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Task Design, Team Context, and Psychological Safety: An Empirical Analysis of R&D Projects in High Technology Organizations

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High technology organizations need to develop new products or processes that address the dual goals of exploration and exploitation. The competing viewpoints and the asymmetric nature of market returns associated with these goals in R&D projects can heighten stress levels among project team members and reduce their psychological safety. While current research calls for greater focus on task design for improving psychological safety, we know little about how team contextual factors affect this relationship. This study develops and tests a conceptual framework that examines the moderating role of R&D team contextual factors, namely, relative exploration and project-organization metric alignment on the relationship between a key task design variable, namely, team autonomy, and psychological safety. Relative exploration captures the extent to which exploration goals are emphasized over exploitation goals in an R&D project, while project-organization metric alignment measures the extent to which project metrics are aligned with broader organizational metrics. Furthermore, we examine the performance consequences of psychological safety in R&D projects. The empirical analysis is conducted using primary data collected from multiple informants across 110 R&D projects in 34 high technology business units. Our results indicate that relative exploration and project-organization metric alignment have contrasting moderating effects. Furthermore, the effect of psychological safety on project performance is found to be indirect and mediated through team turnover. Implications of the study findings, limitations, and directions for future research are discussed.

Key words: R&D project management; psychological safety; exploration; exploitation; team turnover
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1. Introduction

To compete in dynamic, fast-paced environments, high technology organizations need to develop products and processes that address the dual goals of exploration and exploitation (Gupta et al. 2006, March 1991, Rothaermel and Alexandre 2009). Exploration involves introducing new products, entering new technology fields, or opening up new markets; these goals have stochastic outcomes but can result in higher market returns. In contrast, exploitation involves reducing development costs and development times or improving quality; these goals have deterministic outcomes and are usually associated with lower market returns (Levinthal and March 1993). Given the competing viewpoints and the asymmetric nature of market returns associated with exploration and exploitation, managing R&D projects with these dual goals presents a daunting challenge. This challenge has increased significantly in the recent global economic recession with R&D projects facing severe budget cuts despite increasing their focus on developing new products and processes (Jana 2009, McKinsey Global Report 2010, R&D Magazine 2010). For example, Burgelman et al. (2008) observe that R&D project team members at 3M's Optical Systems Division often encountered extreme distress and deteriorating team dynamics when faced with time and budget constraints on new product development projects. This resulted in frequent team turnovers and reduced project performance.

Noting this challenge, recent studies have called for greater attention toward examining the role of project task design—i.e., the system of arrangements and procedures for organizing project tasks (Cohen and Bailey 1997, Sinha and Van de Ven 2005)—on psychological safety (e.g., Bendoly and Swink 2007, Edmondson and Nembhard 2009, Loch and Wu 2007). Psychological safety is a "belief that the team is safe for interpersonal risk taking" (Edmondson 1999, p. 354). The focus on psychological safety is important in R&D projects since team members often engage in risk taking actions for addressing project execution challenges (Greve 2003, Lee et al. 2011). Research on project task design informs us that providing team members with decision-making autonomy can enhance their psychological safety (Bunderson and Boumgarden 2010, Hoegl and Parboteeah 2006, Thompson 2004). That is, when project team members are given greater decision-making authority to plan, design, and to manage their tasks, it is likely that such decisions will be well accepted among them and will result in positive team behaviors (Adler and Borys 1996).

Although the relationship between team autonomy and psychological safety is broadly acknowledged in the literature, there is very little understanding of how team context influences this relationship (Mathieu et al. 2006, Zellmer-Bruhn and Gibson 2006). Team context can create substantial variation in psychological safety levels across R&D project teams, even within the same organization (Edmondson 1999, 2002). In an R&D project environment, team context includes the degree of uncertainty in tasks and technology that surrounds these project teams (Pisano et al. 2001, Zellmer-Bruhn and Gibson 2006). This can manifest by way of greater emphasis on exploration goals relative to exploitation goals (Uotila et al. 2009). Further, team context also involves the organizational mechanisms that support the functioning of R&D project teams (Ancona and Caldwell 1992). A better understanding of team context in R&D projects can help managers anticipate and address the team dynamics issues that are associated with their performance (Edmondson and Nembhard 2009, Marks et al. 2001). This study, therefore, has a twofold research agenda.

First, we build on the team effectiveness framework proposed by Cohen and Bailey (1997) to investigate the relationships among team autonomy, team context, and psychological safety in R&D projects. Specifically, we look at two fundamental factors characterizing team context in R&D projects: (i) relative exploration, which captures the extent to which exploration goals are emphasized over exploitation goals in a project (Uotila et al. 2009), and (ii) project-organization metric alignment, which measures the extent to which project metrics are aligned with broader organizational metrics (Bunderson and Boumgarden 2010). Our research examines how these team contextual factors influence the relationship between team autonomy and psychological safety.

Second, we investigate the performance consequences of psychological safety. Current research indicates that psychological safety is an emergent characteristic of teams whose impact on project performance is not direct but mediated through team outcomes (Edmondson and Nembhard 2009, Faraj and Yan 2009). One such outcome is the turning over of project team members, which is often associated with poor project performance (Kessler and Chakrabarti 1999, Slotegraaf and Atuahene-Gima 2011). Given the importance of minimizing turnover in R&D projects (Burgelman et al. 2008), we first investigate the effects of psychological safety on team turnover—which measures the extent to which the project team's core membership changes during project execution (Edmondson et al. 2001, Narayanan et al. 2011). We then examine the effects of team turnover on project performance.

The empirical analysis is conducted using panel data collected from multiple informants across 110 R&D projects at 34 high technology business units that belong to fast clockspeed industries (e.g., semiconductor, medical devices) (Beckman and Sinha 2005, Chandrasekaran et al. 2011, Fine 1998). Narrowing the scope of this research to fast clockspeed industries represents an important step in our study. This not only allows us to sample R&D projects with dual goals of exploration and exploitation, which are common in such industries (Lewis et al. 2002), but also helps control for external sources of heterogeneity. Consistent with our predictions, the study findings suggest that the effect of team autonomy on psychological safety is conditional on team contextual factors characterizing an R&D project. Further, these factors have contrasting moderating effects; although relative exploration negatively moderates the relationship between team autonomy and psychological safety, project-organization metric alignment positively moderates this relationship. Next, with respect to the performance consequences, we find that the effect of psychological safety on R&D project performance is indirect and mediated through team turnover. That is, psychological safety reduces team turnover in R&D projects and this decrease in turnover translates into improved R&D project performance.

The rest of the study is organized in the following manner. In section 2, we review the literature on psychological safety that leads to a discussion of the conceptual framework and testable hypotheses. Section 3 details the research design and data collection approach and section 4 provides details regarding the analysis and the results. Finally in section 5, we conclude by spelling out the major contributions, limitations, and directions for future research.

2. Theoretical Background and Hypotheses

Psychological safety describes team members' perceptions of the consequences of interpersonal risk taking and experimentation within teams (Edmondson 1999). As psychological safety increases, team members are able to express their ideas freely and provide suggestions about their work without fear of reprisal, criticism, or punishment (Edmondson and Nembhard 2009).

Our review of the literature highlights a number of studies that have focused on the performance consequences of psychological safety across different industry settings. They include intensive care units in hospitals (Nembhard and Edmondson 2006, Tucker et al. 2007), Six-Sigma projects (Choo et al. 2007, Siemsen et al. 2009), software development (Faraj and Yan 2009), and manufacturing (Bunderson and Boumgarden 2010). Despite this substantial body of literature, there is a general lack of empirical consensus on how psychological safety impacts project performance. Although some studies report evidence suggesting a direct link between psychological safety and project performance (Baer and Frese 2003, Lee et al. 2011, Nembhard and Edmondson 2006), others indicate an indirect link that is mediated through team outcomes (Choo et al. 2007, Faraj and Yan 2009, Siemsen et al. 2009, Tucker et al. 2007).

In contrast, while research examining the antecedents to psychological safety is limited, the small set of studies in this area often converge on the role of task-design factors as primary drivers of psychological safety (e.g., Edmondson 1999, Faraj and Yan 2009, Mathieu et al. 2006). For instance, Edmondson (1999) observes that team members were more likely to feel safe taking risks in self-managed teams that had high levels of decision-making autonomy compared to traditional teams that had low levels of decision-making autonomy. Similarly, Faraj and Yan (2009) find that increasing decision-making autonomy to design team boundary activities is associated with psychological safety in software development teams. Further, a study by Mathieu et al. (2006) finds support for the relationship between team empowerment and safety climate in customer service work teams. Beyond this general consensus on the relationship between task design and psychological safety, however, not much is known about the role of team context on this relationship. Since R&D project teams rarely function as isolated entities within an organization, subtle variations in their team contexts can produce substantial variations in the effects of task design (Gibson et al. 2003, Hackman 2002), even within the same organization. Understanding the interplay between task design and team contextual factors on psychological safety is a matter of considerable importance for R&D project managers.

Building on the gaps identified in the existing literature, we characterize psychological safety as an emergent characteristic of an R&D project team. Emergent characteristics vary as a function of task design and team context (Cohen and Bailey 1997, Faraj and Yan 2009). We therefore examine the effects of team autonomy and the team contextual factors, namely, relative exploration and project-organization metric alignment, on psychological safety. The study of antecedents and performance consequences of an emergent characteristic within a single framework not only makes the framework holistic and rigorous, but also helps generate actionable insights for improving R&D project performance (Edmondson and Nembhard 2009, Marks et al. 2001).

2.1. Team Autonomy and Psychological Safety

Task design refers to task or project characteristics that can be modified to enhance team dynamics (Cohen and Bailey 1997, Stewart 2006). Decisions related to task design form a critical element of project execution in R&D projects and have pervasive implications for their outcomes (Shaw 1981). A key task design decision in a project involves determining the level of decision-making autonomy that will be granted to project team members (Stewart 2006). Higher levels of team autonomy can allow project team members to "manage themselves, assign jobs, plan and schedule work, make production- or service-related decisions, and take action on problems" (Kirkman and Shapiro 2001, p. 557). Furthermore, team members also experience greater freedom to make day-to-day tactical project decisions (e.g., project management and resource allocation decisions) independent of external supervision (Naveh 2007, Stewart 2006).

We extend the above set of arguments to examine the effects of team autonomy on psychological safety in R&D projects. Team autonomy can influence the development of psychological safety through two distinct mechanisms. First, greater responsibility in making day-to-day project decisions generates greater initiative among team members and promotes open and direct communication channels among them (Hoegl and Parboteeah 2006, Thompson 2004). Team members do not have to "wait for managerial permission or guidance before engaging in [necessary] risk-taking activities" and can freely exchange their views with each other without the fear of reprisal or punishment by a project leader (Kirkman et al. 2004, p. 177). Second, given that team members are familiar with the "ground realities" of a project, higher levels of team autonomy allow them to make critical task decisions and mobilize a coordinated response to project execution challenges (Haas 2010, Hackman 2002). Such a response reduces opportunities for apportioning individual blame among team members, raising their perceptions of each other's ability and integrity (Bendoly and Swink 2007, Hoegl et al. 2004, Lee et al. 2011) and enhancing their psychological safety. Therefore, we posit the following hypothesis.[§]

HYPOTHESIS 1. *Team autonomy is positively associated with psychological safety in R&D projects.*

2.2. Moderating Effect of Relative Exploration

The term "relative exploration" captures the extent to which exploration goals are emphasized over exploitation goals in an R&D project. It reflects the duality that arises from pursuing both exploration and exploitation goals in a project. Few studies have explicitly conceptualized or measured this duality within a project (Crossan and Hurst 2006). We therefore know little about the dynamics of these goals at the project level or their implications from a project management standpoint (Cardinal 2001, Chao and Kavadias 2008, Lewis et al. 2002). In our study we argue that an increase in relative exploration within an R&D project can erode the potential benefits associated with team autonomy in multiple ways (Birkinshaw et al. 2002, Haas 2010).

First, as relative exploration increases, team members face greater uncertainty regarding their individual responsibilities and the specific nature of the project tasks to be performed (Haas 2006, Thompson 1967). With R&D projects frequently operating under time and budget constraints, this uncertainty can elevate stress levels among team members, particularly more so in autonomous teams where team members have the added responsibility of making day-to-day tactical project decisions (Alvesson 2004, Bodensteiner et al. 1989, Edmondson 2008, Holmqvist 2004). For instance, Holmqvist (2004, p. 76) reports that team members engaged in R&D projects with high levels of relative exploration often "got stuck" in discussing individual ideas and problem-solving techniques, failing to reach a consensus and make sufficient progress on project execution. This delay created additional pressure and compounded existing stress levels among the team members. Second, while team members face greater difficulty in addressing task-related problems during uncertainties, the absence of top-down authority structures and clear mapping of interdependencies in autonomous teams can reduce their ability to evaluate the consequences of their actions (Bunderson and Boumgarden 2010, Edmondson 1999). Third, at high levels of relative exploration, team autonomy can create "isolation risks" among team members by precluding a mutual understanding of project tasks and by reducing joint problem-solving effort (Haas 2010). As Haas (2010, p. 993) notes:

> The isolation risks created by autonomy are greater for more uncertain tasks, characterized by higher novelty or complexity (Galbraith 1973, Tushman 1979). The more novel the task for the team members involved, the more isolation endangers strategic effectiveness because they have little experience with similar tasks to exploit as they develop, select and pursue the team strategic options.

Haas (2010) further argues that isolation risks are particularly detrimental to team dynamics when uncertainty in the team context is high as they frequently lead to a "not-invented-here" syndrome (Katz and Allen 1982) and conflicts in such environments (Hoegl and Parboteeah 2006). Taken together, the above arguments suggest that an increase in relative exploration weakens the positive relationship between team autonomy and psychological safety in R&D projects.

HYPOTHESIS 2. *Relative exploration moderates the relationship between team autonomy and psychological safety in R&D projects such that the positive effect of team autonomy on psychological safety becomes weaker as relative exploration increases.*

2.3. Moderating Effect of Project-Organization Metric Alignment

Research on project management argues for the importance of aligning R&D project level metrics with the overall organizational metrics to improve project execution (Bendoly et al. 2007, Im and Rai 2008, Tatikonda and Rosenthal 2000). This is because decisions relating to exploration and exploitation goals in R&D projects are typically made at the firm level whereas the actual execution of these decisions occurs at the project level (Chao et al. 2009, Gerwin and Ferris 2004, Wheelwright and Clark 1992). Poor fit between strategy and execution can result in insufficient allocation of resources to these projects and can create ambiguity regarding the task content and project deliverables (Amabile 1998). Aligning metrics across these levels not only reduces this ambiguity, but also provides team members with a sense of direction and clarity regarding the expectations from senior management (Choo et al. 2007, Sinha and Van de Ven 2005). Team members interact with greater confidence and have reduced stress levels since they are able to evaluate their autonomous actions with respect to senior management expectations (Bunderson and Boumgarden 2010). This can increase psychological safety among project team members. Supporting this point, Kirsch et al. (2002) note that project team members were more likely to make task-related decisions judiciously and realize the psychological benefits of autonomy when project metrics were unambiguous and aligned with the overall organizational metrics.

Furthermore, such an alignment can function as a governing instrument for R&D projects, which typically have team members from different functional backgrounds performing tasks (Ancona and Caldwell 1992). The various functions within an organization each have disparate business environments and priorities; hence reaching consensus among team members from different functional backgrounds can be a challenge when team autonomy is high (Denison et al. 1996). Aligning project-level metrics with the organizational metrics establishes accountability across team members from different functional backgrounds for their actions, encourages them to embrace the same set of work values, and work collectively toward executing project tasks (Jansen et al. 2006, Kirsch et al. 2002). Rewards and punishments for team members are based on evaluations of collective effort rather than individual autonomous actions when project-organization metric alignment is high (Sarin and Mahajan 2001). The absence of direct spotlight on individual actions minimizes the fear of failure among team members (Hackman 2002), thereby enhancing their psychological safety. Based on the above arguments, we propose the following hypothesis.

HYPOTHESIS 3. *Project-organization metric alignment moderates the relationship between team autonomy and psychological safety in R&D projects such that the positive effect of team autonomy on psychological safety becomes stronger as project-organization metric alignment increases.*

2.4. Consequences of Psychological Safety

Research has broadly characterized psychological safety as an emergent characteristic of project teams whose influence on project performance is indirect and mediated through team outcomes (e.g., Edmondson 2002, Faraj and Yan 2009). In particular, anecdotal evidence suggests that lower levels of psychological safety can reduce team stability through frequent team member turnover especially in high technology settings (Edmondson et al. 2001, Hackman 2002, Tucker and Edmondson 2002). For example, Hackman (2002, p. 125) in a study of Xerox's customer service teams observes that "market pressures, new strategies and the presence of competing goals" created high stress environments and led to turnover in Xerox's customer service teams. In this study, we extend existing anecdotal evidence to formally examine the mediating effects of team turnover in the relationship between psychological safety and R&D project performance.

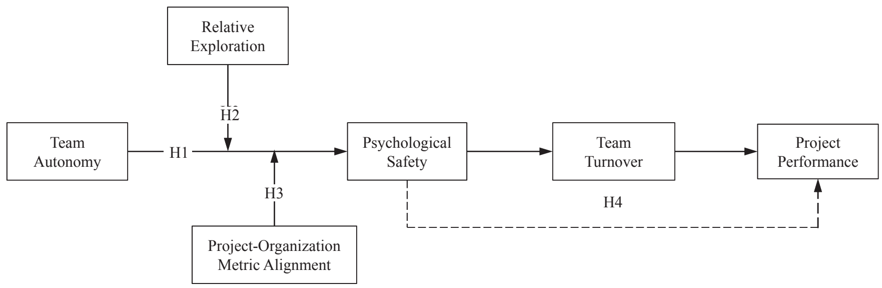
Team turnover is defined as the extent to which a team's core membership changes during project execution (Akgün and Lynn 2002, Narayanan et al. 2011, Slotegraaf and Atuahene-Gima 2011). We argue that team turnover can negatively impact R&D project performance as it disrupts project execution in several ways. First, team turnover can result in greater time spent on team-building activities. Second, during the transition period, the departing employee is less likely to take on important or challenging tasks or become involved in consequential decision-making activities. In many cases, the workloads of remaining project team members will increase to offset the vacant position. Third, the process of finding a suitable replacement for those leaving a project midway is time consuming as a significant amount of knowledge possessed by team members in R&D projects is tacit (Narayanan et al. 2011). Even if a suitable replacement employee is found quickly, there is an initial "set-up cost" involved, i.e., the replacement employee will need time and training to get familiar with the project environment and task details (Oldham and Cummings 1996, Osterman 1987).

Turnover in R&D project teams can be minimized by increasing their psychological safety (Aiken et al. 2002, Edmondson et al. 2001). Psychological safety promotes a shared interpersonal context among team members and provides a safe work environment to take interpersonal risks and develops strong social ties within the team (Siemsen et al. 2009). Team members not only derive greater satisfaction working in psychologically safe environments but also espouse greater willingness to stay on their teams throughout the project duration (Faraj and Yan 2009). For example, Aiken et al. (2002) show that the turnover among nurses in hospital work teams significantly reduced with increase in their perceived levels of psychological safety. The absence of psychological safety, in contrast, can foster team turnover in several ways. First, when psychological safety is low, team members experience anxiety due to expectations of negative consequences associated with experimentation and risk taking (Kramer 1991). To reduce anxiety, individual team members may often reduce contact with each other through voluntary turnover (Pelled 1996). Second, low levels of psychological safety can also create fear and job insecurity in the minds of team members when working on challenging projects and can drive them to look for other employment opportunities beyond the project team. Given that team turnover has direct consequences for project performance, the above arguments suggest that the effect of psychological safety on project performance is indirect and mediated through team turnover. That is, psychological safety increases project performance through a corresponding decrease in team turnover.

HYPOTHESIS 4. *The effect of psychological safety on project performance is indirect and mediated through team turnover.*[1]

We summarize the posited relationships in the conceptual framework shown in Figure 1. As seen in the figure, the team contextual factors, relative exploration, and project-organization metric alignment,

Figure 1 Conceptual Framework



moderate the relationship between team autonomy and psychological safety. The effect of psychological safety on project performance is indirect and mediated through team turnover.

3. Research Design

3.1. Data Collection

We collected primary data from R&D projects across multiple high technology business units using a web-based survey. The data collection process took place between January 2008 and March 2009 and formed a part of a larger study investigating exploration and exploitation goals in high technology organizations (Chandrasekaran et al. 2011).

The first step in this process involved obtaining contact information of senior managers (i.e., Chief Technology Officers, R&D Directors, and R&D Vice Presidents) in high technology business units. This was done by approaching industry associations such as the *Life Science Alley Institute*, the *Minnesota High Technology Association*, and the *Joseph M. Juran Center for Leadership in Quality*. Next, a brief executive summary that described the study's purpose and its implications for practice was sent to an identified senior manager within each business unit.

Of the 190 senior managers contacted, 41 managers initially expressed their interest to learn more about the study. We conducted follow-up phone conversations and in-person meetings with each manager to explain the research design (i.e., our interest in collecting data from multiple informants across R&D projects), the research method (i.e., web-based survey), and the expected time commitment. Five business units opted not to participate in this study citing confidentiality concerns. We dropped two other business units from our sample since they were not from a fast clockspeed industry (Beckman and Sinha 2005, Fine 1998). The final sample therefore consisted of 34 business units (30 units in North America and 4 units outside North America) located within 28 high technology organizations and belonging to five major industry segments: semiconductor, medical device, electronics, aerospace, and other high tech (e.g., precision manufacturing), giving us a response rate of 17.89%. Comparisons of basic demographics (i.e., sales, R&D expenditures, and the number of employees) between the 28 sampled organizations and the industry population (data obtained from *COMPUSTAT* database) indicated no systematic pattern of differences, minimizing concerns of non-respondent bias (Li et al. 2007). In addition, follow-up emails and telephone conversations with managers from a number of non-responding units indicated that they did not participate due to time constraints or confidentiality concerns.

Within each business unit, we asked the senior manager to sample a minimum of two R&D projects that were of strategic importance (He and Wong 2004). This research design is consistent with other multi-unit product development studies (e.g., Eisenhardt and Tabirizi 1995). Only projects that were completed during the past 12 months were sampled to reduce recollection bias (Li et al. 2007, Pavlou and El Sawy 2006). As discussed previously, a web-based survey was designed to collect data from these projects. The survey required responses on separate question sets from two different sets of informants: project leaders and project team members.[2] This type of survey design had many benefits. First, it allowed us to reduce the number of questions per survey informant, increasing the potential for high item response rate and greater accuracy of responses. Second, it allowed us to collect data on specific constructs from the most knowledgeable informant within a project (Gatignon et al. 2002). Third, it reduced concerns regarding common method bias in the data.

An initial version of the survey was pretested at two high technology business units (one medical device and one semiconductor) involving 15 R&D projects (not included in the sample). Following refinements to the survey, we sent out invitation e-mails enclosing a link to the final version of the survey to identified senior managers across the 34 business units. The senior managers forwarded the e-mail to the project leaders and the team members of the sampled projects within their business units. Overall, we collected data from 249 project-level informants across 110 projects with responses from the project leader and at least one team member from each project. Table 1 provides a detailed breakdown of the sample based on industry demographics.

3.2. Measures

We used multi-item scales to measure the constructs in our study. Data on project performance, team turnover, and project-organization metric alignment were collected from project leaders, whereas team members provided data on team autonomy, exploration, exploitation, and psychological safety. Further, project performance is measured on a 7-point Likert scale whereas all other constructs are measured on a 5-point Likert scale. The measurement items constituting the individual constructs are reported in Table A1 in the Appendix. A description of the individual constructs and of their measurement items follows.

3.2.1. Dependent Variables.

3.2.1.1. Project Performance: Project performance is measured using a 5-item scale (Cronbach's α = 0.74), which captures the success of a project relative to its goals across each of the following dimensions: schedule, budget, quality, technical performance, and overall satisfaction. The use of a multiple dimensions to measure project performance is consistent with the extant literature (e.g., Cummings 2004, Hoegl et al. 2004). Such a measure reflects the notion that R&D projects have multiplicity of performance goals that need to be taken into account to obtain a holistic assessment of their outcomes (Gerwin and Barrowman 2002, Krishnan and Ulrich 2001). To compute project performance, we averaged responses across the five items for each project. A review of histogram for this scale indicated that project performance was approximately normally distributed with values ranging from 1 to 6.8 on a 7-point Likert scale. This eliminated any concerns that the sample was biased toward high-performing projects only (Li et al. 2007).

3.2.1.2. Team Turnover: Team turnover is measured using a 2-item scale (Cronbach's α = 0.77) adapted from Narayanan et al. (2011) that captures the extent to which project manager and core team members stayed on the project for its complete duration. A high value on this scale implies that the R&D project team is associated with low turnover.

Table 1 Sample Demographic Information by Industry

Industry type	Number of high technology firms	Number of business units	Number of R&D projects
Semiconductor	4	6	12
Medical device	10	14	60
Electronics	2	2	10
Aerospace	5	5	14
Other high tech	7	7	14
Total	28	34	110

3.2.1.3. Psychological Safety: Psychological safety is measured using a 6-item scale (Cronbach's α = 0.80) developed by Edmondson (1999) that captures the extent to which project team members were able to discuss problems and issues openly and engage in interpersonal risk taking without fear of reprisal, criticism, or punishment.

3.2.2. Independent and Moderator Variables.

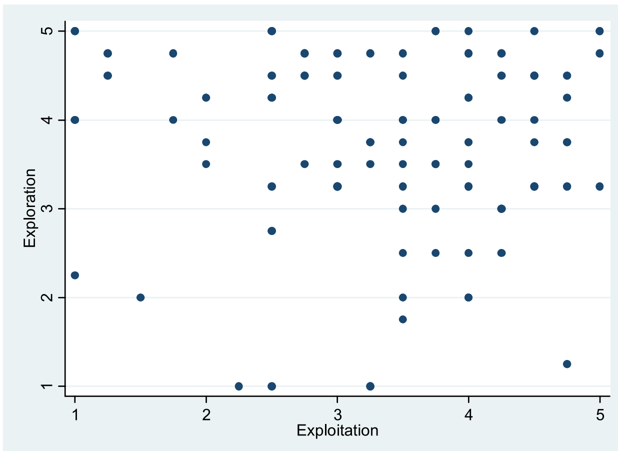
3.2.2.1. Team Autonomy: Team autonomy is measured using a 5-item scale (Cronbach's α = 0.73) adapted from Thompson (2004) that captures the extent of involvement of team members in task-design decisions such as scheduling work, determining goals, performance evaluation, and assignment of tasks.

3.2.2.2. Relative Exploration: Relative exploration is computed as the ratio of exploration goals to the sum of exploration and exploitation goals in a project (i.e., Relative Exploration = Exploration/[Exploration + Exploitation]). A high value of relative exploration for a project indicates that it has greater focus on exploration goals compared to exploitation goals.

To compute relative exploration, we first measured exploration and exploitation in a project using multi-item scales adapted from He and Wong (2004). Exploration is measured using a 4-item scale (Cronbach's α = 0.75) that captures the extent to which project's goals are aimed at introducing new generations of products, redesigning the process for producing new generation of products, entering new technology, and opening new markets. Exploitation is measured using a 4-item scale (Cronbach's α = 0.80) that captures the extent to which a project's goals are aimed at reducing variation in existing process, refining existing product quality, reducing cost, and improving flexibility.

To determine if project team members were able to differentiate between the measures of exploitation and exploration and rate them appropriately, we examined the distribution of their responses to these measures using cross-tabulation and scatter plot. The cross-tabulation of the projects in the study sample was carried out by classifying them across four categories based on the importance (i.e., "High" for scale averages >3, "Low" for scale averages ≤ 3) of these goals: (i) *Low Exploitation—Low Exploration*, (ii) *High Exploitation—Low Exploration*, (iii) *Low Exploitation—High Exploration*, and (iv) *High Exploitation—High Exploration*. As Figure 2 indicates, a majority of projects in the study sample exhibited high levels of exploration and exploitation (52 projects, 48%), followed by a significant number of projects that had higher levels of exploration relative to exploitation (35 projects, 32%). Further, among the 52 projects that

Figure 2 Levels of Exploration and Exploitation for Projects in Study Sample



		Exploitation: Low	Exploitation: High
Exploration	High	35 projects (C)	52 projects (D)
Exploration	Low	5 projects (A)	16 projects (B)

exhibited high levels of exploration and exploitation, the Pearson pair-wise correlation between exploration and exploitation was positive but statistically insignificant ($r = 0.16$, $p > 0.1$). This provided evidence of sufficient variation in these measures across projects in the study sample and indicates that respondents were able to appropriately differentiate between these measures.

3.2.2.3. Project-Organization Metric Alignment: Project-organization metric alignment is measured using a 4-item scale (Cronbach's $\alpha = 0.66$) adapted from Ghoshal and Bartlett (1994) that captures the extent to which the project goals and processes are aligned with broader organizational goals of the business unit.

3.2.3. Control Variables. External factors pertaining to characteristics of R&D projects may be a potential source of heterogeneity in our analysis. Hence, we controlled for several such factors in our analysis.

3.2.3.1. Team Size: Team size has been used as a control variable in many studies (e.g., Atuahene-Gima 2003, Haas 2006) based on the premise that bigger teams have access to more and better resources compared to smaller teams. We included the natural logarithm of the number of full-time project team members, *ln(Team Size)*, in the analysis.

3.2.3.2. Duration: The duration of a project is an indicator of both the time and effort required in the project (Cummings 2004). This variable is measured as an ordinal categorical variable in our data ($1 \leq 1$ year, $2 = 1$–5 years, and $3 \geq 5$ years). Two dummy variables (*Duration_2* and *Duration_3*) representing the three categories were included in the analysis.

3.2.3.3. Budget: The total budgetary allocation for a project is measured as an ordinal categorical variable ($1 \leq$ \$100,000, 2 = \$100,000–\$1 Million, 3 = \$1 Million–\$10 Million, and $4 \geq$ \$10 Million). Three dummy variables (*Budget_2*, *Budget_3*, and *Budget_4*) representing the four categories were included in the analysis.

3.2.3.4. Project Complexity: Project complexity is measured on a 4-item scale (Cronbach's $\alpha = 0.63$) informed by project leaders that captures the extent of technical expertise and information processing requirements in a project (Choo et al. 2007).

3.2.3.5. Team Diversity: Team diversity is measured on a 4-item scale (Cronbach's $\alpha = 0.73$) informed by project team members that captures the diversity within a project team in terms of company tenure, education, age, and functional background (Jehn 1997).

3.2.3.6. Project Leadership: It is plausible that the nature of project leadership can influence the extent to which project team members feel comfortable taking risks in R&D environments (Edmondson 1999). More specifically, a transformational leadership style, wherein project leaders lead-by-doing, challenge existing assumptions about project tasks, and create an environment that promotes out-of-the-box thinking (Vera and Crossan 2004), is likely to enhance psychological safety within a team (Siemsen et al. 2009). We measured the extent of such leadership as informed by project team members on a 4-item scale (Cronbach's $\alpha = 0.76$) adapted from Vera and Crossan (2004).

3.2.3.7. Project Incentive: Incentive structures within a project can influence team dynamics and are often used by project leaders to guide project execution (Kirsch et al. 2002). Sarin and Mahajan (2001) further suggest that a process-based incentive structure that emphasizes team learning and rewards team members on accomplishing major milestones in a project is frequently used in R&D projects. We therefore control for the extent of process-based incentive in a project as informed by project team members on a four-item scale (Cronbach's $\alpha = 0.65$) adapted from Sarin and Mahajan (2001).

3.2.3.8. Team Cohesion: Team cohesion captures the extent to which team members stick together, defend each other from criticism, and help each other with their tasks. Increased levels of cohesion among team members can lead to the development of a transactive memory system and enhance psychological safety of a team (Hoegl and Parboteeah 2006, Lewis 2003). However, team cohesion can also result in "groupthink" and reduce R&D project performance (Choi and Thompson 2006). We therefore control for team cohesion in our analysis as informed by project team members on a 4-item scale (Cronbach's $\alpha = 0.89$) adapted from Lewis (2003).

4. Analysis and Results

We conducted confirmatory factor analysis (CFA) to assess the convergent and discriminant validity of multi-item scales. The measurement model included 30 items representing the seven constructs shown in the conceptual framework—independent and moderator variables (team autonomy, project-organization metric alignment, exploration, and exploitation) and dependent variables (psychological safety, team turnover, and project performance). The fit indices indicated that the model fit the data reasonably well ($\chi^2 = 653.6$, df = 384, Norm $\chi^2 = 1.70$, RMSEA = 0.07, SRMR = 0.07). Convergent validity was assessed by examining the path coefficients from the constructs to their corresponding measurement items (Anderson and Gerbing 1988). All path coefficients were significant ($p < 0.01$) with values ranging from 0.41 to 0.97. Furthermore, the composite reliabilities for all constructs were in acceptable ranges with values between 0.61 and 0.85 (Raykov 1998). Discriminant validity was assessed in two ways. First, we analyzed all possible pairs of constructs in a series of two-factor CFA models (Bagozzi and Phillips 1982). Each model was estimated twice—once constraining the correlation between constructs to unity and once freely estimating the correlation. The chi-square difference between the two models was statistically significant ($\Delta\chi^2_{(\Delta df=1)} > 3.84$, $p < 0.01$) for all possible pairs of constructs implying that the unconstrained model had a better fit than the constrained model. This provided evidence for the discriminant validity of the constructs. Second, we examined the average variance extracted (AVE) for the constructs, which ranged from 0.51 to 0.80. The AVE for each construct was greater than its squared correlation with any other construct, further indicating their discriminant validity (Fornell and Larcker 1981). Overall, we found the constructs and their measurement items to be reliable and valid. Table 2 summarizes the descriptive statistics and pairwise correlations for the variables used in the analysis.

The hypotheses tests are carried out in two steps using STATA 11 (StataCorp, LP, College Station, TX, USA). In the first step, we estimate the main effect of team autonomy on psychological safety and the moderating effects of relative exploration and project-organization metric alignment on this relationship. In the second step, we estimate the performance effects of psychological safety.

Table 2 Descriptive Statistics and Correlation Matrix

	Variables	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	ln(Team Size)	2.43	0.77	1.00																		
2	Duration_2	0.47	0.50	0.02	1.00																	
3	Duration_3	0.14	0.35	0.19	−0.38	1.00																
4	Budget_2	0.43	0.50	−0.02	−0.03	0.03	1.00															
5	Budget_3	0.23	0.42	0.05	0.18	−0.03	−0.47	1.00														
6	Budget_4	0.10	0.30	0.27	−0.01	0.04	−0.29	−0.18	1.00													
7	Team Diversity	3.98	0.61	0.06	0.07	0.01	−0.08	0.03	−0.07	1.00												
8	Project Complexity	3.47	0.33	−0.12	0.18	−0.08	−0.18	0.11	0.00	0.35	1.00											
9	Project Leadership	3.73	0.77	0.19	−0.05	0.08	−0.09	0.21	0.04	0.37	0.18	1.00										
10	Project Incentive	3.19	0.83	0.12	−0.01	−0.05	−0.02	−0.05	0.24	−0.07	0.21	0.14	1.00									
11	Team Cohesion	4.15	0.37	−0.03	0.02	−0.21	−0.03	−0.07	0.01	−0.02	0.10	0.19	0.01	1.00								
12	Team Autonomy	3.49	0.75	0.06	−0.02	−0.05	−0.03	−0.05	−0.05	0.13	−0.03	0.30	0.20	−0.01	1.00							
13	Project-Organization Metric Alignment	3.00	0.78	0.32	0.08	−0.09	0.04	−0.05	0.09	−0.01	0.03	0.07	0.31	−0.26	0.13	1.00						
14	Exploration	3.72	1.00	0.18	0.01	0.02	−0.19	0.08	0.20	0.08	0.21	0.16	0.11	0.08	−0.06	0.02	1.00					
15	Exploitation	3.35	1.03	−0.04	−0.01	0.03	0.10	−0.03	−0.16	0.02	0.01	0.18	−0.10	−0.08	0.14	0.08	−0.04	1.00				
16	Relative Exploration	0.53	0.12	0.15	0.04	−0.02	−0.19	0.05	0.22	0.10	0.13	−0.01	0.14	0.09	−0.13	−0.01	0.70	−0.71	1.00			
17	Psychological Safety	4.15	0.53	0.03	0.04	−0.16	−0.21	−0.04	0.10	0.30	0.30	0.35	0.09	0.37	0.29	−0.04	0.02	−0.08	0.07	1.00		
18	Team Turnover	2.37	1.18	0.09	0.14	0.40	−0.08	0.29	0.06	0.02	−0.01	−0.16	−0.04	−0.41	−0.13	0.05	−0.01	−0.02	0.03	−0.34	1.00	
19	Project Performance	4.59	0.96	0.12	0.02	0.00	0.01	−0.06	0.05	0.28	0.07	0.17	0.18	−0.18	0.34	0.17	0.06	0.14	−0.07	0.11	0.16	1.00

$|\rho| \geq 0.16$ significant at 0.10 level, $|\rho| \geq 0.19$ significant at 0.05 level, $|\rho| \geq 0.27$ significant at 0.01 level.

4.1. Effect of Team Autonomy and Moderating Effects of Team Contextual Factors

The first step model for a project *i* nested within a business unit *j* is specified as follows:

$$\begin{aligned}
&Psychological\ Safety_{ij} = \beta_0 + \beta_1 In(Team\ Size)_{ij} \\
&\quad + \beta_2 Budget_2_{ij} + \beta_3 Budget_3_{ij} + \beta_4 Budget_4_{ij} \\
&\quad + \beta_5 Duration_2_{ij} + \beta_6 Duration_3_{ij} \\
&\quad + \beta_7 Team\ Diversity_{ij} + \beta_8 Project\ Complexity_{ij} \\
&\quad + \beta_9 Project\ Leadership_{ij} + \beta_{10} Project\ Incentive_{ij} \\
&\quad + \beta_{11} Team\ Cohesion_{ij} + \beta_{12} Team\ Autonomy_{ij}[TA] \\
&\quad + \beta_{13} Relative\ Exploration_{ij}[RE] \\
&\quad + \beta_{14} Project\text{-}Organization\ Metric\ Alignment_{ij} \\
&\qquad [POMA] + \beta_{15} TA_{ij} \times RE_{ij} + \beta_{16} TA_{ij} \times POMA_{ij} + \varepsilon_{ij}
\end{aligned}$$

Given the nested structure of the data, it is necessary to control for unobserved heterogeneity across business units in the analysis (Rothaermel and Hess 2007). Theoretically, either a fixed effects or a random effects estimator can be used to control for unobserved heterogeneity (Greene 2003). The Hausman test (Hausman 1978) results, however, suggest that a fixed-effects estimator is a consistent and efficient estimator for the first step model.[3] We therefore ran a fixed-effects within-groups (WG) estimator (Gujarati and Porter 2009) with robust standard errors clustered by business unit [using *xtreg* with *fe, vce(r)*] to estimate this model. To improve the interpretability of our results and to reduce multicollinearity concerns, we mean-centered the independent and moderator variables before creating their interaction terms. For all other variables, we used their uncentered values in our analysis. The average variance inflation factor (VIF) was <3 suggesting no multicollinearity issues (Hair et al. 1998). The estimation results for this model are shown in Table 3.

Hypothesis 1 suggests a positive association between team autonomy and psychological safety. The regression results in Column 2 show a significant positive relationship between team autonomy and psychological safety ($\beta = 0.30$, $p < 0.01$), providing support for Hypothesis 1.

Hypothesis 2 predicts that increase in relative exploration weakens the positive association between team autonomy and psychological safety. The regression results in Column 4 indicate a significant negative moderation effect ($\beta = -0.11$, $p < 0.01$) of relative exploration on this relationship, providing support for Hypothesis 2. To better understand the moderation effect of relative exploration, we created a conditional effects plot (Aiken and West 1991) for the relationship between team autonomy and psychological

Table 3 Effect of Team Autonomy and Moderating Effects of Team Context

	Dependent variable: Psychological Safety			
Predictor variables	Column 1	Column 2	Column 3	Column 4
Constant	2.63*** (0.99)	2.74*** (0.99)	3.41*** (1.14)	3.24*** (1.16)
In(Team Size)	−0.21** (0.10)	−0.18** (0.09)	−0.14* (0.08)	−0.14* (0.08)
Duration_2	0.20 (0.12)	0.13 (0.11)	0.15 (0.11)	0.13 (0.11)
Duration_3	−0.07 (0.18)	−0.11 (0.18)	−0.22 (0.18)	−0.24 (0.15)
Budget_2	−0.21 (0.16)	−0.22 (0.16)	−0.39* (0.21)	−0.45** (0.22)
Budget_3	−0.22 (0.20)	−0.24 (0.20)	−0.61** (0.28)	−0.61** (0.29)
Budget_4	0.11 (0.24)	0.14 (0.23)	−0.13 (0.36)	−0.13 (0.33)
Team Diversity	0.11 (0.13)	0.06 (0.12)	0.06 (0.22)	0.04 (0.22)
Project Complexity	0.45 (0.27)	0.48* (0.25)	0.32 (0.40)	0.28 (0.40)
Project Leadership	0.12* (0.07)	0.13* (0.07)	0.15 (0.09)	0.12 (0.09)
Project Incentive	0.02 (0.08)	0.00 (0.08)	0.07 (0.06)	0.08 (0.06)
Team Cohesiveness	0.00 (0.14)	0.01 (0.15)	−0.05 (0.23)	0.04 (0.22)
Team Autonomy [TA]		0.12* (0.06)	0.05 (0.06)	0.04 (0.06)
Project-Organization Metric Alignment [POMA]			−0.05 (0.06)	−0.04 (0.05)
Relative Exploration [RE]			0.05 (0.09)	0.13 (0.08)
TA × RE				−0.11*** (0.03)
TA × POMA				0.11*** (0.04)
R-Square	36.35	39.47	41.60	49.10
ΔR-Square	–	3.12***	2.13***	9.63***
F	4.61***	6.11***	9.11***	27.68***
N	34	34	32	32
n†	106	106	86	86

Sample sizes reported in the analysis are lower than $n = 110$ because of missing data on key variables. Results from additional analysis carried out by imputing missing values are consistent with reported findings, and are available upon request.
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$.
Table reports unstandardized values of coefficient estimates.

safety across different levels (*high*—two standard deviations above the mean, and *low*—two standard deviations below the mean) of relative exploration. The plot in Figure 3 indicates that at low levels of relative exploration, an increase in team autonomy is associated with an increase in psychological safety. In contrast, at high levels of relative exploration, an increase in team autonomy is associated with a decrease in psychological safety.

Hypothesis 3 predicts that project-organization metric alignment strengthens the positive association between team autonomy and psychological safety. The regression results in Column 4 indicate a significant positive moderation effect ($\beta = 0.11$, $p < 0.01$) of project-organization metric alignment on this relationship, providing support for Hypothesis 3. We plot the moderation effect of project-organization metric alignment in Figure 4 following the procedure discussed earlier. The conditional effects plot indicates that at low levels of project-organization metric alignment, an increase in team autonomy is associated with a decrease in psychological safety. In contrast, at high levels of project-organization metric alignment, an increase in team autonomy is associated with an increase in psychological safety.

Figure 3 Moderating Effect of Relative Exploration

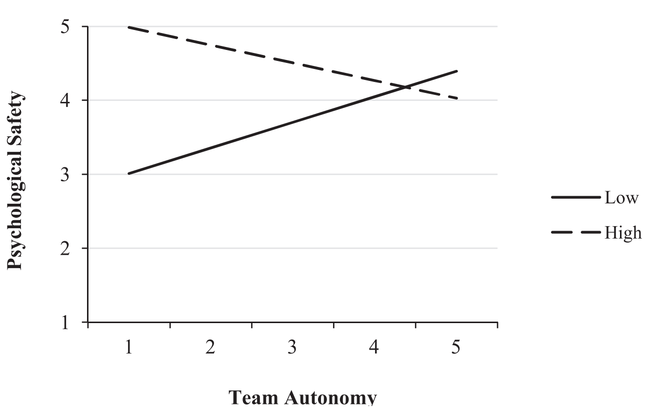
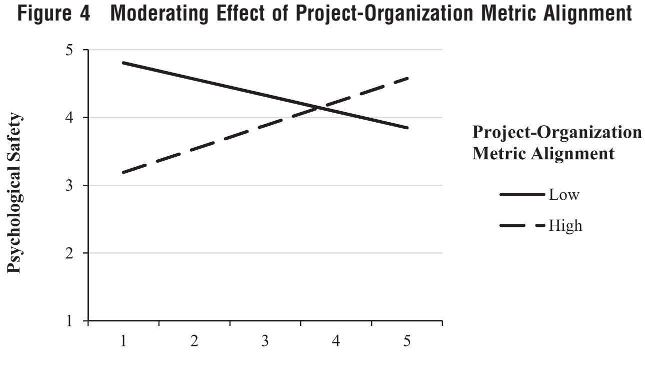


Figure 4 Moderating Effect of Project-Organization Metric Alignment



4.2. Performance Effects of Psychological Safety

The analysis in the second step involves estimating two separate regression models. The first model examines the relationship between psychological safety and team turnover, and the second model examines the relationship between team turnover and project performance. We use uncentered values for all variables in these models. The average VIF was <3 indicating that multicollinearity was not a concern (Hair et al. 1998). Each model is specified below. For a project *i* nested within a business unit *j*:

$$\begin{aligned} TeamTurnover_{ij} &= \beta_0 + \beta_1 ln(TeamSize)_{ij} \\ &+ \beta_2 Budget\_2_{ij} + \beta_3 Budget\_3_{ij} + \beta_4 Budget\_4_{ij} \\ &+ \beta_5 Duration\_2_{ij} + \beta_6 Duration\_3_{ij} \\ &+ \beta_7 Team\ Diversity_{ij} + \beta_8 Project\ Complexity_{ij} \\ &+ \beta_9 Project\ Leadership_{ij} + \beta_{10} Project\ Incentive_{ij} \\ &+ \beta_{11} Team\ Cohesion_{ij} + \beta_{12} Psychological\ Safety_{ij} + \varepsilon_{ij} \end{aligned}$$

$$\begin{aligned} ProjectPerformance_{ij} &= \beta_0 + \beta_1 ln(TeamSize)_{ij} \\ &+ \beta_2 Budget\_2_{ij} + \beta_3 Budget\_3_{ij} + \beta_4 Budget\_4_{ij} \\ &+ \beta_5 Duration\_2_{ij} + \beta_6 Duration\_3_{ij} \\ &+ \beta_7 Team\ Diversity_{ij} + \beta_8 Project\ Complexity_{ij} \\ &+ \beta_9 Project\ Leadership_{ij} + \beta_{10} Project\ Incentive_{ij} \\ &+ \beta_{11} Team\ Cohesion_{ij} + \beta_{12} Psychological\ Safety_{ij} \\ &+ \beta_{13} Team\ Turnover_{ij} + \varepsilon_{ij} \end{aligned}$$

The Hausman test result for each model is insignificant indicating that a random effects estimator is a consistent and efficient estimator compared to a fixed-effects estimator. We therefore use a random-effect estimator with robust standard errors clustered by business unit [using *xtreg* with *re, vce(r)*] for each model. Table 4 presents the regression results for the two models.

Hypothesis 4 posits that the effect of psychological safety on project performance is indirect and mediated through team turnover. To test for mediation, we first examined the individual paths among psychological safety, team turnover, and project performance. Although the regression results in Column 6 indicate a significant negative relationship ($\beta = -0.39$, $p < 0.01$) between psychological safety and team turnover, those in Column 8 indicate a positive but insignificant effect on project performance ($\beta = 0.19$, $p = 0.19$). Further, the regression results in Column 9 indicate a significant negative relationship ($\beta = -0.31$, $p < 0.05$) between team turnover and project performance. Taken together, the above results suggest that the effect of psychological safety on project performance is indirect and mediated through team turnover.

To formally test for mediation, we use a bootstrapping approach suggested by Preacher and Hayes

Table 4 Performance Effects of Psychological Safety

	Dependent variables				
	Team Turnover		Project Performance		
Predictor variables	Column 5	Column 6	Column 7	Column 8	Column 9
Constant	−2.20* (1.32)	−1.65 (1.21)	4.28*** (1.63)	4.01** (1.72)	3.30** (1.66)
ln(Team Size)	−0.04 (0.13)	−0.06 (0.14)	0.09 (0.13)	0.10 (0.13)	0.08 (0.14)
Duration_2	0.55*** (0.19)	0.56*** (0.19)	0.02 (0.22)	0.02 (0.23)	0.18 (0.24)
Duration_3	1.52*** (0.18)	1.47*** (0.20)	−0.10 (0.40)	−0.08 (0.42)	0.39 (0.46)
Budget_2	0.36 (0.25)	0.27 (0.26)	0.00 (0.22)	0.05 (0.22)	0.15 (0.21)
Budget_3	1.17*** (0.26)	1.08*** (0.26)	−0.19 (0.24)	−0.14 (0.24)	0.22 (0.27)
Budget_4	0.68 (0.43)	0.69* (0.40)	0.02 (0.41)	0.02 (0.40)	0.24 (0.35)
Team Diversity	0.20 (0.20)	0.26 (0.18)	0.48*** (0.17)	0.45*** (0.16)	0.54*** (0.14)
Project Complexity	−0.01 (0.29)	0.08 (0.31)	−0.17 (0.31)	−0.21 (0.16)	−0.19 (0.29)
Project Leadership	−0.30** (0.12)	−0.26** (0.12)	0.04 (0.10)	0.02 (0.10)	−0.06 (0.10)
Project Incentive	−0.03 (0.12)	−0.02 (0.11)	0.22 (0.16)	0.21 (0.16)	0.20 (0.15)
Team Cohesion	−0.71*** (0.25)	−0.57** (0.24)	−0.46 (0.31)	−0.52 (0.34)	−0.67** (0.34)
Psychological Safety		−0.39** (0.18)		0.19 (0.18)	0.08 (0.18)
Team Turnover					−0.31*** (0.12)
R-Square	47.39	49.58	16.22	16.71	22.90
Δ R-Square	–	2.19***	–	0.51***	6.68***
χ^2	258.57***	276.22***	20.91**	21.06***	66.29***
N	34	34	34	34	34
n	106	106	106	106	106

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.
Table reports unstandardized values of coefficient estimates.

(2004, 2008), which generates confidence intervals for the indirect effect of psychological safety on project performance through team turnover. The bootstrapping approach is a robust alternative to the conventional Sobel test for examining mediation (Cole et al. 2008, Sy et al. 2010). A key assumption in Sobel tests is that the indirect effect is normally distributed. Such an assumption is unlikely to hold in many cases even when the constituent relationships that make up the indirect effect are normally distributed. As such, the absence of non-normal indirect effects can introduce power problems. A non-parametric approach such as bootstrapping circumvents this problem by avoiding any distributional assumptions about the indirect effect. The 95% confidence interval for the indirect effects of psychological safety on project performance is (0.0127 and 0.3779). Since the confidence interval does not include zero, the indirect effect of psychological safety on project performance is significant, offering support for a mediation relationship. Hypothesis 4 is therefore supported.

4.3. Robustness Checks

We conducted a number of additional tests to check the robustness of the results. First, we estimated each model in our analyses using the quantile regression procedure (Koenker 2005). The quantile regression estimator dampens the effect of the outliers and minimizes heteroskedasticity concerns that may arise from differences across business units and firms. The results from this procedure were consistent with the reported results.

Second, we carried out analysis to control for potential macro effects: namely, industry effects and firm effects. To control for industry effects, we included four industry dummy variables in our analyses and found no significant change in the results.[4] To control for firm-level effects, we repeated our analyses by nesting the 110 projects within 28 organizations (instead of 34 business units) and obtained consistent results.

Third, to check if endogeneity associated with psychological safety and team turnover posed a major concern in our analysis, we ran a Durbin-Wu-Hausman test for each of the variables (Davidson and MacKinnon 1993). This test involves generating residuals from the models predicting psychological safety and team turnover and including them in the subsequent models predicting team turnover and project performance, respectively. The absence of statistically significant effects for the residuals of psychological safety ($t = 0.61, p = 0.53$) and team stability ($t = -0.62$, $p = 0.54$) suggest no major concerns due to endogeneity issues (Hamilton and Nickerson 2003). In the absence of endogeneity concerns, Wooldridge (2002) cautions that the two-stage least squares (2SLS) procedure is less efficient than the ordinary least squares procedure and can often inflate standard errors leading to type II errors. Nonetheless, to ensure that endogeneity associated with psychological safety and team turnover did not pose a serious concern to the results, we carried out analysis using the 2SLS procedure (using *ivreg 2sls* command in STATA 11). Specifically, we used this approach to estimate the two models where endogeneity could affect the results: Model 1—i.e., model predicting team turnover with psychological safety as the endogenous independent variable, and Model 2—i.e., model predicting project performance with team turnover as the endogenous independent variable. To minimize multicollinearity issues (which can arise due to similarity of independent variables across the first and the second stage models), we estimated the above models using a subset of control variables. The 2SLS results presented in Table A2 in the Appendix indicate the corrected effects of psychological safety on team turnover to be negative and statistically significant ($\beta = -1.21$, $p < 0.10$). Similarly, the corrected effect of team turnover on project performance is negative and statistically significant ($\beta = -0.54$, $p < 0.01$). The consistency of these results with the reported results reaffirms that endogeneity associated with psychological safety and team turnover did not pose a major concern in the analysis.

Fourth, we validated the perceptual measures of project performance and team autonomy by collecting additional data from informants. Specifically, to validate the perceptual measure of project performance in our analysis that is based on responses from project leaders, we carried out additional analysis using: (i) an objective measure of schedule overrun that is based on responses from the project leaders and is measured as a ratio of the time ahead (or behind) schedule to the total time allocated for the project (Bajaj et al. 2004), and (ii) a perceptual measure of project performance that is based on responses from team members on the same scale as the one used by project leaders. Although schedule overrun represents only one dimension of project performance, it is nevertheless correlated ($r = 0.31$, $p < 0.05$) with the perceptual measure of project performance used in the analysis. Similarly, the perceptual measure of project performance obtained from team members is highly correlated with the one obtained from project leaders ($r = 0.85$, $p < 0.01$). Next, to validate the perceptual measure of team autonomy that is based on responses from team members, we also requested project leaders to provide their responses to this measure. The measure of team autonomy obtained from project leaders' responses is highly correlated with team member responses ($r = 0.81$, $p < 0.01$). Taken together, these findings confirm the robustness of team autonomy and project performance measures used in the analysis.

Fifth, given that we had responses from two team members for 29 projects in our study sample, we performed inter-rater reliability (r_{wg}) tests for the constructs of team autonomy ($r_{wg} = 0.85$), psychological safety ($r_w = 0.71$), exploration ($r_{wg} = 0.78$), and exploitation ($r_{wg} = 0.70$). The average r_{wg} was well above the recommended threshold value of 0.60 indicating the internal consistency and the precision of team members' responses (Shadish et al. 2002).

Finally, we performed a power analysis to ensure that sample size is not an issue in the study (Cohen 1988). The effect size that represents the strength of the relationship between the predictors and dependent variable is calculated based on the coefficient of determination (R^2) from each of the seven columns (Columns 1–9) in our analysis. For the estimated R^2 and the number of predictors in each column, a type I error rate of 0.05, and a desired statistical power of 0.9, the minimal acceptable sample size was 41 projects, which was considerably less than the size of study sample.

5. Discussion

5.1. Summary of Findings

With growing competitive pressures to reduce costs and limit R&D spending, high technology organizations are increasingly demanding greater efficiencies from their R&D projects. This has resulted in R&D projects facing the challenge of managing the dual goals of exploration and exploitation. The asymmetric nature of these goals within the same project can create dysfunctional dynamics among team members and can reduce their psychological safety. Although researchers have stressed the importance of team autonomy for building psychological safety (Edmondson and Nembhard 2009, Faraj and Yan 2009), we know little about how team context affects this relationship in R&D projects. Further, there is considerable ambiguity on how psychological safety subsequently influences R&D project performance. Our research informs on these unexplored relationships.

Our results suggest that team context plays an important role in determining how team autonomy influences psychological safety in R&D projects. Specifically, we find that relative exploration and project-organization metric alignment have contrasting moderating effects. That is, team autonomy is negatively associated with psychological safety when relative exploration is high and positively associated with psychological safety when relative exploration is low. In contrast, team autonomy is positively associated with psychological safety when project-organization metric alignment is high and negatively associated with psychological safety when project-organization metric alignment is low. Besides moderating the relationship between team autonomy and psychological safety, the importance of studying team contextual factors is further derived from the fact that the baseline direct effect of team autonomy on psychological safety becomes insignificant when the team contextual factors are included in the analysis. With respect to the performance consequences of psychological safety, we find that the latter has an indirect mediated impact on project performance through team turnover. Team turnover occurs frequently in R&D projects within high technology organizations due to the inherently stressful nature of the work environments in such organizations (Slotegraaf and Atuahene-Gima 2011). Our findings suggest that higher levels of psychological safety can minimize team turnover and improve R&D project performance.

5.2. Contributions

Our study makes three important contributions to the academic literature. First, in contrast to existing studies which have primarily examined exploration and exploration goals at the firm level (Chandrasekaran et al. 2011, He and Wong 2004), we conceptualize and measure these goals at the project level where they are operationalized. In doing so, we are able to track and measure the "tension" between these goals, which arises due to their competing viewpoints and the asymmetric nature of their market returns, and examine its effect on team dynamics (Lewis et al. 2002). Our study, thus, responds directly to the call for greater focus on conceptualizing and measuring this inherent tension in the new product development literature (Dougherty and Hardy 1996, Lewis et al. 2002).

Second, our findings relating to the positive main effects of team autonomy on psychological safety and the negative moderation effect of relative exploration on this relationship highlight the "double-edged" nature of team autonomy in high technology organizations (Haas 2010, Thomas et al. 2005). Although high levels of autonomy can nurture creativity in R&D projects with high levels of relative exploration, the absence of clear authority relations and top-down leadership can make interpersonal interactions unpredictable and can cause isolation risks within such teams, reducing their psychological safety. Our findings thus call into question the unqualified endorsement of the benefits of team autonomy in the literature and highlight the specific contingencies associated with such benefits. Our results indicate that a significant challenge for R&D managers is to understand how to alleviate the negative effects of team autonomy on psychological safety. A potential solution that emerges from our findings is to have greater alignment between R&D project metrics and broader organizational metrics. Such alignment not only provides an overarching structure for team members to exercise their autonomy effectively, but also enables a more predictable environment for interpersonal interactions. To verify this, we carried out post-hoc analysis to examine the interaction between relative exploration and team autonomy across high and low levels of project-organization metric alignment[5] (values above median represent high levels of project-organization metric alignment and below median represent low levels of project-organization metric alignment). The analysis indicates that the interaction between relative exploration and team autonomy is negative and significant ($\beta = -0.132$, $p < 0.05$) at low levels of project-organization metric alignment. However, for projects with high levels of project-organization metric alignment, the interaction between relative exploration and team autonomy is non-significant ($\beta = -0.054$, $p > 0.30$). Collectively, the post-hoc analysis findings provide added support to the argument that increasing project-organization metric alignment can mitigate the negative effects of team autonomy on psychological safety when relative exploration is high.

Finally, our findings provide greater clarity on how psychological safety influences R&D project performance. Considerable ambiguity exists in the literature regarding the underlying mechanisms through which psychological safety influences performance—i.e., does psychological safety directly influence project performance or are its effects indirect and relayed through intermediate team outcomes. The empirical analyses in this study carried out using multi-informant panel data provide rigorous empirical evidence in favor of the indirect effects of psychological safety on project performance through reduced team turnover.

5.3. Limitations and Future Research

Our study has several limitations, some of which can serve as extensions for future research. In particular, a limitation of this study is the use of perceptual measures for the constructs in our conceptual framework. Given that the data were collected from R&D projects across multiple business units in high technology organizations, it was not possible to find common, objective measures for the constructs in our conceptual framework. In the absence of objective measures, we minimize single-source concerns by using data from multiple respondents from a project. Further, given that the data in our study originated from a cross-sectional survey, we have no means of observing how psychological safety evolves during the course of the project and influences the outcome measures of team turnover and project performance. Finally, our study may have missed additional team contextual factors that moderate the relationship between team autonomy and psychological safety. However, the inclusion of multiple control variables at the project level as well as the high explanatory power of the model predicting psychological safety minimizes concerns regarding the omission of important moderators.

With regard to directions for future research, our findings call for greater attention to identifying additional project level factors that can influence team dynamics in R&D projects with high levels of relative exploration. For example, future research could identify specific project management practices (e.g., agile project management practices, risk management practices) that can reduce technical problem solving and coordination challenges in such R&D projects. Another potential area for future research is to examine the challenges associated with development of psychological safety in distributed R&D project teams (Hoegl et al. 2004). Although our study sample consists entirely of R&D projects carried out internally within a single business unit, high technology organizations are increasingly collaborating with supplier firms to execute complex R&D projects (e.g., development of automobiles, aircrafts, computer hardware, large software applications). Such projects are often executed in distributed project organizational structures that span firm and/or country boundaries (Eppinger and Chitkara 2006, Sinha and Van de Ven 2005), and pose greater challenges for effective governance and management (Cusumano 2008). We call upon future research to examine whether or not conceptual frameworks that examine the antecedents and consequences of psychological safety in collocated R&D projects can be applied to distributed R&D projects.

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Appendix A

Table A1 Measurement Items in the Survey Questionnaire

Construct	Measurement Items
Exploration (CR = 0.92, AVE = 0.80)	How do you rate the following objectives when working on this project? *1 = Very Unimportant; 2 = Unimportant; 3 = Neutral; 4 = Important; 5 = Very Important* Introducing new generation of products Redesigning the process for producing new generation products Entering new technology fields Opening up new markets
Exploitation (CR = 0.85, AVE = 0.60)	How do you rate the following objectives when working on this project? *1 = Very Unimportant; 2 = Unimportant; 3 = Neutral; 4 = Important; 5 = Very Important* Reducing variation in existing processes Refining existing quality Increasing flexibility in existing process Reducing development cost
Team Autonomy (CR = 0.88, AVE = 0.59)	Please rate the amount of input your team has on the following decisions when working on this project. *1 = Very Little Input; 2 = A Little Input; 3 = Uncertain; 4 = Some Input; 5 = A Lot of Input* Planning and determining goals Who will be on the team Decisions concerning leadership inside the team Performance evaluation for the team Task assignments within the team
Project-Organization Metric Alignment (CR = 0.82, AVE = 0.53)	The following statements refer to the connection between the project and the organizational goals, plans, and strategies. *1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree* The performance standards in our unit are pretty well established and known to all of the project team members My team gets rewarded or punished based on the rigorous measurement of business Everything that we do in our project gets measured and recorded by our management We use a scorecard/dashboard approach to connect our project goals with the overall product line goals

(continued)

Table A1 Continued

Construct	Measurement Items
Psychological Safety (CR = 0.91, AVE = 0.61)	The following statements describe the dynamics in the team that you worked in during this project. *1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree* Members of the team were able to discuss problems and tough issues openly Members of the team accepted each other's differences No one on this team acted in a way that undermined our efforts If you make a mistake, it is often held against you (*reverse coded*) Working in this team, my unique skills and talents are valued and utilized It is safer to take risks when working in this team
Team Turnover† (CR = 0.86, AVE = 0.75)	The following statements refer to the connection between the project and the organizational goals, plans, and strategies. *1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree* The core members of our team remained on the project until completion The project manager who started this project remained on until completion
Project Performance (CR = 0.88, AVE = 0.59)	Please rate the success of this project relative to its goals *1 = Significantly Worse; 2 = Worse; 3 = Somewhat Worse; 4 = About Same; 5 = Somewhat Better; 6 = Better; 7 = Significantly Better* Adherence to schedule Adherence to budget Adherence to quality Technical performance Overall satisfaction
Team Diversity (CR = 0.81, AVE = 0.55)	The following statements relate to the diversity of this project team. *1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree* The project team members came from various functional backgrounds The project team members have different educational backgrounds (e.g., Bachelor's, Master's, Ph.D) The project team members have large diversity in terms of company tenure The project team members are from different age groups
Project Complexity (CR = 0.65; AVE = 0.62)	The following statements refer to the task characteristics of the project. *1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree* It took time to understand the project's necessary tasks and objectives The project required a lot of different skills and knowledge from team members The project required a lot of analysis The project was relatively simple (*reverse coded*)
Project Leadership (CR = 0.85; AVE = 0.59)	The following statements refer to the characteristics of the project leader in charge of this project. *1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree* My project leader is able to get others committed to his/her vision of the future My project leader leads by "doing" rather than simply by "telling" My project leader enables me to think about old problems in new ways My project leader challenges me to reexamine some of my basic assumptions
Project Incentive (CR = 0.76, AVE = 0.51)	The following statements refer to the rewards and incentive systems that are used to evaluate this project. *1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree* The team is rewarded for completing major milestones/phases accomplished in their project Teamwork behavior is taken into account when evaluating/rewarding the team Team learning is one of the top priorities of our project
Team Cohesion (CR = 0.94,AVE = 0.80)	The following statements relate to the relationship among team members in this project. *1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 4 = Strongly Agree* Project team members stick together Project team members help each other on the job Project team members get along with each other Project team members defend each other from criticism by outsiders

†Items representing this construct were reverse coded during analysis for ease of interpretation.
CR, composite reliabilities; AVE, average variance extracted.
Measurement Items in the Survey Questionnaire.

Table A2 Two-Stage Least Squares Estimation to Correct for Endogeneity of Psychological Safety and Team Turnover

	Dependent variable	
Predictor variables	Team Turnover Model 1	Project Performance Model 2
Constant	0.74 (1.27)	4.36^{***} (1.64)
ln(Team Size)	0.17 (0.16)	0.16 (0.11)
Team Diversity	0.32 (0.25)	0.52^{***} (0.14)
Project Complexity	0.48 (0.44)	0.08 (0.27)
Project Leadership	−0.05 (0.12)	−0.05 (0.09)
Project Incentive	−0.02 (0.12)	0.21 (0.14)
Team Cohesion	-0.63^{*} (0.35)	-1.10^{***} (0.38)
Psychological Safety	-1.21^{*} (0.64)	
Team Turnover		-0.54^{***} (0.18)
R-Square	18.49	0.11
χ^2	90.46^{***}	47.93^{***}
n	106	106

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.
First stage models not shown for parsimony.
Two-Stage Least Squares Estimation to Correct for Endogeneity of Psychological Safety and Team Turnover.

Notes

[1]As per Baron and Kenny (1986), a "mediation" relationship requires the presence of hypothesized direct effect (in this case, a hypothesized direct effect between psychological safety and project performance). More recently, Zhao et al. (2010) question this criterion and suggest that the presence of direct effect is not a necessary pre-condition for positing a mediation relationship. They further propose an alternative and robust estimation procedure for testing an indirect mediation relationship, which we employ in the analysis section when testing this hypothesis. We thank an anonymous reviewer for offering this insight.

[2]We also collected business unit level data from 64 R&D Directors and Business Unit Managers that are not used in this research.

[3]This test is used to check whether the assumption of independence between the random effects arising from business-unit level heterogeneity and the predictors is justified. If the test is not rejected, then the random effects estimator is a preferred over the fixed-effects estimator in carrying out the analysis (Wooldridge 2002).

[4]The results for the model predicting psychological safety are obtained from quantile regression estimation. A fixed effect estimation with business unit as the panel variable could not be estimated when including industry dummy variables since the business units are already nested within industry categories. The results for the models predicting team stability and project performance are obtained using random effects estimation. The results from this analysis are available upon request.

[5]Becerra and Gupta (2003) suggest a subgroup analysis over a moderated regression analysis to test three-way interactions since a moderated regression approach would require entering all three two-way interaction effects which can create multi-collinearity issues.

[§]The word "proposition" has been changed to "hypothesis" throughout the article after first online publication on 21 Feb 2012.

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