to 504 professors who satisfied these conditions in 2010, and collected 228 responses after two waves of requests (response rate = 45%).[6]

Using dissertation databases, we then searched for the PhD students of the survey respondents who had graduated in 2000–2011.[7] After removing professors who supervised no student, we obtained the final sample of 143 professors and their 685 students. The professors had on

[2] The academic system in Japan since has been reformed, but these descriptions were the case during our sampling period.

[3] The survey inquired into several subjects, and only those parts relevant to academic training are used in this study.

[4] The selected universities are all research-intensive, including both top-tier schools (e.g., the University of Tokyo) and mid-tier schools. See Online Supplement S1 for the list of universities.

[5] We prepared the sampling list using the national database of Grants-in-Aid for Scientific Research (GiA), which is the primary funding source for Japanese scientists (https://kaken.nii.ac.jp/en/).

[6] To examine non-response bias, we randomly selected 27 non-respondents and found no significant difference between the response and non-response groups. In particular, we compared publication counts over the previous five years (25.6 vs. 22.5, $p > .1$) as well as affiliation to seven top-tier universities (60% vs. 70%, $p > .1$).

[7] We excluded students who graduated after 2011, as their postgraduate careers cannot be analyzed, and those who graduated before 1999, as the connection to the survey data is obscured. We also excluded non-Japanese students (11% of all students) since identifying their careers poses a challenge.

average 26 years' academic experience, and each had graduated an average of 1.1 PhD students/year. We traced the career of the PhD graduates through CV databases and found that 70% chose academic careers after graduation and 55% remained in academia after 10 years.

Publication data. We downloaded bibliometric data for all the articles published by the sampled mentors and their protégés up to 2018 from the Web of Science (WoS). After removing false matches on the basis of authors' full names, affiliations, and research areas, we obtained 20,100 publications by the mentors and 10,800 publications by their protégés. Protégés published an average of 3.5 articles before graduation, and their publication performance increased gradually over their careers.

Datasets. Using the final sample of 143 mentors and their 685 protégés, we constructed two datasets for regression analyses corresponding to two separate time periods. The first dataset is a cross-section of the PhD study period with a protégé as the unit of analysis. The second dataset is an unbalanced panel for 1–12 years after graduation. For the second, we focus on the years when the protégé holds a faculty position, excluding their postdoc years, to better capture the creativity of the protégé as an independent scientist without contamination from postdoc supervisors. Table 1 presents the descriptive statistics and correlation matrix of the variables in each dataset.

3.3. Measures

Mentor creativity. To measure the creativity of mentors, we focus on their inclination towards novel research. The first step is to identify novel publication in their corpus of publications. The combinatorial novelty perspective, which views that novelty arises from making new combinations of preexisting components, has been embraced by scholars in various disciplines (Burt, 2004; Mednick, 1962; Schumpeter, 1939; Simonton, 2003; Weitzman, 1998). For example, Nelson and Winter (1982) stated that "the creation of any sort of novelty in art, science or practical life – consists to a substantial extent of a recombination of conceptual and physical materials that were previously in existence." To measure novelty of individual publications, Uzzi et al. (2013) examined the atypicality of referenced journal pairs in a publication. Wang et al. (2017) identified novel publications as those that make referenced journal combinations that have never occurred in the past. They found that only about 10% of publications are novel, and these novel papers are more likely to be highly cited but also have higher variance in their citation performance, displaying a high-risk/high-gain profile. Novel papers also face delayed recognition and tend to gain their impact outside their home field. Hence, prior work suggests that coding for new combinations of prior knowledge in the publication produces a useful measure of the priori novelty of a scientific publication. Adopting the novelty measure proposed by Wang et al. (2017), we classify a scientific publication as novel if it references unprecedented combinations of journals. To create the mentor-level creativity variable based on the publication-level novelty indicator, we compute the share of mentors' publications that are novel. In this calculation, we use mentors' publications in which mentors are listed as the first, second, last, or corresponding author and that were published before the focal protégé started their PhD studies (five years or more before the protégé's graduation year).

Protégé Creativity (PhD). Similarly, we compute the share of protégés' novel publications to measure *Protégé Creativity*. The protégé's creativity is measured first during their PhD studies, in which they are listed as the first, second, or corresponding author during the last three years before graduation.[8] Note that there is a temporal gap between the sets of publications for measuring mentor creativity and protégé creativity, which mitigates the risk of spurious correlations.

Protégé Creativity (Prof.). We also measure the protégé's creativity after they gained a faculty position (i.e., assistant, associate, or full professor). We compute the ratio of novel publications in each year in which they are listed as the first, second, last, or corresponding author.

Autonomy. To measure the autonomy of the protégé in the mentoring process, we surveyed the degree of autonomy allowed to them in five research functions: (a) choosing the topic, (b) formulating hypothesis, (c) planning experiment, (d) analyzing data, and (e) writing papers.[9] The survey asked mentors to rate the role their protégés played in each function on a three-point scale: 0 = no role, 0.5 = supplementary role, and 1 = main role, and we use the average score across the five tasks.[10]

Exploration. We measure the intellectual distance between protégés' research topics during their PhD studies and their mentors' research topics before the focal protégé started their PhD program. Based on (A) the set of references in mentors' past publications and (B) the set of references in protégés' publications during their PhD studies, we calculate the *overlap coefficient* also known as the *Szymkiewicz–Simpson coefficient*, the size of the intersection between A and B divided by the size of the smaller of A and B. Since the *overlap coefficient* indicates similarity, which is the opposite to being distant or explorative, we convert the measure by subtracting it from 1. The final variable, *Exploration*, ranges from 0 (i.e., perfect overlap in research topics between the protégé and mentor; no exploration) to 1 (i.e., no overlap in research topics; maximum exploration). We also tried the *cosine similarity coefficient*, another commonly used similarity measure, and obtained consistent results.

Protégé attributes. As a proxy of protégés' ability, we draw on the rank of the undergraduate program in which the protégé was enrolled (*BS Univ Rank*). A nationwide tutoring school publishes the rankings of undergraduate programs every year based on students' academic performance, which is considered a reasonable reflection of their overall ability.[11] We also include two career variables. Whether the protégé remains in the same lab after graduation may affect the relationship between mentor creativity and protégé creativity. Thus, we prepare a dummy variable coded 1 if a protégé was affiliated in each year to the same lab as their PhD studies, and 0 otherwise (*Inbred*). We control for a protege's academic rank in each year: A dummy variable is coded 1 if a protégé was in a tenured faculty position (*Tenured*). We also control for the number of publications during the PhD study period (*#Pub Protégé (PhD)*) and the number of publications in each year after graduation (*#Pub Protégé (Prof.)*). We measure internal competition among protégés by counting the number of students who graduated from the same lab in the same year (*#PhD Same Cohort*). We also control for the field of the PhD degree (*PhD field dummies*)[12] and the year of graduation (*Year Graduation*) because publication performance can differ among years and fields. Finally, we control for the protégé's gender (*Female*).

Mentor attributes. We control for some relevant attributes of the mentor. We measure the productivity of the lab by counting all articles

[8] We excluded the few papers in which protégés were the last author. Since protégés are unlikely to lead a project, being the last author but not the corresponding author seems to suggest that they played only a marginal role.

[9] To lower the burden of survey response, we asked supervisors to rate students' role in general rather than for any specific student. This overlooks potential variation among multiple students of the same responding supervisor. This limitation is addressed in the robustness analysis. We also asked about the degree of autonomy in carrying out experiment, but we dropped this factor because it varies very little among respondents (i.e., most students played a main role).

[10] In addition to this aggregate measure, we also tested autonomy in respective functions (a–e) and found largely consistent results.

[11] The tutoring school grades students based on their practice exams. After actual entrance exams in all universities every year, the tutoring school surveys which students passed the exams and publishes ranking of all universities on the basis of student grades. For this study, we normalized the ranking scores.

[12] The degree fields include Agriculture, Engineering, Medicine, Pharmaceutical, Philosophy, and Science.

Table 1

Descriptive statistics and correlation matrix.

(A) During Protégés' PhD Studies (Cross-Sectional Data)

	Variables	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10
1	Protégé Creativity (PhD)	.102	.243	.000	1.000										
2	Mentor Creativity	.104	.100	.000	1.000	***.082***									
3	Autonomy	.622	.268	.000	1.000	.041	−.060								
4	Exploration	.843	.154	.167	1.000	***.096***	.031	.006							
5	#PhD Same Cohort	2.047	1.275	1.000	7.000	.065	−.049	***−.135***	.058						
6	Ln(#Pub Mentor)	3.385	.758	.000	5.204	−.037	−.025	***−.104***	−.012	***.378***					
7	Ln(#Pub Protégé (PhD))	.644	.621	.000	2.708	.055	.025	***−.080***	***.103***	−.065	***.134***				
8	Female	.232	.422	.000	1.000	.017	−.027	−.043	−.020	.020	.007	−.012			
9	PhD Univ Rank	.556	.332	.007	1.000	.016	***−.077***	.069	−.019	***.165***	***.259***	.049	.046		
10	BS Univ Rank	1.889	5.773	−.500	66.000	.021	−.010	.060	−.076	.018	−.022	−.045	.023	***.094***	
11	Graduation Year	2006.085	2.909	2000.000	2011.000	.050	***.149***	.049	−.058	.033	−.087	***−.125***	.009	***−.078***	***.148***

(B) After Protégés Become Faculty Members (Panel Data)

	Variables	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Protégé Creativity (Prof.)	.117	.289	.000	1.000														
2	Mentor Creativity	.087	.077	.000	.400	***.076***													
3	Autonomy	.633	.284	.000	1.000	−.062	***−.091***												
4	Exploration	.863	.134	.167	1.000	***.069***	.023	.038											
5	#PhD Same Cohort	1.906	1.152	1.000	7.000	−.024	−.019	***−.165***	***.107***										
6	Ln(#Pub Mentor)	3.440	.739	.000	5.204	−.032	.056	***−.085***	−.005	***.366***									
7	Ln(#Pub Protégé (Prof.))	.916	.314	.693	1.946	−.026	.027	***.116***	.029	***−.098***	***.106***								
8	Female	.135	.342	.000	1.000	−.004	−.023	***−.146***	−.003	.026	−.062	***−.102***							
9	Inbred	.325	.469	.000	1.000	.009	−.028	***.107***	.047	.012	−.050	−.017	***−.078***						
10	BS Univ Rank	1.508	2.878	−.100	62.000	−.011	.058	.031	−.066	***.082***	.039	.016	−.036	.028					
11	PhD Univ Rank	.556	.316	.009	1.000	.016	−.013	***.181***	***−.085***	***.107***	***.365***	***.072***	−.047	.012	***.134***				
12	Univ Rank	.333	.332	.000	1.000	.001	−.022	***.126***	.009	.005	***.111***	***.070***	***−.138***	***.444***	***.096***	***.357***			
13	PRO	.050	.219	.000	1.000	−.055	−.022	***.130***	−.018	−.015	.006	−.031	−.016	***−.126***	−.010	−.005	***−.210***		
14	Tenured	.118	.323	.000	1.000	−.050	.032	.027	.011	−.031	.025	.032	***−.090***	***−.152***	−.022	−.036	***−.109***	***.166***	
15	Graduation Year	2005.038	2.803	2000.000	2011.000	−.003	***.174***	.029	−.017	−.014	***−.070***	−.019	−.026	.008	***.073***	***−.174***	***−.073***	−.040	***−.107***

Notes: (A) $N = 685$. (B) $N = 861$. Bold italic: $p < 0.05$.

published by a protégé's mentor during the protégé's PhD studies (*#Pub Mentor*).[13] We also incorporate the random effects of mentors in regression analyses to control for unobserved and time-invariant individual differences.

Organizational context. We control for the ranking of the PhD program in which a protégé was enrolled, drawing on the performance of competitive research funding at the university level. For the cross-sectional data, we compute the total research funds allocated to each university during the PhD study period and normalize it by dividing it by its maximum value (*PhD Univ Rank*). Thus, the variable ranges from 0 to 1, where *PhD Univ Rank* = 1 indicates the university with the largest amount of competitive research funding. Extending this variable to the panel data, we compute the ranking of the university to which a protégé was affiliated in each year based on funding performance (*Univ Rank*). If the affiliation of a protégé was not a Japanese university, *Univ Rank* is coded 0. Instead, a dummy variable is coded 1 if the affiliation is not in Japan (*Foreign*) and another dummy is coded 1 if the affiliation is a public research organization (*PRO*).

4. Results

We test the hypotheses and estimate the effects of mentor creativity and the moderating effects of autonomy and exploration on protégé creativity in two time periods: (1) in the short term during protégés' PhD studies and (2) in the long term after the protégé has become a faculty member. We draw on cross-sectional data for the former and panel data for the latter.

4.1. Short-term effects: during protégés' PhD studies

To examine the effects of mentor creativity and mentoring style on protégé creativity in the short term, we use the dependent variable, *Protégé Creativity (PhD),* the ratio of novel publications authored by the protégé during the PhD studies.

The dataset we analyze has a hierarchical structure where one mentor can have multiple protégés. The general model specification can be described as follows:

$$y_{mp} = \alpha + \beta^T x_{mp} + \mu_m + \varepsilon_{mp}$$

where m is the mentor index, and p is the protégé index. y_{mp} is the dependent variable (i.e., protégé creativity during PhD study) for protégé p of mentor m. α is the intercept. x_{mp} is the vector of independent variables, and β is the corresponding vector of coefficients. μ_m is the error term specific to the mentor, which does not change between protégés and may be correlated with independent variables. ε_{mp} is the idiosyncratic error term, which is assumed to be well-behaved and independent of independent variables and μ_m. The appropriate estimation method for this model depends on the property of μ_m: (1) if it is absent, then pooled OLS (i.e., omitting it) is the most efficient; (2) if it is uncorrelated with independent variables, then mentor random effects should be incorporated; and (3) if it is correlated with the independent variables, then mentor fixed effects should be incorporated. To decide model specification, we first run the Breusch and Pagan test, which favors the random-effect model over pooled OLS.[14] Second, the Hausman test does not support the fixed-effect model over the random-effect model ($p > 0.1$ for all models). Based on these testing results, we employ random-effects linear regressions with random errors clustered at the mentor level.

Regression results are reported in Table 2. We ran two sets of regression models. The first set is based on the full sample (Models 1–5), while the second set is based on a sub-sample of protégés who stayed in academic careers after the completion of PhD (Models 6–10). The two sets of results are largely consistent.[15] With the full sample, Model 1 tests H1 that mentor creativity has a positive effect on protégé creativity. The result, however, shows an insignificant effect ($b = 0.169$, $p > 0.10$), rejecting this hypothesis.

Model 2 adds autonomy into the regression, and we observe a significantly positive effect of autonomy on protégé creativity ($b = 0.057$, $p < 0.10$), while the effect of mentor creativity remains insignificant. We further investigate the moderating effect of autonomy by interacting mentoring creativity with autonomy (Model 3). Note that in Model 3, the coefficient of mentor creativity ($b = -0.347$, $p < 0.10$) indicates the marginal effect of mentor creativity on protégé creativity when autonomy equals 0, which is the minimum value of autonomy in our sample. Similarly, the coefficient of autonomy ($b = -0.054$, $p > 0.10$) indicates the marginal effect of autonomy on protégé creativity when mentor creativity equals 0, which is the minimum value of mentor creativity in our sample. We are most interested in the interaction effect between mentor creativity and autonomy, which is significantly positive ($b = 0.986$, $p < 0.01$), indicating that autonomy magnifies the effect of mentor creativity on protégé creativity. Fig. 1A further plots the marginal effects of mentor creativity on protégé creativity at different levels of autonomy. When autonomy is very low, the effect of mentor creativity on protégé creativity is negative. As autonomy increases, the effect of mentor creativity rises and becomes significantly positive. This finding supports H2b and rejects H2a.

Analyzing the effects of exploration, Model 4 incorporates exploration with mentor creativity as focal independent variables and displays a significantly positive effect of exploration ($b = 0.163$, $p < 0.05$), while the effect of mentor creativity remains insignificant. Model 5 interacts mentor creativity with exploration and shows an insignificant interaction effect ($b = -0.244$, $p > 0.10$). This suggests that the effect of mentor creativity on protégé creativity does not depend on the level of exploration in the research content during PhD study. Fig. 1B plots the marginal effects of mentor creativity at different levels of exploration. The effect of mentor creativity on protégé creativity is insignificant, and it does not change regardless of the level of exploration. Therefore, the result supports neither H3a nor H3b.

4.2. Long-term effects: after protégés become faculty members

To investigate mentorship effects on protégé creativity in the long term, we draw on the panel data and track protégés' careers for up to 12 years after graduation. To better capture protégé's personal creativity without contamination from postdoc supervisors, we exclude the postdoc period and analyze only the years after the protégé attained a faculty position.[16] Regression results are reported in Table 3. The dependent variable, *Protégé Creativity (Prof.),* is the ratio of novel publications in each year, and it is specified using the following model:

$$y_{mpt} = \alpha + \beta^T x_{mpt} + \mu_m + \tau_{mp} + \varepsilon_{mpt}$$

where m is the mentor index, p is the protégé index, and t is the year index. y_{mpt} is the dependent variable (i.e., protégé creativity in year t after graduation) for protégé p of mentor m. α is the intercept. x_{mpt} is the vector of independent variables, and β is the corresponding vector of coefficients. μ_m is the error term specific to the mentor, which does not

[13] Supervisors are listed as a co-author in most publications authored by a member of life science labs.

[14] As the test results vary between models, we also ran pooled OLS and confirmed consistent results (see Online Supplement S2).

[15] The exception is that the main effect of autonomy is positive for the full sample (Model 2) but insignificant for the subsample (Model 7), which may be due to the smaller sample size.

[16] We also ran the same set of regression analyses for the postdoc period before the students earned faculty positions. As anticipated, the results were unclear probably because of their dependent status.

Table 2
Mentoring and protégé creativity: during protégés' PhD studies.

	Full Sample					Protégés who stay in academic careers after PhD				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Mentor Creativity	.169	.180	−.347†	.147	.356	.221	.239	−.472**	.237	.219
	(.152)	(.151)	(.187)	(.151)	(.286)	(.205)	(.210)	(.177)	(.202)	(.460)
Autonomy		.057†	−.054				.043	−.091†		
		(.034)	(.045)				(.041)	(.047)		
Mentor Creativity x Autonomy			.986**					1.247**		
			(.344)					(.445)		
Exploration				.163***	.190***				.183**	.180*
				(.049)	(.055)				(.060)	(.080)
Mentor Creativity x Exploration					−0.244					.023
					(0.264)					(0.575)
#PhD Same Cohort	.021*	.022*	.023*	.020†	.020†	.021†	.022†	.022†	.019†	.019†
	(.010)	(.010)	(.011)	(.010)	(.010)	(.011)	(.011)	(.012)	(.011)	(.011)
Ln(#Pub Mentor)	−.022	−.022	−.024	−.025	−.025	−.019	−.018	−.024	−.017	−.017
	(.016)	(.015)	(.016)	(.016)	(.016)	(.019)	(.019)	(.019)	(.020)	(.020)
Ln(#Pub Protégé (PhD))	.026†	.028*	.031*	.019	.019	.036*	.037*	.039*	.029†	.029†
	(.013)	(.013)	(.013)	(.014)	(.014)	(.017)	(.017)	(.016)	(.017)	(.017)
Female	.012	.014	.017	.018	.018	.005	.008	.014	.008	.008
	(.029)	(.029)	(.028)	(.030)	(.030)	(.035)	(.035)	(.035)	(.036)	(.036)
PhD Univ Rank	.025	.025	.028	.034	.034	−0.003	−0.003	.001	.005	.005
	(.034)	(.033)	(.032)	(.033)	(.033)	(.034)	(.034)	(.033)	(.032)	(.032)
BS Univ Rank	−.007	−.010	−.012	−.008	−.007	−.017	−.020	−.021	−.017	−.017
	(.024)	(.024)	(.023)	(.022)	(.022)	(.025)	(.025)	(.024)	(.022)	(.022)
Field dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Graduation Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chi-squared	74.025***	72.215***	80.489***	95.425***	96.107***	91.598***	90.144***	88.223***	109.676***	113.531***
Log likelihood	16.231	17.314	21.065	11.725	11.838	30.230	30.786	34.937	29.272	29.273
#Protégé	685	685	685	659	659	478	478	478	463	463
#Mentor	143	143	143	138	138	130	130	130	126	126

Notes: Unstandardized coefficients (robust errors in parentheses). Two-tailed test. Random-effects linear regressions. Random-effects are incorporated at the mentor level. Maximum likelihood estimation. In models 6–10, Protégés who left academic careers after PhD completion are excluded.

† $p < 0.1$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

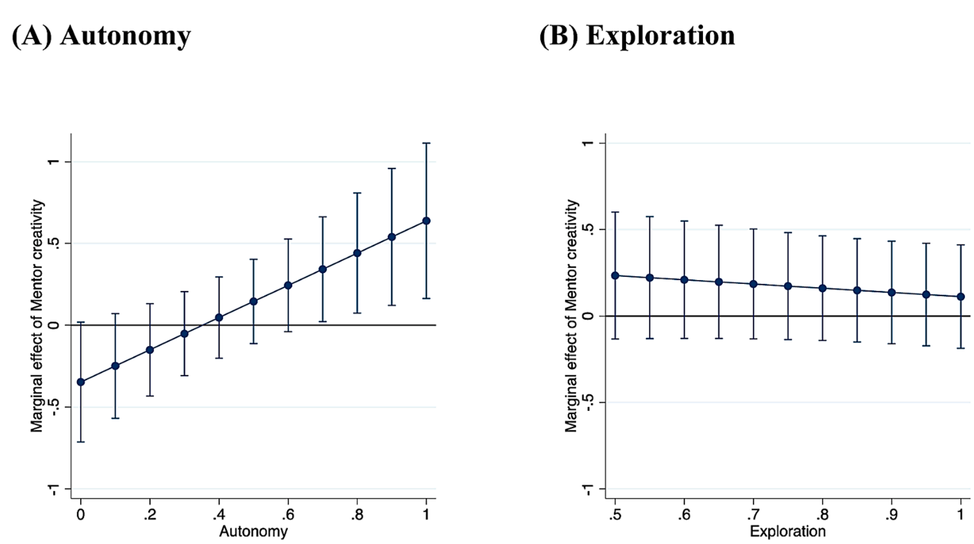

Fig. 1. Mentoring and Protégé Creativity: During Protégés' PhD Studies
Note: The estimations are based on (A) Model 3 and (B) Model 5 in Table 2 with the mean values of all independent variables except for the focal independent variables.

change between protégés or over time but may be correlated with independent variables. μ_{mp} is the error term specific to the mentor-protégé pair but does not change over time, which may be correlated with independent variables. ε_{mpt} is the idiosyncratic error term, which is assumed to be well-behaved and independent of independent variables, μ_m, and μ_{mp}. Similar to the prior section, the appropriate estimation method for this model depends on the properties of μ_m and μ_{mp}. For mentor effects, similar to the short-term analysis, the Breusch and Pagan test suggests including the random effects of mentors over omitting

Table 3
Mentoring and protégé creativity: after protégés become faculty members.

	Model 1	Model 2	Model 3	Model 4	Model 5
Mentor Creativity	.329*	.303†	−.221	.375*	−1.408†
	(.157)	(.169)	(.241)	(.146)	(.827)
Autonomy		−.052	−.153*		
		(.052)	(.072)		
Mentor Creativity x Autonomy			1.023*		
			(.497)		
Exploration				.109*	−.048
				(.054)	(.082)
Mentor Creativity x Exploration					2.011*
					(1.022)
#PhD Same Cohort	−.014	−.014	−.013	−.018	−.017
	(.010)	(.010)	(.010)	(.011)	(.011)
Ln(#Pub Mentor)	−0.013	−0.015	−0.025	.004	.003
	(.019)	(.019)	(.020)	(.016)	(.016)
Ln(#Pub Protégé (Prof.))	−.022	−.020	−.020	−.010	−.014
	(.025)	(.026)	(.026)	(.024)	(.024)
Female	.003	−0.001	.012	.000	−.002
	(.021)	(.020)	(.021)	(.020)	(.021)
Inbred	.008	.010	.006	.001	−0.001
	(.023)	(.024)	(.024)	.022)	(.021)
BS Univ Rank	.054*	.055*	.047*	.056**	.049*
	(.024)	(.022)	(.022)	(.021)	(.021)
PhD Univ Rank	.003	.010	.031	.011	.022
	(.047)	(.048)	(.046)	(.046)	(.045)
Univ Rank	−.035	−.033	−.038	−.037	−.040
	(.032)	(.032)	(.033)	(.032)	(.032)
PRO	−.060	−.055	−.051	−.057	−.049
	(.041)	(.041)	(.041)	(.040)	(.041)
Tenured	−.044†	−.040	−.043†	−.042†	−.045*
	(.024)	(.025)	(.023)	(.022)	(.021)
Field dummies	Yes	Yes	Yes	Yes	Yes
Graduation Year dummies	Yes	Yes	Yes	Yes	Yes
Chi-squared	88.480***	101.762***	96.649***	103.539***	102.783***
Log likelihood	−120.677	−120.034	−117.118	−89.169	−87.600
#Obs.	861	861	861	832	832
#Protégé	252	252	252	242	242
#Mentor	100	100	100	96	96

Notes: Unstandardized coefficients (robust errors in parentheses). Two-tailed test. Random-effects linear regressions. Random-effects are incorporated at the mentor level. Maximum likelihood estimation.
† $p < 0.1$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

them,[17] and the Hausman test does not support fixed over random-effects ($p > 0.1$ for all models). In terms of mentor-protégé-pair effects, the Breusch and Pagan test does not support including random-effects over omitting them ($p > 0.1$ for all models). Finally, the Baltagi-Li test finds no significant sign of first-order serial correlation ($p > 0.1$ for all models). Thus, we employ linear regressions with random errors clustered at the mentor level.

We find a significantly positive effect of mentor creativity (Model 1: $b = 0.329$, $p < 0.05$), supporting H1. The observation that mentor creativity has an insignificant effect in the short term but a significantly positive effect in the long term suggests that mentorship effect on protégé creativity may take time to manifest but is enduring. This observation also provides some assurance for the treatment effect of mentorship as opposed to the selection effect. The mutual selection between creative mentors and creative protégés would lead to a strong positive correlation in the short term, while the treatment effect of mentorship may take time to materialize.

Model 2 adds autonomy into the regression and displays an insignificant effect of autonomy, which is consistent with the subsample analysis in the short term (Table 2 Model 7). The effect of mentor creativity remains significantly positive after adding autonomy. Model 3 further interacts mentor creativity with autonomy. Note that the coefficient of mentor creativity becomes insignificant, which means when autonomy equals 0, mentor creativity has no effect on protégé creativity. The interaction effect between mentor creativity and autonomy is significantly positive ($b = 1.023$, $p < 0.05$). Fig. 2A plots marginal effects of mentor creativity at different levels of autonomy. Consistent with the short-term results, the effect of mentor creativity on protégé creativity is magnified by autonomy: it is insignificant when autonomy is low but significantly positive when autonomy is high. This result supports H2b and rejects H2a.

Finally, we investigate the role of exploration. Model 4 includes exploration and mentor creativity as focal independent variables. The effect of exploration is significantly positive ($b = 0.109$, $p < 0.05$), consistent with the subsample analysis in the short term (Table 2 Model 9). The effect of mentor creativity remains significantly positive after adding exploration. Model 5 interacts mentor creativity with exploration. We find a significantly positive interaction effect between exploration and mentor creativity ($b = 2.001$,$p < 0.05$). Note that the coefficient of mentor creativity turns significantly negative ($b = -1.408$, $p < 0.10$), which indicates the marginal effect of mentor creativity when exploration equals 0. Fig. 2B plots the marginal effect of mentor creativity at different levels of exploration within its range in our sample. It

[17] As the result of the Breusch and Pagan test varies between models, we also ran pooled OLS models and confirmed consistent results (see Online Supplement S2).

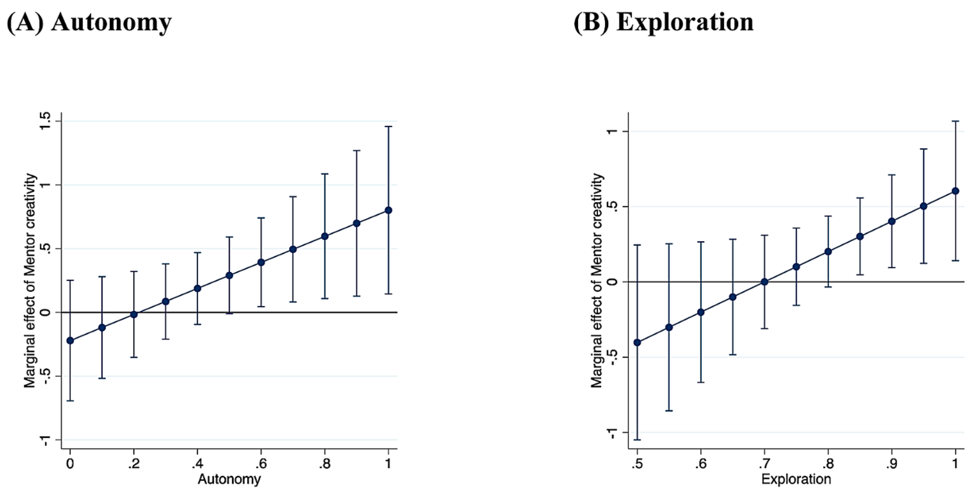

Fig. 2. Mentoring and Protégé Creativity: After Protégés Become Faculty Members
Note: The estimations are based on (A) Model 3 and (B) Model 5 in Table 3 with the mean values of all independent variables except for the focal independent variables.

suggests a negative, though insignificant, effect of mentor creativity when exploration is low but a positive effect when exploration is high. Taken together, the results suggest that the mentor's creativity is transferred to the protégé only if mentoring involves explorative research. This supports H3b and rejects H3a. The moderating effect of exploration is consistent with the moderating effect of autonomy. However, the moderating effect of exploration is different between the short and long terms. When exploration is low, mentor creativity has an insignificant effect on protégé creativity in both the short and the long terms (i.e., short- and long-term results do converge). However, when exploration is high, mentor creativity has an insignificant effect in the short term but a significantly positive effect in the long term. This difference is consistent with the observed difference in the main effect of mentor creativity and supports our argument that mentorship effect takes time to manifest.

Although we conceptualize the moderating effects of autonomy and exploration, it is plausible that they operate as mediating factors; that is, creative mentors may allow greater autonomy and exploration, which in turn stimulate protégé creativity. To test the potential mediating effect of autonomy, we compare Models 1 and 2. Both models show that mentor creativity is significantly positive with very similar coefficient sizes (Model 1: 0.329 vs. Model 2: 0.303).[18] This suggests that the effect of mentor creativity on protégé creativity is not mediated through autonomy. Similarly, comparing Models 1 and 4 reveals no substantial difference in the coefficient of mentor creativity, suggesting that the positive effect of mentor creativity on protégé creativity is not mediated through exploration.

4.4. Mentorship effect: selection vs. treatment

An important methodological challenge in studying mentorship effect is to distinguish between a selection effect, in which creative mentors and creative protégés select each other, and a treatment effect, where creative mentors increase the creativity of their protégés (Dougherty and Dreher, 2007; Johnson et al., 2010). Our theory concerns the treatment effect, but our research design cannot completely rule out a possible selection effect. To accurately estimate the treatment effect, we would need an experimental design where we could randomly pair mentors and protégés or a perfect control variable for the initial creativity of the protégé before mentoring. Unfortunately, neither is feasible for this study.

To address this issue, however, our research design has two features. First, we controlled for the protégés' undergraduate university ranking to proxy the students' initial ability, although it is an imperfect control. Second, systematic sorting of mentors and protégés based on creativity is mitigated in our research setting, as students enter the lab in the early stage of undergraduate studies and the sorting is mainly driven by students' preference of research fields.

We further scrutinize the selection vs. treatment explanations and test them against our empirical observations. Regarding the main effect of mentor creativity, our theory is that creative mentors train their protégés to become creative, whereas the alternative selection explanation is that creative mentors are more likely to select or be selected by creative protégés. The fact that the effect of mentor creativity on protégé creativity is insignificant in the short term but significantly positive in the long term supports the treatment rather than the selection explanation, as the treatment effect takes time to manifest while the selection effect should be more immediate.

Regarding the moderating effects of autonomy or exploration, our theory is that autonomy and exploration magnifies the effect of mentor creativity. One alternative selection explanation would be that when autonomy or exploration is high, the mutual selection between creative mentors and protégés is stronger. This is implausible in our context, as autonomy and exploration are determined after the selection completes. Another alternative selection explanation is that more creative protégés are given a higher level of autonomy and exploration than less creative protégés, and this advantage is stronger with more creative mentors than with less creative mentors. This explanation is however inconsistent with the results about autonomy, as we do not observe a significant main effect of autonomy in the long run. This explanation is also inconsistent with the results about exploration, as the moderating effect of exploration is insignificant in the short term.

Furthermore, we conduct an additional test to try to untangle the selection and treatment effects. Table 4 analyzes protégés' productivity (i.e., the log number of publications) as a dependent variable instead of protégés' creativity (i.e., the share of novel publications). If our results are driven by the selection effect, we expect that more productive protégés should also receive higher autonomy and exploration than less productive protégés. However, in the short term, the interaction effect between autonomy and mentor creativity is negative, which is inconsistent with the selection argument but seems to suggest the treatment effect that autonomy under a creative mentor is risky and reduces productivity. In the long term, main and interaction effects of mentor

[18] In the pooled OLS regression models (Online Supplement S2), we conducted seemingly unrelated regression estimations and compare coefficients of mentor creativity using Wald tests, finding insignificant differences.

Table 4
Mentoring and protégé productivity.

(A) During protégés' PhD studies

	Model 1	Model 2	Model 3	Model 4	Model 5
Mentor Creativity	.225	.184	.969†	−.148	−1.110
	(.304)	(.297)	(.533)	(.223)	(1.204)
Autonomy		−.222	−.049		
		(.135)	(.182)		
Mentor Creativity x Autonomy			−1.489†		
			(.874)		
Exploration				.415**	.604**
				(.139)	(.187)
Mentor Creativity x Exploration					−1.668
					(1.039)
#PhD Same Cohort	−.035†	−0.037*	−.038*	−.035†	−.035†
	(.019)	(.018)	(.018)	(.018)	(.018)
Ln(#Pub Mentor)	.183***	.186***	.189***	.177***	.177***
	(.042)	(.043)	(.042)	(.043)	(.043)
Female	−.032	−.035	−.038	−.023	−.022
	(.059)	(.058)	(.059)	(.061)	(.060)
PhD Univ Rank	.013	.021	.021	.032	.028
	(.104)	(.105)	(.103)	(.103)	(.104)
BS Univ Rank	−0.005	.003	.003	−0.001	.003
	(.047)	(.047)	(.047)	(.040)	(.041)
Field dummies	Yes	Yes	Yes	Yes	Yes
Graduation Year dummies	Yes	Yes	Yes	Yes	Yes
Chi-squared	157.311***	157.273***	184.013***	156.469***	164.484***
Log likelihood	−590.374	−588.614	−587.483	−567.023	−566.062
#Protégé	685	685	685	659	659
#Mentor	143	143	143	138	138

(B) After Protégés Become Faculty Members

	Model 1	Model 2	Model 3	Model 4	Model 5
Mentor Creativity	−.155	−.138	−.070	−.126	.416
	(0.213)	(0.212)	(0.313)	(0.219)	(1.635)
Autonomy		.048	.062		
		(.066)	(.099)		
Mentor Creativity x Autonomy			−.130		
			(.587)		
Exploration				−.014	−.113
				(.109)	(.176)
Mentor Creativity x Exploration					1.095
					(1.388)
#PhD Same Cohort	−.038*	−.037*	−.038*	−.038*	−.038*
	(.015)	(.015)	(.015)	(.016)	(.016)
Ln(#Pub Mentor)	.053†	.054†	.055†	.052†	.052†
	(.028)	(.027)	(.028)	(.029)	(.029)
Female	−.110***	−.107***	−.108***	−.115***	−.117***
	(.030)	(.031)	(.031)	(.031)	(.032)
Inbred	.044	.043	.044	.057*	.056†
	(.029)	(.029)	(.029)	(.029)	(.029)
BS Univ Rank	−.002	−.004	−.003	.005	−.000
	(.036)	(.036)	(.036)	(.037)	(.037)
PhD Univ Rank	−.041	−.045	−.047	−.031	−.024
	(.065)	(.065)	(.066)	(.066)	(.065)
Univ Rank	.070	.068	.069	.064	.062
	(.057)	(.057)	(.057)	(.058)	(.059)
PRO	.020	.019	.019	.027	.028
	(.053)	(.053)	(.053)	(.054)	(.053)
Tenured	−.079†	−.079†	−.079†	−.079†	−.081†
	(.046)	(.046)	(.046)	(.047)	(.047)
Field dummies	Yes	Yes	Yes	Yes	Yes
Graduation Year dummies	Yes	Yes	Yes	Yes	Yes
Chi-squared	138.705***	138.344***	140.082***	134.665***	133.817***
Log likelihood	−1391.542	−1391.248	−1391.221	−1334.512	−1334.103
#Obs.	2140	2140	2140	2068	2068
#Protégé	302	302	302	285	285
#Mentor	107	107	107	103	103

Notes: Unstandardized coefficients (robust errors in parentheses). Two-tailed test. Random-effects linear regressions. Random-effects are incorporated at the mentor level. Maximum likelihood estimation.

† $p < 0.1$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

creativity, autonomy, and exploration are all insignificant, which is also inconsistent with the selection explanation. These results do not challenge our treatment explanation, however, which does not state any effect on protégés' productivity.

All the evidence seems to converge and suggest that our results are driven by the treatment effect rather than the selection effect.

4.5. Robustness tests

We carry out additional analyses to check the robustness of our results. First, our autonomy measure is constructed from the survey on mentors and at the level of mentor rather than in particular mentor-protégé dyads. This has the advantage that our results are not driven by mentors assigning different levels of autonomy based on different protégés' initial creativity. However, it has the disadvantage of missing more fine-grained dyadic information and the perceptions of the protégés. To address this issue, we collected additional data to measure autonomy using the survey instrument from the protégés' perspective (*Autonomy (Protégé)*). Specifically, we conducted a follow-up survey for protégés in 2018 and collected responses from 160 protégés remaining in academic careers. We find the autonomy reported by protégés to be reasonably correlated with that reported by mentors.[19] We replicate regressions using this alternative measure of autonomy to test the robustness of the moderating effect of autonomy (Table 5). The interaction effect between autonomy and mentor creativity remains positive in the short term but loses significance in the long term, which might be explained by the smaller sample size.

Second, the measure of exploration is based on references in publications. One potential issue is that it is based on the same set of publications for measuring protégé creativity during their PhD studies, so it can be interpreted as either an antecedent or a consequence of the protégés' creativity. In an attempt to address this issue, our follow-up protégé survey asked the protégés to identify the strategic positioning of their thesis topics in relation to the mentor's research line: central, peripheral, or unrelated (*Exploration (Protégé)*). Protégés' self-reported exploration measure is positively correlated with the bibliometric measure of exploration.[20] Table 5 further replicates the regression analysis using the protégé's reported exploration measure. Compared with our main results, the interaction effect between exploration and mentor creativity becomes significantly positive in the short term and remains positive in the long term.

Third, our focal dependent variables are ratio-based measures, the share of publications that are novel. It has two limitations: (1) the measure might have high fluctuation when the denominator is small (for example, when students have published only 1 or 2 papers), and (2) considering that novel papers are relatively rare, it hides the distinction between those who have and have not published any novel paper. Therefore, we also construct a dummy variable, which takes 1 for protégés with at least one novel paper, and 0 for those without. We repeat the short- and long-term analyses, and the results (Online Supplement S3) are consistent with those we report using the ratio-based measures, specifically a positive main effect of mentor creativity and positive moderating effects of both autonomy and exploration in the long term.

Fourth, for the long-term analysis, we further exclude protégé-years in which the protégé worked as a faculty member in the same lab as the mentor, as publications in this period might still partially reflect the mentor's immediate influence. Results are reported in Online Supplement S4. In this more restricted setting, the positive effect of mentor creativity loses significance, which could however be due to the smaller sample size, as the size of the coefficients are comparable to the result in Table 3. On the other hand, we consistently observe the positive moderating effects of autonomy and exploration.

4.6. Supplementary analyses

We examine potential boundary conditions for the effects of mentor creativity and mentoring style to test whether our results are contingent on some environmental factors. First, we look into the cohort size (Online Supplement S5). We expect the mentorship effect to become smaller as the cohort size increases because the mentor has less time for each protégé. The cohort sizes range from 1 to 7, with a mean value of 2. We approximately halve the sample into two subsets: (1) cohort size $= 1$ and (2) cohort size > 1. In the short term, results for both groups resemble the results for the whole sample, and we observe no significant differences in the direct or moderating effects between the two subsamples. In the long term, we find significantly positive effects of mentor creativity and positive moderating effects of autonomy in only the small cohorts but not in large cohorts. The moderating effect of exploration is insignificant in both samples, but the result for small cohorts is closer to the reported main result. This suggests that our results might not hold when the cohort size is large and the mentoring relation is less intense.

Second, we investigate university ranking (Online Supplement S6). On the one hand, top-tier universities may provide more resources and supports, which could facilitate the mentorship effects. On the other hand, they may also provide alternative sources for students to acquire creativity skills and thereby weaken the mentorship effects. We split the universities where the protégés did their PhD studies into top-tier and low-tier. We observe a significant main effect of mentor creativity only at top-tier universities, suggesting that low-tier universities may lack a supporting system to facilitate the mentorship effect. The moderating effect of autonomy is significantly positive in low-tier universities but insignificant in top-tier universities. This may suggest that autonomy is particularly important for low-tier universities to enable an effective mentorship effect, while in top-tier universities additional resources conductive to the mentorship effect are available, and autonomy is therefore less critical. The moderating effect of exploration is comparable between top- and low-tier universities.

5. Discussion and conclusions

This study explores mentorship as a channel for individuals (i.e., protégés) to acquire and develop creativity at the personal level. We show that mentoring transmits key creativity components from the mentor to the protégé. Therefore, mentors' creativity has a positive effect on their protégés'. Furthermore, we explore how this mentorship effect is moderated by mentoring styles: autonomy and exploration. We test the effects of mentor creativity and moderating effects of autonomy and exploration on protégé creativity using a sample of 143 life sciences professors (i.e., mentors) and their 685 PhD students (i.e., protégés) in Japan.

Our empirical results show that mentor creativity has a significantly positive effect on protégé creativity in the long run after the protégé has become independent researchers (i.e., faculty members), while this mentor effect is insignificant in the short run during protégé's PhD study. This finding is in line with our main theoretical expectation built on the componential model of creativity (Amabile, 1988) and the model of mentor functions (Kram, 1985). Specifically, mentor functions of *coaching, challenging assignments*, and *role modeling* are important

[19] The survey asked protégés to rate their responsibilities in (a) setting the topic, (b) formulating hypotheses, (c) planning, and (d) writing, on a four-point scale: (1) protégé = none & mentor = main; (2) protégé = supplementary & mentor = main, (3) protégé = main & mentor = supplementary, and (4) protégé = main & mentor = none. The validity of the survey measures was examined through correlation between protégé and mentor survey ratings, respectively for the four functions (a, b, c, and d). Spearman's correlation tests find significantly positive correlations in (a) and (d) ($r_s = .168$, $p < 0.05$ and $r_s = .142$, $p < 0.1$) but not in (b) and (c) ($p > 0.1$).

[20] A Spearman's correlation test finds that the student survey measure and the bibliometric measure are significantly positively correlated ($r_s = .181$, $p < .05$).

Table 5
Subsample analysis with self-reported measures of autonomy and exploration.

(A) During protégés' PhD studies

	Model 1	Model 2	Model 3	Model 4	Model 5
Mentor Creativity	.600†	.602†	−1.928	.592†	−.656
	(.319)	(.317)	(1.447)	(.304)	(.519)
Autonomy(Protégé)		−.006	−.081*		
		(.028)	(.037)		
Mentor Creativity x Autonomy(Protégé)			.889†		
			(.526)		
Exploration(Protégé)				.047	−0.033
				(.031)	(.036)
Mentor Creativity x Exploration(Protégé)					.712*
					(.314)
#PhD Same Cohort	.015	.016	.015	.021	.020
	(.026)	(.026)	(.026)	(.027)	(.027)
Ln(#Pub Mentor)	.002	.003	.005	.000	.000
	(.026)	(.027)	(.027)	(.027)	(.028)
Ln(#Pub Protégé (PhD))	.030	.032	.033	.027	.032
	(.026)	(.026)	(.026)	(.027)	(.026)
Ln(#Pub Protégé (MS))	.070†	.068	.068†	.075†	.068†
	(.042)	(.042)	(.041)	(.041)	(.039)
Female	−.035	−.029	−.031	−.039	−.046
	(.055)	(.057)	(.055)	(.056)	(.057)
PhD Univ Rank	.115	.108	.099	.105	.108
	(.070)	(.071)	(.069)	(.069)	(.068)
BS Univ Rank	−.015	−.015	−.016	−.019	−.022
	(.041)	(.040)	(.040)	(.040)	(.040)
Field dummies	Yes	Yes	Yes	Yes	Yes
Graduation Year dummies	Yes	Yes	Yes	Yes	Yes
Chi-squared	74.518***	81.704***	97.949***	76.998***	79.390***
Log likelihood	1.822	1.476	3.025	3.147	5.743
#Protégé	160	159	159	160	160
#Mentor	90	89	89	90	90

(B) After Protégés Become Faculty Members

	Model 1	Model 2	Model 3	Model 4	Model 5
Mentor Creativity	.278	.293	−0.396	.287	−0.427
	(.189)	(.200)	(1.362)	(.199)	(.388)
Autonomy(Protégé)		.021	.001		
		(.034)	(.038)		
Mentor Creativity x Autonomy(Protégé)			.255		
			(.507)		
Exploration(Protégé)				.053*	.003
				(.025)	(.032)
Mentor Creativity x Exploration(Protégé)					.512*
					(.249)
#PhD Same Cohort	.001	.002	.003	.007	.007
	(.016)	(.017)	(.017)	(.017)	(.017)
Ln(#Pub Mentor)	−.004	−.010	−.011	−.016	−.009
	(.031)	(.035)	(.035)	(.032)	(.032)
Ln(#Pub Protégé (Prof.))	−.075*	−.074†	−.072†	−.086*	−.082*
	(.038)	(.038)	(.038)	(.038)	(.037)
Ln(#Pub Protégé (MS))	−.035	−.040	−.041	−.040	−.047
	(.032)	(.032)	(.032)	(.032)	(.032)
Female	.036	.045	.039	.047	.057
	(.066)	(.069)	(.068)	(.062)	(.062)
Inbred	.066*	.067*	.068*	.058*	.063*
	(.030)	(.030)	(.031)	(.029)	(.029)
BS Univ Rank	.163***	.162***	.165***	.159***	.159***
	(.043)	(.043)	(.044)	(.047)	(.048)
PhD Univ Rank	−.151*	−.147†	−.159*	−.185*	−.190*
	(.074)	(.076)	(.076)	(.079)	(.079)
Univ Rank	−.097*	−.105*	−.107*	−.090*	−.091*
	(.041)	(.041)	(.042)	(.039)	(.039)
PRO	−.145**	−.147**	−.147**	−.152**	−.149**
	(.047)	(.047)	(.048)	(.047)	(.050)
Tenured	.012	.009	.010	.020	.026
	(.039)	(.041)	(.041)	(.039)	(.040)
Field dummies	Yes	Yes	Yes	Yes	Yes
Graduation Year dummies	Yes	Yes	Yes	Yes	Yes
Chi-squared	185.770***	227.497***	225.787***	271.175***	328.827***
Log likelihood	−57.179	−56.982	−56.786	−55.333	−53.888
#Obs.	366	366	366	366	366
#Protégé	110	110	110	110	110
#Mentor	75	75	75	75	75

Notes: Unstandardized coefficients (robust errors in parentheses). Two-tailed test. Random-effects linear regressions. Random-effects are incorporated at the mentor level. Maximum likelihood estimation. Autonomy (Protégé) and exploration (Protégé) are measured by a supplementary survey of protégés. The supplementary survey also asked the number of protégé's publications during master degree programs before they started PhD training (*Ln(#Pub Protégé (MS))*) as an additional proxy of protégé's ability.

† $p < 0.1$.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

channels to pass creativity components from the mentor to the protégé, in forms of *skills in the task domain* and *skills in creative thinking*. Furthermore, the effect of mentor effect on protégé creativity takes time to manifest, which echoes the call in the mentorship literature for studying long-term personal growth of protégé (Kram and Ragins, 2007). This observation also highlights the value of the mentorship lens for understanding how individuals develop creativity at the personal level long after the mentor-protégé relationship is terminated, which is complementary to the leadership lens focusing on the immediate effects of the leader-employee relationship (Shalley et al., 2004; van Knippenberg and Hirst, 2020; Woodman et al., 1993).

We also find that the effect of mentor creativity is positively moderated by autonomy and exploration. In other words, autonomy and exploration magnify the positive effect of mentor creativity on protégé creativity. This suggests that *skills in creative thinking* is more important than *skills in the task domain* for protégés to develop their creativity through mentorships, since skills in the tasks domain are more contextual and domain-specific (Amabile, 1988) and its transfer prefers lower levels of autonomy and exploration. This finding is also in line with Zuckerman's seminal study of Nobel laureates that the most important things that those elite scientists learned from their masters were about the standards of performance, scientific taste and styles of work, and socialization and self-confidence, rather than substantive knowledge or cutting-edge method/techniques (Zuckerman, 1977).

We found somewhat mixed direct effects of autonomy on protégé creativity. In the short run, the effect of autonomy is significantly positive for the full sample but insignificant for the subsample of PhD students who stay in the academia after graduation, and it is insignificantly negative in the long run. These findings speak to the mixed theories and empirical evidence regarding the effect of autonomy on creative performance (Cohen and Bailey, 1997; Langfred, 2004; Langfred and Moye, 2004). Our results suggest that the positive motivational gains from autonomy (Perkmann et al., 2019; Sauermann and Cohen, 2010; Sauermann and Stephan, 2013) might be offset by the negative effects in terms of insufficient guidance (Stern et al., 2008) and inefficiency and uncertainty in work organization (Shibayama, 2019). It is important for future research to explore what conditions are ideal for reaping the positive gains from autonomy without suffering from its losses.

On the other hand, we found consistently positive effects of exploration on protégé creativity for different samples and time periods. This finding adds to the long-standing view that exploration is an important source of creativity in the sociology and social psychology literatures (Audia and Goncalo, 2007; March, 1991; Skilton and Dooley, 2010; Merton, 1973). Our finding further extends this view into the context of mentorship, where the protégé explore outside the mentor's main area of expertise.

This study has several limitations. The most important one is that we cannot perfectly distinguish between a selection effect and a treatment effect of mentorship. The risk that our result is driven by selection is mitigated by the characteristics of the research setting, and evidence in our main results and additional analyses seems to converge and suggest that the results are driven by the treatment effect of mentoring. However, a randomized experiment or perfectly controlling for (or matching) protégés' initial creativity would be ideal to accurately estimate and test the mentorship effect.

Second, from a theoretical point of view, the creative performance of the protégés (both short and long terms) likely also depends on other group members and collaborators, not captured in our model. From an empirical point of view, we used protégés' collaborative publications to assess their individual creative performances. Although it is standard practice to use scientists' publications (including those with coauthors) to assess their research performance at the individual level, this approach might be less reliable when studying protégés during their PhD studies. To address this concern, we included only papers listing the protégé as the first, second, or corresponding author. Nonetheless, we need to consider how this omitted collaboration effect might affect our results. It is plausible that this effect is caused by the mentorship effect. That is, creative mentors provide an environment in which the protégé works with creative peer and collaborators. In this case, the collaboration effect partially mediates the overall mentorship effect. By omitting the collaboration effect, we thus observe the total mentorship effect. It is also possible that the collaboration effect causes the mentoring effect, but this is unlikely in our research setting. It is the professor who shapes the lab and students' collaboration network rather than the other way around. Also, the temporal design of our measures further mitigates this risk, as publications used for measuring mentor creativity are older than publications used for measuring protégé creativity. Alternatively, the collaboration effect and the mentorship effect may be commonly caused by a third factor associated with protégé creativity. This circles back to our discussion of various control variables and the treatment vs. selection effect.

Third, our study also faces some threats of external validity. We study a particular type of mentoring, formal faculty-student mentoring. Although our theory is not specific to this particular type of mentoring, it is unclear whether our findings can be generalized to informal faculty-student mentoring, youth mentoring, or workplace mentoring. Furthermore, we had a relatively small sample in a special setting (life sciences in Japan). It is possible that some cultural and institutional factors might challenge the generalizability of our findings. For example, the strong professor-student tie and somewhat insulated lab environment common in Japan helps us observe the effect of mentoring (Shibayama, 2021). In fact, our supplementary analysis finds the moderating effect of autonomy in smaller cohorts, where the professor-student tie can be stronger. It is plausible that other factors, such as colleagues and the specific institutional environment, play a larger role and that the effect of mentors is smaller in other academic systems. Even within our sample, we observe somewhat different results between top-tier and low-tier universities, which vary in research and education infrastructure at the institutional level. Another feature of PhD training in Japan is that it is less project-based, which potentially allows students more autonomy and exploration, but the same mentoring styles may be impractical in a more project-oriented setup. Finally, the field of life sciences has some distinctive features compared with other natural and social sciences. For example, high strategic uncertainty in life sciences may be associated with potentially high levels of autonomy, but stronger control may be imposed in other fields by the nature of their work (Whitley, 2000). It is of interest to investigate field differences, for example between big science and small science fields and between more and less interdisciplinary fields.

This study contributes to several lines of literature. First, it contributes to the creativity literature through advancing a relational perspective in the study of individual creativity. More specifically, it explores the role of mentoring for an individual to acquire and develop creativity. This study also contributes to the mentorship literature.

While the mentorship effect on protégé career outcomes has been studied extensively, the study advances this line of inquiry by responding to two calls: (1) to explore creativity at the personal level as a new protégé outcome for investigation, and (2) to examine differences in mentors and mentoring styles beyond merely comparing protégés with and without mentors (Allen and Eby, 2010; Dougherty and Dreher, 2007; Kram and Ragins, 2007). This study also speaks to the literature of science and higher education. Prior studies raised concern that the increasing bureaucratization in science may endanger the long-term progress of science by reducing PhD education, from training them to become fully autonomous scientists, to teaching them to perform subordinate and dependent tasks (Fox, 1992; Hackett, 1990; Laudel and Glaser, 2008; Shibayama, 2019; Walsh and Lee, 2015). This study further suggests that a lack of autonomy and exploration during mentoring may further inhibit the PhD student's ability to acquire and develop creativity. Shibayama (2019) suggested that autonomy and exploration help protégés go beyond their mentors' research domain.[21] Our findings show these mentoring styles are important facilitating factors for the transfer of creativity from mentors to protégés.

Our findings have implications for mentoring in practice. Organizations can use mentoring as an effective tool to improve first individual creative performance and then organizational creative and innovative performance. Using creative individuals as mentors and fostering a mentoring style with high levels of autonomy and exploration will allow organizations to maximize the benefits of mentoring. These findings also speak directly to PhD students, supervisors, and science policymakers. For PhD students aspiring to make original contributions to the stock of scientific knowledge, it is important to choose mentors who are inclined to conduct novel research. On the other hand, an effective mentorship for transferring creativity does not mean that the PhD student should work on topics that are at the core of the mentor's expertise or under close supervision of the mentor. PhD students and supervisors should rather ensure that the student has both autonomy and exploratory opportunities in terms of research content in order to maximize students' learning in the long term. Science policy should also protect the autonomy and exploration of PhD students, for example by providing independent fellowships to PhD students, rather than awarding grants to supervisors to recruit PhD students as research assistants. However, future research should further investigate the optimal level of autonomy and exploration and how to balance active mentoring and autonomy/exploration.

CRediT authorship contribution statement

Jian Wang: Conceptualization, Methodology, Formal analysis, Writing – review & editing. **Sotaro Shibayama:** Conceptualization, Methodology, Data curation, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[21] Shibayama (2019) aimed to understand the conflicting relationship between mentors and protégés, in which the levels of autonomy and exploration were analyzed, but did not look into the mechanism of protégés' learning from their mentors.

References

Abbott, A., 1981. Status and status strain in the professions. Am. J. Sociol. 86, 819–835.
Aghion, P., Dewatripont, M., Stein, J.C., 2008. Academic freedom, private-sector focus, and the process of innovation. RAND J. Econ. 39, 617–635.
Allen, T.D., Eby, L.T., Allen, T.D., Eby, L.T., 2010. Common bonds: an integrative view of mentoring relationships. The Blackwell handbook of mentoring: A multiple perspectives approach. Wiley-Blackwell, Malden, MA, pp. 397–419.
Allen, T.D., Eby, L.T., Poteet, M.L., Lentz, E., Lima, L., 2004. Career benefits associated with mentoring for proteges: a meta-analysis. J. Appl. Psychol. 89, 127–136.
Alvesson, M., Lee Ashcraft, K., Thomas, R., 2008. Identity matters: reflections on the construction of identity scholarship in organization studies. Organization 15, 5–28.
Amabile, T.M., 1983. The social psychology of creativity: a componential conceptualization. J. Pers. Soc. Psychol. 45, 357–376.
Amabile, T.M., 1988. A model of creativity and innovation in organizations. Res. Organ. Behav. 10, 123–167.
Amabile, T.M., Pratt, M.G., 2016. The dynamic componential model of creativity and innovation in organizations: making progress, making meaning. Res. Organ. Behav.v 36, 157–183.
Anderson, N., Potočnik, K., Zhou, J., 2014. Innovation and creativity in organizations:a state-of-the-science review, prospective commentary, and guiding framework. J. Manag. 40, 1297–1333.
Argote, L., Ingram, P., 2000. Knowledge transfer: a basis for competitive advantage in firms. Organ. Behav. Hum. Decis. Process. 82, 150–169.
Audia, P.G., Goncalo, J.A., 2007. Past success and creativity over time: a study of inventors in the hard disk drive industry. Manag. Sci. 53, 1–15.
Bandura, A., 1977. Social Learning Theory. Prentice Hall, Englewood Cliffs, N.J.
Barron, F., 1955. The disposition toward originality. The Journal of Abnormal and Social Psychology 51 (3), 478.
Borgatti, S.P., Cross, R., 2003. A relational view of information seeking and learning in social networks. Manag. Sci 49, 432–445.
Bryant, S.E., 2005. The impact of peer mentoring on organizational knowledge creation and sharing - An empirical study in a software firm. Group Organ. Manag. 30, 319–338.
Burt, R.S., 2004. Structural holes and good ideas. Am. J. Sociol. 110, 349–399.
Carraher, S.M., Sullivan, S.E., Crocitto, M.M., 2008. Mentoring across global boundaries: an empirical examination of home- and host-country mentors on expatriate career outcomes. J. Int. Bus. Stud. 39, 1310–1326.
Cattani, G., Ferriani, S., Lanza, A., 2017. Deconstructing the outsider puzzle: the legitimation journey of novelty. Organ. Sci. 28, 965–992.
Chao, G.T., O'Leary-Kelly, A.M., Wolf, S., Klein, H.J., Gardner, P.D., 1994. Organizational socialization: its content and consequences. J. Appl. Psychol. 79, 730–743.
Chao, G.T., Walz, P.M., Gardner, P.D., 1992. Formal and informal mentorships - a comparison on mentoring functions and contrast with nonmentored counterparts. Pers. Psychol. 45, 619–636.
Clynes, M., Corbett, A., Overbaugh, J., 2019. Why we need good mentoring. Nat. Rev. Cancer 19, 489–493.
Cohen, S.G., Bailey, D.E., 1997. What makes teams work: group effectiveness research from the shop floor to the executive suite. J. Manag. 23, 239–290.
Covaleski, M.A., Dirsmith, M.W., Heian, J.B., Samuel, S., 1998. The calculated and the avowed: techniques of discipline and struggles over identity in Big Six public accounting firms. Adm. Sci. Q. 43, 293–327.
Crossan, M.M., Lane, H.W., White, R.E., 1999. An organizational learning framework: from intuition to institution. Acad. Manag. Rev. 24, 522–537.
Donaldson, S.I., Ensher, E.A., Grant-Vallone, E.J., 2000. Longitudinal examination of mentoring relationships on organizational commitment and citizenship behavior. J. Career Dev. 26, 233–249.
Dougherty, D., 1992. Interpretive Barriers to Successful Product Innovation in Large Firms. Organ. Sci. 3, 179–202.
Dougherty, T.W., Dreher, G.F., Ragins, B.R., Kram, K.E., 2007. Mentoring and career outcomes. The Handbook of Mentoring at Work: Theory, Research and Practice. Sage Publications, Los Angeles, CA, pp. 51–93.
Drazin, R., Glynn, M.A., Kazanjian, R.K., 1999. Multilevel theorizing about creativity in organizations: a sensemaking perspective. Acad. Manag. Rev. 24, 286–307.
Feldman, D.C., 1981. The multiple socialization of organization members. Acad. Manag. Rev. 6, 309–318.
Fleming, L., Sorenson, O., 2004. Science as a map in technological search. Strat. Manag. J. 25, 909–928.
Ford, C.M., 1996. Theory of individual creative action in multiple social domains. Acad. Manage. Rev. 21, 1112–1142.
Fox, M.F., 1992. Research, teaching, and publication productivity - mutuality versus competition in academia. Sociol. Educ. 65, 293–305.
Freidson, E., 1984. The changing nature of professional control. Annu. Rev. Sociol. 10, 1–20.

Gong, Y., Huang, J.C., Farh, J.L., 2009. Employee learning orientation, transformational leadership, and employee creativity: the mediating role of employee creative self-efficacy. Acad. Manag. J. 52, 765–778.
Grant, R.M., 1996. Toward a knowledge-based theory of the firm. Strat. Manag. J. 17, 109–122.
Greenwood, R., Suddaby, R., 2006. Institutional entrepreneurship in mature fields: the big five accounting firms. Acad. Manag. J. 49, 27–48.
Grigoriou, K., Rothaermel, F.T., 2014. Structural microfoundations of innovation:the role of relational stars. J. Manag. 40, 586–615.
Grosser, T.J., Venkataramani, V., Labianca, G., 2017. An alter-centric perspective on employee innovation: the importance of alters' creative self-efficacy and network structure. J. Appl. Psychol. 102, 1360–1374.
Gruber, M., Harhoff, D., Hoisl, K., 2013. Knowledge recombination across technological boundaries: scientists vs. engineers. Manag. Sci. 59, 837–851.
Guilford, J.P., 1967. The Nature of Human Intelligence. McGraw Hill, New York.
Gupta, A.K., Smith, K.G., Shalley, C.E., 2006. The interplay between exploration and exploitation. Acad. Manag. J. 49, 693–706.
Haas, M.R., 2010. The double-edged swords of autonomy and external knowledge: analyzing team effectiveness in a multinational organization. Acad. Manag. J. 53, 989–1008.
Hackett, E.J., 1990. Science as a vocation in the 1990s - the changing organizational culture of academic science. J. High. Educ. 61, 241–279.
Hackman, R.J., Oldham, G., 1976. Motivation through the design of work: test of a theory. Organ. Behav. Hum. Perform. 16, 250–279.
Hall, R.H., 1968. Professionalization and Bureaucratization. Am. Sociol. Rev. 33, 92–104.
Hargadon, A.B., Bechky, B.A., 2006. When collections of creatives become creative collectives: a field study of problem solving at work. Organ. Sci. 17, 484–500.
Harvey, S., 2014. Creative synthesis: exploring the process of extraordinary group creativity. Acad. Manag. Rev. 39, 324–343.
Hatch, N.W., Dyer, J.H., 2004. Human capital and learning as a source of sustainable competitive advantage. Strat. Manag. J. 25, 1155–1178.
Huber, G.P., 1991. Organizational learning: the contributing processes and the literatures. Organ. Sci. 2, 88–115.
Humberd, B.K., Rouse, E.D., 2016. Seeing you in me and me in you: personal identification in the phases of mentoring relationships. Acad. Manag. Rev. 41, 435–455.
Johnson, W.B., Rose, G., Schlosser, L.Z., Allen, T.D., Eby, L.T., 2010. Student-faculty mentoring: theoretical and methodological issues. The Blackwell Handbook of Mentoring: A Multiple Perspectives Approach. Wiley-Blackwell, Malden, MA, pp. 49–69.
Kam, B.H., 1997. Style and quality in research supervision: the supervisor dependency factor. High. Educ. 34, 81–103.
Kaplan, S., Vakili, K., 2015. The double-edged sword of recombination in breakthrough innovation. Strat. Manag. J. 36, 1435–1457.
Kim, Y.J., Kim, J., 2020. Does negative feedback benefit (or harm) recipient creativity? The role of the direction of feedback flow. Acad. Manag. J. 63, 584–612.
Kneller, R., Whitley, R., Gläser, J., Engwall, L., 2010. The changing governance of japanese public science. Reconfiguring Knowledge Production: Changing Authority Relationships in the Sciences and Their Consequences for Intellectual Innovation. Oxford University Press, Oxford; New York, pp. 110–145.
Kram, K.E., 1985. Mentoring at Work: Developmental Relationships in Organizational Life. Scott Foresman, Glenview, Ill.
Kram, K.E., Ragins, B.R., Ragins, B.R., Kram, K.E., 2007. The landscape of mentoring in the 21st century. The Handbook of Mentoring at Work: Theory, Research, and Practice. Sage Publications, Los Angeles, CA, pp. 659–692.
Krebs, H.A., 1967. The making of a scientist. Nature 215, 1441–1445.
Kuhn, T.S., 1962. The Structure of Scientific Revolutions. University of Chicago Press, Chicago, IL.
Langfred, C.W., 2004. Too much of a good thing? Negative effects of high trust and individual autonomy in self-managing teams. Acad. Manag. J. 47, 385–399.
Langfred, C.W., Moye, N.A., 2004. Effects of task autonomy on performance: an extended model considering motivational, informational, and structural mechanisms. J. Appl. Psychol. 89, 934–945.
Laudel, G., Glaser, J., 2008. From apprentice to colleague: the metamorphosis of early career researchers. High. Educ. 55, 387–406.
Leahey, E., Beckman, C.M., Stanko, T.L., 2016. Prominent but less productive: the impact of interdisciplinarity on scientists' research. Adm. Sci. Q. 62, 105–139.
Lee, A., Dennis, C., Campbell, P., 2007. Nature's guide for mentors. Nature 447, 791–797.
Levinthal, D.A., March, J.G., 1993. The myopia of learning. Strat. Manag. J. 14, 95–112.
Li, E.Y., Liao, C.H., Yen, H.R., 2013. Co-authorship networks and research impact: a social capital perspective. Res. Policy 42, 1515–1530.
Li, Y., Li, N., Li, C., Li, J., 2020. The boon and bane of creative "stars": a social network exploration of how and when team creativity is (and is not) Driven by a star teammate. Acad. Manag. J. 63, 613–635.
Liu, H., Mihm, J., Sosa, M.E., 2018. Where do stars come from? The role of star vs. nonstar collaborators in creative settings. Organ. Sci. 29, 1149–1169.
MacKinnon, D.W., 1965. Personality and the realization of creative potential. American Psychologist 20 (4), 273.
Mainhard, T., van der Rijst, R., van Tartwijk, J., Wubbels, T., 2009. A model for the supervisor-doctoral student relationship. High. Educ. 58, 359–373.
March, J.G., 1991. Exploration and exploitation in organizational learning. Organ. Sci. 2, 71–87.
Mazmanian, M., Orlikowski, W.J., Yates, J., 2013. The autonomy paradox: the implications of mobile email devices for knowledge professionals. Organ. Sci. 24, 1337–1357.
McFadyen, M.A., Cannella, A.A., 2004. Social capital and knowledge creation: diminishing returns of the number and strength of exchange relationships. Acad. Manag. J. 47, 735–746.
McFadyen, M.A., Semadeni, M., Cannella, A.A., 2009. Value of strong ties to disconnected others: examining knowledge creation in biomedicine. Organ. Sci. 20, 552–564.
Mednick, S.A., 1962. The associative basis of the creative process. Psychol. Rev. 69, 220–232.
Merton, R.K., 1973. The Sociology of Science. University of Chicago Press, Chicago, IL.
Misu, T., Horoiwa, A., Chayama, S., 2010. Career Paths of Recent Doctoral Graduates in Science. NISTEP Research Material. NISTEP, Tokyo.
Morrison, E.W., 1993. Newcomer information-seeking - exploring types, modes, sources, and outcomes. Acad. Manag. J. 36, 557–589.
Mumford, M.D., 2003. Where have we been, where are we going? Taking stock in creativity research. Creat. Res. J. 15, 107–120.
Nahapiet, J., Ghoshal, S., 1998. Social capital, intellectual capital, and the organizational advantage. Acad. Manag. Rev. 23, 242–266.
Nelson, R.R., Winter, S.G., 1982. An Evolutionary Theory of Economic Change. Belknap Press of Harvard University Press, Cambridge, MA.
NISTEP, 2005. Study For evaluating the achievements of the S&T basic plans in Japan: comparative analysis on abilities and careers of human resources in science and technology between Japan and the US, NISTEP Report. NISTEP, Tokyo.
Noe Raymond, A., Greenberger David, B., Wang, S., 2002. Mentoring: What we Know and Where We Might go, Research in Personnel and Human Resources Management. Emerald Group Publishing Limited, pp. 129–173.
Nonaka, I., 1994. A dynamic theory of organizational knowledge creation. Organ. Sci. 5, 14–37.
Nonaka, I., Takeuchi, H., 1995. The Knowledge-Creating Company: How Japanese companies Create the Dynamics of Innovation. Oxford University Press, New York.
Oldham, G.R., Cummings, A., 1996. Employee creativity: personal and contextual factors at work. Acad. Manag. J. 39, 607–634.
Payne, S.C., Huffman, A.H., 2005. A longitudinal examination of the influence of mentoring on organizational commitment and turnover. Acad. Manag. J. 48, 158–168.
Pelz, D.C., Andrews, F.M., 1976. Scientists in organizations: Productive Climates For Research and development. University of Michigan, Ann Arbor. Rev. ed. Institute for Social Research.
Perkmann, M., McKelvey, M., Phillips, N., 2019. Protecting scientists from Gordon Gekko: how organizations use hybrid spaces to engage with multiple institutional logics. Organ. Sci. 30, 298–318.
Perretti, F., Negro, G., 2006. Filling empty seats: how status and organizational hierarchies affect exploration versus exploitation in team design. Acad. Manag. J. 49, 759–777.
Perry-Smith, J.E., Mannucci, P.V., 2017. From creativity to innovation: the social network drivers of the four phases of the idea journey. Acad. Manag. Rev. 42, 53–79.
Perry-Smith, J.E., Shalley, C.E., 2003. The social side of creativity: a static and dynamic social network perspective. Acad. Manag. Rev. 28, 89–106.
Polanyi, M., 1958. Personal Knowledge; Towards a Post-Critical Philosophy. University of Chicago Press, Chicago.
Ragins, B.R., Cotton, J.L., 1999. Mentor functions and outcomes: a comparison of men and women in formal and informal mentoring relationships. J. Appl. Psychol. 84, 529–550.
Ramaswami, A., Dreher, G.F., Allen, T.D., Eby, L.T., 2010. The benefits associated with workplace mentoring relationships. The Blackwell Handbook of Mentoring: A Multiple Perspectives Approach. Wiley-Blackwell, Malden, MA, pp. 211–231.
Reagans, R., McEvily, B., 2003. Network structure and knowledge transfer: the effects of cohesion and range. Adm. Sci. Q. 48, 240–267.
Rouse, E.D., 2020. Where you end and i begin: understanding intimate co-creation. Acad. Manag. Rev. 45, 181–204.
Sauermann, H., Cohen, W.M., 2010. What Makes Them Tick? Employee Motives and Firm Innovation. Manag. Sci. 56, 2134–2153.
Sauermann, H., Stephan, P., 2013. Conflicting logics? A multidimensional view of industrial and academic science. Organ. Sci. 24, 889–909.
Scandura, T.A., 1992. Mentorship and career mobility - an empirical-investigation. J. Organ. Behav. 13, 169–174.
Schumpeter, J.A., 1939. Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process, 1st ed. McGraw-Hill Book Company, inc., New York, London.
Shalley, C.E., Zhou, J., Oldham, G.R., 2004. The Effects of personal and contextual characteristics on creativity: where should we go from here? J. Manag. 30, 933–958.
Sharma, A., 1997. Professional as agent: knowledge asymmetry in agency exchange. Acad. Manag. Rev. 22, 758–798.
Shibayama, S., 2019. Sustainable development of science and scientists: academic training in life science labs. Res. Policy 48, 676–692.
Shibayama, S., 2021. Development of originality under inbreeding: a case of life science labs in Japan. High. Educ. Q. n/a.
Shipton, H., Fay, D., West, M., Patterson, M., Birdi, K., 2005. Managing people to promote innovation. Creat. Innov. Manag. 14, 118–128.
Simonton, D.K., 2003. Scientific creativity as constrained stochastic behavior: the integration of product, person, and process perspectives. Psychol. Bull. 129, 475–494.
Singh, V., Bains, D., Vinnicombe, S., 2002. Informal mentoring as an organisational resource. Long Range Plan. 35, 389–405.

Skilton, P.F., Dooley, K.J., 2010. The effects of repeated collaboration on creative abrasion. Acad. Manag. Rev. 35, 118–134.

Stern, Z., Katz-Navon, T., Naveh, E., 2008. The influence of situational learning orientation, autonomy, and voice on error making: the case of resident physicians. Manag. Sci. 54, 1553–1564.

Swap, W., Leonard, D., Shields, M., Abrams, L., 2001. Using mentoring and storytelling to transfer knowledge in the workplace. J. Manag. Inf. Syst. 18, 95–114.

Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strat. Manag. J. 18, 509–533.

Tharenou, P., Saks, A.M., Moore, C., 2007. A review and critique of research on training and organizational-level outcomes. Hum. Resour. Manag. Rev. 17, 251–273.

Tierney, P., Farmer, S.M., 2011. Creative self-efficacy development and creative performance over time. J. Appl. Psychol. 96, 277–293.

Tortoriello, M., Krackhardt, D., 2010. Activating cross-boundary knowledge: the role of Simmelian ties in the generation of innovations. Acad. Manag. J. 53, 167–181.

Uzzi, B., 1996. The sources and consequences of embeddedness for the economic performance of organizations: the network effect. Am. Sociol. Rev. 61, 674–698.

Uzzi, B., Mukherjee, S., Stringer, M., Jones, B., 2013. Atypical combinations and scientific impact. Science 342, 468–472.

Uzzi, B., Spiro, J., 2005. Collaboration and creativity: the small world problem. Am. J. Sociol. 111, 447–504.

van Knippenberg, D., Hirst, G., 2020. A motivational lens model of person × situation interactions in employee creativity. J. Appl. Psychol. 105, 1129–1144.

von Hippel, E., Tyre, M.J., 1995. How learning by doing is done: problem identification in novel process equipment. Res. Policy 24, 1–12.

Wallace, J.E., 1995. Organizational and professional commitment in professional and nonprofessional organizations. Adm. Sci. Q. 40, 228–255.

Walsh, J.P., Lee, Y.N., 2015. The bureaucratization of science. Res. Policy 44, 1584–1600.

Wanberg, C.R., Welsh, E.T., Hezlett, S.A., 2003. Mentoring research: a review and dynamic process model. In: Research in personnel and human resources management, 22. Elsevier Science Ltd, Oxford, England, pp. 39–124.

Wang, J., 2016. Knowledge creation in collaboration networks: effects of tie configuration. Res. Policy 45, 68–80.

Wang, J., Lee, Y.N., Walsh, J.P., 2018. Funding model and creativity in science: competitive versus block funding and status contingency effects. Res. Policy 47, 1070–1083.

Wang, J., Veugelers, R., Stephan, P., 2017. Bias against novelty in science: a cautionary tale for users of bibliometric indicators. Res. Policy 46, 1416–1436.

Weitzman, M.L., 1998. Recombinant Growth*. Q. J. Econ. 113, 331–360.

Whitley, R., 2000. The Intellectual and Social Organization of the Sciences, 2nd ed. Oxford University Press, Oxford, UK; New York, NY.

Woodman, R.W., Sawyer, J.E., Griffin, R.W., 1993. Toward a theory of organizational creativity. Acad. Manag. Rev. 18, 293–321.

Yoshioka-Kobayashi, T., Shibayama, S., 2020. Early career training and development of academic independence: a case of life sciences in Japan. Stud. High. Educ. 1–23.

Yoshioka-Kobayashi, T., Shibayama, S., 2021. Determinants of Career Selection By Master Students in Life and Information sciences. The University of Tokyo. IFI Working Paper Series.

Zhang, X., Bartol, K.M., 2010. Linking empowering leadership and employee creativity: the influence of psychological empowerment, intrinsic motivation, and creative process engagement. Acad. Manag. J. 53, 107–128.

Zhou, J., 2003. When the presence of creative coworkers is related to creativity: role of supervisor close monitoring, developmental feedback, and creative personality. J. Appl. Psychol. 88, 413–422.

Zuckerman, H., 1977. Scientific Elite: Nobel Laureates in the United States. Free Press, New York.