

A Multi-Method Study of Iterative Processes in Creative Project Teams

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ABSTRACT

The broad objective of this dissertation is to deepen our understanding of how creative project teams can perform more effectively. Creative project teams are teams engaged in innovative efforts. Common examples of such teams in organizations include those engaged in product development, research and development, entrepreneurship, and producing scientific knowledge or cultural products such as entertainment.

Scholarship related to the performance of creative project teams has typically conceptualized processes in these teams as static rather than dynamic phenomena. Given the chaotic nature of innovation processes, static conceptualizations of process do not adequately capture this phenomenon. Consequently, the lack of research on dynamic innovation processes in these teams limits our ability as scholars to offer prescriptive guidance on how teams can navigate the chaotic journey of innovation more effectively.

The broad objective of this dissertation was accomplished through two studies which examined the iterative processes adopted by creative teams in greater depth. Study 1 is a longitudinal case study of team innovation processes in two project teams in an interactive media development studio. To gain a more accurate map of iterative processes in these teams, cycles of planning, enacting, and reviewing activities were tracked as they unfolded over the course of these projects.

Two distinct cycles of planning, enacting, and reviewing activities are identified: experimentation cycles and validation cycles. Experimentation cycles are discovery-oriented processes where teams gather insights into project requirements, constraints, and design specifications through trial-and-error. Validation cycles are correction-oriented processes where teams align their output with project requirements through incremental modifications. These

findings are then built upon to develop testable propositions about the relationship between the duration of planning, enacting, and reviewing activities and the innovativeness and quality of team outcomes.

Some of the propositions developed in Study 1 are tested in Study 2. Specifically, Study 2 examines how structuring the duration of transition phases affects team performance on a creative task. The proposed model relates the duration of transition phases in experimentation cycles to the rate of improvement in prototype performance, group atmosphere, and the quality of team outputs. To investigate these effects, a lab experiment was conducted where groups of participants performed a creative, open-ended task in which they were to build a floating vessel from Lego pieces according to certain specifications. Participants were instructed to iterate on their designs before collaborating to design and build their group's vessel. The results showed support for the proposed model.

The findings from this dissertation have broader implications on theories of performance in creative project teams and team innovation. In particular, it suggests that researchers should pay attention to psychosocial effects, such as team emergent states like group atmosphere, when considering models of iterative processes rather than just focusing on the costs and benefits of obtaining information. A more significant implication is that the proposed framework of dynamic group processes can potentially trigger novel questions and uncover new phenomena that are crucial to the performance of creative project teams.

CHAPTER 1: INTRODUCTION

Across the globe, firms in many industries face greater competitive pressures in sales and access to resources due to rapid technological advances. Faced with such pressures, the importance of innovation as a means of gaining a competitive edge and for firms' overall survival is more crucial than ever (Amabile, 1988; Ilgen, Hollenbeck, Johnson, & Jundt, 2005).

The case of Research in Motion's (RIM) and Nokia's precipitous decline is a case in point. In 2007, RIM and Nokia together had a 17.3% market share of mobile phone sales in the United States. A mere half decade later, in 2012, these companies' dominance has completely reversed with upstarts Apple and Samsung contributing 40.3 % of handset sales, while RIM and Nokia only accounted for 9.1% of total units sold¹. The latter's decline in market share were compounded by the lower sale price of their handsets relative to their competitors'. In 2012, the average prices of RIM's and Nokia's products were, respectively, 16.0% and 44.0% below Apple's products. The decline in the popularity of RIM's and Nokia's products is reflected in their financial performance. At the end of 2012, RIM's market capitalization had fallen by more than 90% from its peak in June 2008. Nokia's bonds have been downgraded to junk status and investors speculate about the impending bankruptcy of the company. Although the dramatic decline in the fortunes of RIM and Nokia in a relatively short period of time can be attributed to many factors, one reason is their shortcomings in successfully developing innovative responses to competitive threats. This disruptive force of innovation thus emphasizes the importance for managers and management scholars alike to be concerned about ways to innovate better.

¹ Source: Euromonitor International, Oct 2012

Innovation in today's organizations is a complex and complicated process because it requires the unit responsible for innovating to introduce new ideas or reconfigure existing ones in systems with many parts that interact in unpredictable ways. Nokia's dramatic decline was not because it was short of creative talent or ideas. The company had spent \$40 bn in research and development over the past decade, almost four times the amount that Apple spent over the same period (Troianovsky & Grundberg, 2012). With a portfolio of intellectual property estimated at about \$6 bn (Troianovsky & Grundberg, 2012), Nokia was clearly not a company that was starved of good ideas. Rather the company suffered from its inability to integrate these ideas into new products that could be launched into the market. Almost a decade before the release of Apple's iPhone, Frank Nuovo, the former chief designer at Nokia, revealed a phone with a color touch screen set above a single button in a presentation (Troianovsky & Grundberg, 2012). The features of this device included locating a restaurant, playing a racing game, and ordering lipstick. This new concept from Nokia, however, never made it to market, which reinforces the point that innovation is more than just having good ideas - it also involves integrating ideas and reconfiguring existing ones in complex systems.

Amidst this complexity, it is not surprising that teams are often at the core of innovation efforts in organizations. By working in teams, a range of expertise can be brought to bear on these complex problems. Furthermore, complicated tasks can be completed sooner by having team members work in parallel on discrete tasks.

This perspective of innovation situates the locus of innovation at the team level because it suggests that our understanding of why innovation efforts fail or succeed can be enhanced through insights into the factors that affect the success or failure of teams engaged in innovative efforts. Common examples of such teams in organizations include those engaged in product

development, research and development, entrepreneurship, and producing scientific knowledge or cultural products such as entertainment. I refer to these teams as creative project teams because teams members share a high level of interdependence (Saavedra, Earley, & Van Dyne, 1993) with one another and work under time-scarce conditions (Karau & Kelly, 1992) to produce outcomes that are deemed to be novel and valuable to the organization (Amabile, 1996). Because of creative project teams' prevalence in organizations, models of team performance that account for how these teams can perform more effectively will have far-reaching and significant organizational implications.

The broad objective of this dissertation is thus to deepen our understanding of how creative project teams can perform more effectively. My review of scholarship related to the performance of creative project teams – which included research on team innovation and creativity – revealed that much the body of work conceptualized processes in these teams as static rather than dynamic phenomenon. Given the chaotic nature of innovation processes (Cheng & Van de Ven, 1996), static conceptualizations of process do not adequately capture this phenomenon. Consequently, the lack of research on dynamic innovation processes limits our ability as scholars to offer prescriptive guidance on how teams can navigate the chaotic journey of innovation more effectively.

In an attempt to fill this gap in the literature, Study 1 (Chapter 2) is a case study of team innovation processes in two project teams in an interactive media development (IMD) studio. To gain a more accurate map of dynamic processes in these teams, cycles of planning, enacting, and reviewing activities are tracked as they unfold over the course of the projects (Bourdieu, 1977; Brown & Duguid, 1991). I then draw on my findings about different types of plan-enact-review activity cycles to develop a number of testable theoretical propositions about the effects that

different durations of planning, enacting, and reviewing activity phases in each type of cycle will have on team performance.

After two different types of cycles are identified in Study 1, Study 2 addresses the question of how temporal characteristics of one of these activity cycles can affect team performance. In Study 2, I further examine the idea introduced in Study 1 that there is an ideal rhythm of plan-enact-review activity phases for each type of cycle. I chose to focus on this aspect of activity cycles because the switching between phases, which defines this rhythm, are in-process decisions that teams can implement. A deeper understanding these effects can potentially allow teams to have an ongoing influence on their outcomes. Although these effects have been documented in groups and organizations (Gersick, 1988, 1989), their relationship to team performance has not been explicitly tested.

Hence in Study 2, I propose a model that relates the duration of these phases to the rate of improvement in prototype performance, group atmosphere, and the quality of team outputs. To investigate these relationships, a lab experiment was conducted where groups of participants performed a creative, open-ended task where they built a floating vessel from Lego pieces to meet multiple requirements.

In summary, teams are often the locus for much of the activities associated with innovation, which is a complicated but highly relevant process in organizations. This multi-method study of the innovation process in creative project teams is therefore intended to extend theoretical models of team innovation, as well as to guide managers in increasing the effectiveness of their innovation efforts.

CHAPTER 2: AN EXAMINATION OF ACTIVITY CYCLES IN CREATIVE PROJECT TEAMS

A Case Study of Innovation Processes in Two Interactive Media Development Teams

This chapter focuses on better understanding the processes that creative project teams use to innovate. I rely on prior definitions of team process such as Marks and colleagues' (2001), which defines it as "members' interdependent acts that convert inputs to outcomes through cognitive, verbal and behavioral activities directed toward organizing task work to achieve collective goals (p. 357)." These acts include interactions such as goal specification, monitoring the progress of goals, coordination, conflict management, and motivation building (Marks et al., 2001). Process, according to this definition, is distinct from cognitive, motivational, and affective states such as team cohesion and team climate, that emerge from the interaction processes in teams.

An emphasis on team processes is critical because there is strong support that team processes, such as having clearly stated vision and goals and strong internal and external communication, are positively associated with innovation (Hulsheger, Anderson, & Salgado, 2009). The challenge for creative project teams, however, is how these processes are implemented in highly ambiguous situations. These teams face a high degree of ambiguity in their quest for the next groundbreaking innovation. For most teams focused on innovation, the ideal solution is difficult to define because evaluations of team outcomes are dependent on the social and temporal context, as well as beneficiaries' idiosyncratic preferences (Lampel, Lant, & Shamsie, 2000). Creative project teams are thus commonly faced with multiple and conflicting interpretations about what an ideal solution is (Daft & Weick, 1984; Weick, 1979). This ambiguity surrounding the specifications of an ideal solution also extends to the means of

producing or implementing it. Amidst ambiguity, team performance is vulnerable to being derailed by a greater likelihood of delays and errors stemming from difficulties with coordination, more frequent disagreements about how to achieve the team's goals, and a higher potential for interpersonal conflict (Okhuysen & Bechky, 2009). Indeed, ambiguity creates equivocality about what to do, how to do it, who should do it, when to do it, and how fast to complete it. Clear goals, strong communication, and positive processes are undoubtedly critical to performance in creative project teams, but an outstanding concern is how these processes are implemented in situations where there is a high degree of ambiguity. A performance model of creative project teams should thus account for ambiguity reduction processes since these processes are likely to affect team performance.

Innovation Processes in Creative Project Teams

In light of the prevalence and significance of creative project teams, it is not surprising that scholarship on team innovation has proliferated over the last twenty years (Anderson & West, 1998; Drach-Zahavy & Somech, 2001; Hulsheger et al., 2009). Examined through the lens of an input-process-output model of team performance (Hackman, 1987; McGrath, 1984; Steiner, 1972), which has also been adopted in the team innovation literature (West & Anderson, 1996), much of this research has focused on the effect of inputs. For instance, prior work has examined the role of norms (Caldwell & O'Reilly III, 2003), group composition (West & Anderson, 1996; Woodman, Sawyer, & Griffin, 1993), and diversity (Cady & Valentine, 1999; Dahlin, Weingart, & Hinds, 2005; Gibson & Gibbs, 2006) on team innovation outcomes. However, the importance of team processes in innovation has not been lost on researchers (Bain, Mann, & Pirola-Merlo, 2001; Drach-Zahavy & Somech, 2001; Hulsheger et al., 2009). For instance, Taggar (2002) found that team creativity-relevant processes that include task

organization and coordination enabled individual creativity to flourish at the group level in student project teams. Consistent with these findings, Hoegl and colleagues have found a positive relationship between teamwork quality and the performance of teams in R&D (Hoegl, Weinkauff, & Gemuenden, 2004) and software development (Hoegl & Parboteeah, 2007). Most of these studies, however, either measure team process at a single point in time or measure perceptions of overall process quality, without fully capturing the dynamic nature of the phenomenon.

Because most studies treat team processes as static instead of dynamic phenomena, the processes used by creative project teams to successfully develop innovative products are still largely unexplored (Ancona, Okhuysen, & Perlow, 2001; Arrow, McGrath, & Berdahl, 2000; Cronin, Weingart, & Todorova, 2011; McGrath, 1991). This is problematic because static conceptualizations of process do not adequately explain how inputs are transformed into outputs. In the case of innovating teams that face high levels of ambiguity, it is especially crucial to represent dynamic team processes, because in the face of ambiguous goals and expectations, innovation must arise primarily from the process itself. This is evident from the following quote by the creative director of an interactive media development (IMD) studio:

It actually is a lot harder when the goal isn't clearly stated, because then the team has to kinda figure it out. And very often, the client comes to you and says, "We want to build a thing kinda like this." But why? Why do you want to build this? How do you know when it is good? . . . There is a lot of: "We're going to make it look like this. But, not like *that*." Well then, what? Why? There's a lot of swirling around trying to find [the right answer].

This quote suggests that ambiguity is resolved over time as teams strive to figure out solutions through dynamic trial-and-error learning and the examination of multiple alternatives.

The transformation of inputs to outcomes in the context of team innovation thus cannot be adequately represented as a static phenomenon, but as a dynamic process that unfolds over time (Mohr, 1982).

In order to fully understand team innovation processes, a more granular perspective of process that accounts for underlying interaction, behavioral, or activity patterns is necessary (Ballard, Tschan, & Waller, 2008; Eisenhardt, 2004). Capturing these patterns as they unfold provides a more accurate map of dynamic processes than static conceptualizations do (Bourdieu, 1977; Brown & Duguid, 1991), and teams engaged in these dynamic processes will understand more about the pathways that lead to innovative outcomes. For example, Brett, Weingart, and Olekns (2004) found that the evolutionary process in negotiating groups did not follow a smooth path as proposed by rational models, but instead followed a helix model where phases of interactions twisted and turned as one phase took over from another.

A more accurate understanding of dynamic process can subsequently inform theories about the effect of the timing of various types of interventions on team performance. For example, Gersick's (1988) punctuated equilibrium model of group development has been central to research on the timing of coaching interventions (Fisher, 2010; Hackman & Wageman, 2005; Woolley, 1998), feedback (Druskat & Wolff, 1999), and novel contributions (Ford & Sullivan, 2004). In addition, a granular perspective of process that accounts for underlying interaction behavioral, or activity patterns, can also shed light on the effect of temporal variables (Ancona et al., 2001) on team functioning. For example, Tschan (1995, 2002) found that completed sequences of action regulation involving goal orientation, task performance, and monitoring were positively associated with performance in medical emergency teams. More recently, Stachowski, Kaplan, and Waller (2009) found that fewer, shorter, and less-complex interaction

patterns are associated with higher team performance in simulated crisis situations amongst nuclear power plant control rooms crews. A granular perspective of team innovation processes can thus lead to a better understanding of the complex group interactions involved in team innovation, which can, in turn, advance theories of team innovation and performance, as well as contribute to our ability to provide evidence-based prescriptions about how teams can innovate more effectively (Ancona et al., 2001; Arrow, Poole, Henry, Wheelan, & Moreland, 2004; Cronin et al., 2011).

Despite the relevance of granular models of team innovation processes to managers, such models are underrepresented in the research literature. Researchers have examined interaction patterns in dyadic negotiations (Brett et al., 2004) and high-reliability teams (Stachowski et al., 2009; Tschan, 1995, 2002; Waller, 1999; Waller, Gupta, & Giambatista, 2004), but not in creative project teams engaged in innovation. Research that has examined patterns in the innovation process has been conducted at the firm level (Utterback & Abernathy, 1975; Van de Ven, Angle, & Poole, 2000), with little work at the group level. A granular understanding of team innovation processes can therefore add to extant models of team innovation by providing insights into the innovation process as it unfolds over time. These models can subsequently contribute to evidence-based prescriptions for how the innovation process can be more effectively managed.

Thus in this research, I adopt a granular perspective of the dynamic innovation process by examining iterative cycles of planning, enacting, and reviewing activities in creative project teams working on interactive media development (IMD) as they unfold over time. Cycles of planning, enacting, and reviewing activities are examined because these are fundamental to action regulation in teams (Frese & Zapf, 1994), and their sequential completion can lead to a

high level of team performance (Tschan, 1995, 2002). Moreover, the plan-enact-review framework bears close similarities to the action-transition phases in Marks and colleagues' (2001) temporal framework of group process. Cycles of planning, enacting, and reviewing activities are therefore an appropriate framework for capturing iterative processes as they unfold in teams.

I focus on iterative activity cycles because they are commonly adopted by creative project teams and have been found to be positively associated with team performance (e.g., Dow, Fortuna, Schwartz, Altringer, & Klemmer, 2011; Dow, Heddlestone, & Klemmer, 2009; Eisenhardt & Tabrizi, 1995). The iterative process has been described as a way for teams to learn experientially by building their intuition about the solution under development, as well as through trial and error. Iterative processes in this context are not simply a passive, empirical observation of the environment, but can also be a proactive attempt at shaping it (Daft & Weick, 1984). From this perspective, the iterative process involves is a goal-driven, teleological process (Poole, Van de Ven, Dooley, & Holmes, 2000) that involves actively constructing a conceptual framework that is imposed on the environment, followed by a period of reflection (Brown & Duguid, 1991). While these descriptions characterize the functional aspects of iterative processes, there is still a poor understanding about the dynamic nature of these iterative processes in terms of how the activities and interactions that constitute these processes unfold over time. Hence, by examining the fundamental action regulation cycles of planning, enacting, and reviewing activities in IMD teams, the question that I seek to address in this research is how team innovation processes unfold over time. A deeper understanding of the dynamic nature of team innovation processes can contribute to new models of team innovative performance. I illustrate this contribution by drawing on these findings to develop testable propositions about

the relationship between temporal characteristics of the iterative process – specifically, the duration of each activity phase – and team innovative performance. In the rest of this paper, I introduce the research context, discuss the methods for conducting this research, present findings from this research, and develop the theoretical propositions relating the duration of activity phases to team performance.

Research Context: Interactive Media Development Project Teams

The research setting for this study was project groups developing interactive media (IM) products, as the task of interactive media development provides an extreme case (Pettigrew, 1990; Pratt & Kim, 2011) of a creative project team faced with a high level of ambiguity as part of its task of producing innovative outcomes.

As their name implies, interactive media (IM) products (such as video games, educational tools, and applications for mobile devices) are typically valued as an interactive experience. As the definition and assessment of an interactive experience is highly subjective, product outcome specifications and the means for attaining those outcomes are open-ended and difficult to specify. For instance, an IMD team will need to determine how an objective to build a game that is fun translates into actual gameplay mechanics, software code and artistic styles. Given the multiple ways in which the concept of fun can manifest in the team's output, IMD team members are likely to find themselves engaged in tasks that fall into the lower half of McGrath's (1984) circumplex of team tasks, involving judgmental tasks (Laughlin, 1980) with no demonstrably correct answer, as well as undertaking the tasks of resolving conflicts of viewpoints, interests, and power. The subjective evaluation of the IM experience therefore renders project goals highly ambiguous and creates a high degree of equivocation in decision-making, making this setting an extreme example of teams faced with a high level of ambiguity.

Research Site: GameCo

The research site for this fieldwork was an IM studio (hereafter called GameCo) based in a mid-Atlantic city in the United States. At the time, GameCo employed approximately 60 employees with expertise in software engineering, game design and technical art. Most employees were under 30 years of age. GameCo employees worked in cross-functional project teams consisting of software engineers, game designers, and artists. In addition to the technical experts, a producer was also assigned to each team. Producers played a boundary-spanning role and primarily handled administrative and managerial issues.

Prior IM development projects at GameCo included games on various platforms (e.g., mobile phones, stand-alone entertainment systems, TV plug-in games, internet browser games) for a wide spectrum of clients that included video game publishers, media conglomerates, theme parks and a startup toy company, among others. The products developed for each client were unique and varied in dimensions such as gameplay mechanics, game objectives, technological platforms, and visual themes. Even though experiences, knowledge, and skills might be transferable between projects, the idiosyncratic requirements and constraints of each project created a high requirement for novelty, with distinct challenges for each project.

In addition, even though the performance of individual project groups in GameCo varied, the studio as a whole was considered to be successful, as evident from its growth since its founding. This was further supported by informal interviews with senior employees who revealed that a key concern for the studio was managing its growth and expansion, rather than survivability. Thus, even though GameCo could be considered to be relatively young in comparison to long-standing organizations in other industries, it is an established organization in an industry where the base rate of organizational start-up and demise is high. The reputation of

GameCo's senior staff was evident from interviews with industry veterans in the initial phases of this research and from their staff's regular keynote appearances at major industry professional development events. Project teams in GameCo can therefore be considered prototypical of teams in an overall functional IMD studio.

Project Teams Alpha and Beta

Two project teams from GameCo were selected as case studies for this study. These teams were selected on the basis that both projects involved developing interactive experiences from scratch and were approximately equivalent in project scope and duration (see Table 1).

Project team Alpha was tasked with developing a basketball-themed game for Facebook and mobile platforms. In this game, players would create customized characters and play a simulated two-on-two basketball game against their friends. The client for this project was a team in the National Basketball Association (NBA) with an average attendance of more than 20,000 per home game between 2007 and 2012. Project requirements faced by Alpha were ambiguous in that the client did not have a specific idea of what they wanted except for a few high-level goals. These goals were for a game that would: (a) be differentiated from current games in the market, (b) enhance the spectator experience during live games, and (c) potentially serve as an additional revenue stream for the team.

Project team Beta's goal was to develop a five-minute-long motion-controlled multi-player game that allowed theme park guests to experience a sea turtle's journey from the deep sea to its nesting habitat. The resultant game was one where players controlled turtles to avoid obstacles and pick up food as their turtles followed a fixed migratory pathway. The client in this project was a theme park operator based in the United States with average annual attendance exceeding 4 million between 2007 and 2012. Similar to Alpha, goals in this project were also

ambiguous. Aside from its broad objective of wanting GameCo to create an interactive experience to complement its exhibit, the other primary requirement was that the interactive experience be accurate and logically consistent, in line with the educational aims of the main exhibit.

Both project Alpha and Beta teams consisted of five core members, with up to five additional members joining the team over the course of the project. These were not previously existing teams, but rather were put together primarily on the basis of how a potential member's expertise matched the needs of the project and that person's availability to be assigned to that project. Although these teams did not previously exist, team members were likely to have experience working with one another on prior projects.

Table 1: Overview of cases

	Project Team Alpha	Project Team Beta
General description	Developed a game where players could customize characters and play a simulated two-on-two basketball game against their friends through Facebook and mobile devices.	Developed a five-minute long motion-controlled multi-player game that allowed theme park guests to experience a sea turtle's journey from the deep sea to its nesting habitat.
Project client	NBA basketball team with average annual attendance of more than 20,000 per home game over the past 5 years	North American theme park operator with average annual attendance exceeding 4 million over the past 5 years
Client objectives	a) Game should be differentiated from current games in the market. b) Game was to enhance the spectator experience during live basketball games. c) Additional revenue stream for client.	(a) Game was to complement an exhibit on the migratory patterns of turtles. (b) Depictions of migratory patterns, flora and fauna in the ocean should be accurate. b) Game should be simple and intuitive for casual players.
Project duration	Eight months	Eight months
Team members	Five core members. Team expanded to ten members over the course of the project.	Five core members. Team expanded to ten members over the course of the project.

Method

This research used a two-case replication design (Yin, 2009), which improves the external validity of the findings compared to a single-case design. A case study method was appropriate for two reasons. First, little data or prior theory on the phenomenon of interest existed. Second, since the research question asked about how the phenomenon of interest occurred, the case study methodology was appropriate as it allowed examination of the teams' processes as they unfolded over time (Dutton & Dukerich, 1991; Pettigrew, 1990; Yin, 2009). Decisions for selecting the research setting, the specific organization (GameCo) and the focal project teams (Alpha, Beta) within this organization were made on the basis of a theoretical

sampling strategy. Using cycles of planning, enacting, and reviewing activities as sensitizing concepts (Glaser & Strauss, 1967; Patton, 2002) to guide data analysis, cycles were categorized through a constant comparison method (Glaser & Strauss, 1967). These methods are described in more detail in the following paragraphs.

Sampling Strategy

The basis for case selection in this study was first to use IMD teams as an extreme example of project teams confronted with ambiguous goals (Pettigrew, 1990; Pratt & Kim, 2011) so that the phenomenon of interest would be transparently observable. Within the IMD domain, the studio GameCo was selected as the research site because it was a positive exemplar in this industry. Within GameCo, data from project teams Alpha and Beta were selected for data collection because these teams were comparable in scope and duration, overlapped in their life span, and did not share common team members.

Data Sources

Multiple techniques for data collection were used to serve as important triangulation and supplementary sources for understanding team activities, the IMD process, and other key events (Jick, 1979; Miles & Huberman, 1994; Yin, 2009). These were: (a) direct observations, (b) archival documentation of production processes, (c) semi-structured one-on-one interviews, (d) informal interviews, and (e) team artifacts such as videos, game prototypes, artwork, and other outputs.

Direct observations. The primary source of data for this study was direct observations of project team meetings by the first author. These included both pre-scheduled and spontaneous team meetings, playtest sessions, and client calls. While he had some interactions with individual members in these teams, these interactions (aside from informant interviews discussed later)

were casual and not directly related to the work of the teams that being observed. Hence, his role as researcher in this setting was one of an observer-as-participant (Adler & Adler, 1994; Gold, 1957) where he had an overt presence in the research setting and interacted with team members, but was only passively involved in their work under observation. The site was visited on a weekly basis and extensive field notes were taken based on his observations. Field notes included details that were not only relevant to the research questions but also included details that enhanced my understanding of the situational context (Pratt & Kim, 2011). For example, notes included maps of the meetings to record where people stood or sat; information about who spoke to whom; observations of the general mood; which team members were influential; and team member attitudes toward events, the client, and the project in general. Each visit to the site lasted from 60 minutes to four hours. In total, 25 observations at Alpha and 17 observations at Beta were recorded.

Archival documentation of production processes. Another source of data were project documents of production processes. These included (a) project schedules that contained information about deadlines and milestones, (b) design documents that contained information about output specifications, (c) production documents that tracked the status of game assets, (d) email communication among team members, and (e) task tracking and planning documents called *scrum sheets*.

Scrum sheets were documents that were updated daily for planning and coordinating team action. These were spreadsheets that contained detailed information (presented for a three-week period, as described in more detail below) of the task that each individual was responsible for, the status of the task (i.e., whether it was in progress, blocked or completed, the projected total number of hours required to complete the entire task and the projected number of hours

remaining to complete the task) and the capacity of each team member (i.e., number of hours available). These documents were downloaded daily to provide up-to-date snapshots of group activity.

The work done by these teams was highly interdependent in nature, but they used a distributed approach to complete tasks, in which project members often worked on their own for some time on their assigned pieces of the job. Because of this structure, the scrumsheets served as an appropriate and efficient means of capturing the daily activities at the team level. In fact, scrumsheets were used by producers to monitor team progress and inform decisions on staffing allocations and budgets. Furthermore, these documents were shared with clients as a form of accountability, so there was a strong incentive to accurately represent team activities and progress in these documents. The scrumsheets retrieved for this research captured a total of 1,058 unique tasks for Alpha over 76 days, and 527 unique tasks for Beta over 37 days.

Interviews. Over the duration of these projects, informal interviews were conducted with team members. These interviews were spontaneous encounters with project team members to obtain updates on project progress and to clarify events that had been observed. Each interview lasted approximately 5 to 10 minutes and was conducted in the open. Handwritten notes were taken during the interviews, which were summarized and included in the field notes immediately after each interview took place.

One-on-one semi-structured interviews with two members from each team were conducted separately after the teams' projects were completed. The duration of these interviews ranged from 60 to 90 minutes. The informants for these interviews were core members of each team who were involved with the project from inception till end and who were involved in key decisions, such as those relating to design specifications. Informants were asked about project

background, events preceding and subsequent to milestones and critical incidents, obstacles faced, their relationships with their clients, and their overall assessment of the teams' performance. These interviews were audio-recorded and transcribed verbatim. Although these interviews involved informants' retrospective account of events, the reliability of their recall was enhanced by allowing them to reference team documents and communications through a computer terminal in the interview room. The semi-structured interviews provided an additional source for triangulating on how events unfolded in these teams.

Team artifacts. Team artifacts are outputs produced by the team and include prototypes of the game under development, artwork, video captures of gameplay, and video recordings of playtest sessions. These artifacts were retrieved either from team members, or downloaded from a computer folder that was shared among team members.

Analytic Strategy

The units of analysis in this study are cycles of planning, enacting, and reviewing activities. These cycles are temporal segments of behavior (Ballard et al., 2008) that can be described as “series of acts, usually, though not necessarily contiguous in time, that relate to the same task content or process contribution” (Futoran, Kelly, & McGrath, 1989, p. 222). Cycles of planning, enacting, and reviewing activities thus served as sensitizing concepts (Glaser & Strauss, 1967; Patton, 2002) to aid in data analysis.

These cycles were identified by first unitizing activities and interactions from the data. Following the scheme used by Tschan (2002), these units were coded as *planning* if they related to future states or future actions to be performed. *Enacting* was coded if the unit directly related to task performance. *Reviewing* was coded if the unit referred to actions that had been performed or output that had been produced and was being evaluated. Each unit was categorized as only

one activity. These units were then represented in a time-ordered matrix (Miles & Huberman, 1994) to keep track of “sequences, processes and flows” (p. 119) of planning, enacting, and reviewing activities.

Categories of activity cycles were then developed through constant comparison (Glaser & Strauss, 1967). This process involved forming initial clusters of plan-enact-review sequences to minimize differences within clusters while maximizing differences between clusters. For example, the nature of planning activities between categories was compared in terms of the people involved and the coordination issues faced by team members. Differences in how planning, enacting, and reviewing activities manifested were then developed from these initial categorizations. New activities and interactions were then compared with previous incidents coded in the same category. Any differences between these incidents were reconciled by refining the definitions and properties of these categories to accommodate the new data. This process of constantly comparing new data with existing codes was continued until a level of stability was reached.

Findings

I present my findings by first giving a broad overview of how tasks were accomplished in project teams Alpha and Beta. Then, I discuss how sequences of planning, enacting, and reviewing activities manifest as experimentation and validation cycles.

An Overview of Task Accomplishment in Project Teams Alpha and Beta

After a project mandate had been confirmed, a core team was formed comprising team leads who played the role of project visionaries responsible for shaping the direction of the project and acted as gatekeepers who gave final approval for the team’s output. In both Alpha and Beta, the producer, technical director, art director, and lead designer on the team served as

leads. Supporting the core group were peripheral members who were functional specialists largely responsible for output production. The membership of these individuals was more flexible than team leads in that some of them either joined the project midway or divided their time between multiple projects.

The task of designing and producing the interactive media artifact involved a high level of reciprocal interdependence (Thompson, 1967) between functional roles. For instance, to design a user interface (UI) for a game, the artist would need to know what the artistic theme of the game is, where the UI will be located, how much screen space is available, the information that will need to be displayed and how the controls will be triggered. These were decisions made by others, not by the artist; thus, as all of this information was distributed among the team members working on each of those items, the UI artist had to coordinate with a number of team members from the other functions. In addition, some of this information was also negotiated (e.g., how controls are triggered), requiring team members from different functional areas to mutually agree on what this information was.

In light of this high degree of reciprocal interdependence, project teams in GameCo, including teams Alpha and Beta, adopted a scrum methodology for project management. Scrum methodology is a project management method commonly used in software and product development. At its core, the scrum methodology involves members of a cross-functional team working collaboratively to accomplish team milestones in a short period of time, similar to a rugby team passing the ball between team members to cover as much distance as a unit (Takeuchi & Nonaka, 1986). This is in contrast to a linear process where team deliverables are passed from one function to another in a sequential manner, similar to track and field relay team members passing the baton from one member to the next.

Under the scrum methodology, projects were broken down into three-week cycles called *sprints*. Each sprint was marked by specific team goals or deliverables that the team would work together to complete. At the end of each sprint, team members would meet to assess the progress of a project and plan its next steps, sometimes in consultation with other stakeholders. In doing so, the project's direction and progress was informed by completed work and estimates of short-term productive capacity that were more accurate than long-range forecasts.

On a daily basis, the members of each team would meet at a pre-determined time for no more than 15 minutes to update one another on the tasks they had accomplished the day before and the tasks they planned to accomplish that day. In addition to giving the team a macro view of their progress, these meetings (called *scrums*) also helped members prioritize their tasks and learn about who they had to coordinate with. For instance, a programmer might state that he needed adjustments to be made to a graphic before he could integrate it into the game. The artist responsible for doing so would then be able to make that adjustment a higher priority to avoid delaying the team's progress. The scrum process thus allowed for near-constant in-process adjustments (Weingart, 1992) at the individual level so that the teams could more rapidly adapt to current realities to accomplish short-term sprint goals.

Iterative Processes in Projects Alpha and Beta

Cycles of planning, enacting, and reviewing were found to manifest in two distinct forms: experimentation cycles and validation cycles. *Experimentation cycles* consisted of sequences of planning, enacting and reviewing activities that enabled teams to gather insights into project requirements, constraints, and design specifications through trial and error. In *validation cycles*, on the other hand, the sequences of planning, enacting, and reviewing activities provided feedback for teams to adjust their outputs to be in alignment with project requirements. The

following sections elaborate on the properties of experimentation and validation cycles and discuss how planning, enacting, and reviewing activities differentially manifest in the two types of cycles. These differences are summarized in Table 2. Although these cycles are discussed independently for analytic convenience, note that they are not mutually exclusive and can co-occur.

Table 2: Properties of activity cycles

Cycle	Function	Planning phase activities	Enacting phase activities	Reviewing phase activities
Experimentation	For gathering insights into project requirements, constraints and design specifications. Discovery-oriented.	Emphasis: Task simplification for individual effort. Low emphasis on collective planning efforts. Communication patterns: Collaborative problem-solving communication within functional areas; directive communication from programmers to others. Little other collaboration across functional areas.	Emphasis: Speed of completion over output quality. Cycle outputs: Outputs are provisional prototypes that represent selected features of final deliverables. Task performance: Output can be simplified. Low coordination requirements. Action familiarity: Low. Actions involve specifying new relationships between variables.	Emphasis: Forming plausible interpretations from feedback. Feedback content: Relates to output specifications, as well as the tools and resources required to accomplish project goals. Feedback ambiguity: High. Choices about future actions are equivocal.
Validation	For aligning output to project requirements. Correction-oriented.	Emphasis: Collective planning for coordinated effort. Communication patterns: Collaborative problem-solving communication between and within functional areas.	Emphasis: Output quality over speed of completion. Cycle outputs: Outputs are components of final deliverables. Task performance: Output cannot be simplified. High coordination requirements. Action familiarity: High. Actions involve adjusting parameters of known variables	Emphasis: Verifying that output performs to specifications. Feedback content: Feedback relates to output performance. Feedback ambiguity: Low. Choices about future actions are unequivocal.

Experimentation Cycles

Experimentation cycles are sequences of plan-enact-review activities utilized by the project team to gather insights into project requirements, constraints, and design specifications. YI, a software engineer who was primarily responsible for integrating the software code for the game across different gaming platforms in team Alpha, describes this process as follows:

Before we had actually started, before we had any files on that kind of assignment, we weren't actually doing anything that we were committed to. We were just kind of playing around to find how do we do this and how do we play these animations? . . . What part of this is fun? We were experimenting. We were prototyping.

YI's comment highlights two aspects of experimentation cycles. The first is that experimentation cycles serve exploratory purposes. In Alpha, this exploration revolved around technical constraints (e.g., "how do we do this," "how do we play these animations") and project requirements (e.g., "what part of this is fun"). A clearer understanding of these constraints and requirements subsequently affected design specifications of the final deliverable as well as the work flow required to produce it.

The second aspect of experimentation cycles is the notion of *playing around*, which points to the provisional, trial-and-error nature of the activities within and outcomes of these cycles. This idea of enacting and testing various solutions provides opportunities for team members to acquire direct experience with solution implementation. These direct experiences subsequently develop team members' intuition about the particular solution under development for the project on which they are working (Eisenhardt & Tabrizi, 1995). Experimentation cycles can be considered to be provisional, in the sense that team outputs in these cycles are usually prototypes designed to explore the feasibility of specific features or functionalities. These ideas

are then tested against an array of requirements and constraints, the results of which are not possible to predict (Simon, 1969; Thomke, Von Hippel, & Franke, 1998). In team Alpha, for example, these tests ranged from determining whether a basic prototype of the game could work on different mobile platforms to determining an appropriate graphical theme for the game. In team Beta, tests were enacted with early prototypes to ascertain whether the proposed gameplay was intuitive enough for the target audience.

The exploratory, playful, and provisional nature of experimentation cycles is analogous to a rehearsal for a dance that has yet to be fully choreographed because of uncertainties about performer capabilities and audience preference. The choreography emerges over time by having the performers execute different ideas, which allows the choreographers to develop a deeper understanding of their abilities as well as to evaluate ideas from the audience's perspective.

Having discussed the broad purpose of experimentation cycles, the activities in each phase are elaborated upon by first examining activities in the planning phase, followed by those in the reviewing and enacting phases of experimentation cycles.

Planning phase in experimentation cycles. The objective of the planning phase is to establish the tasks required to accomplish goals for the next cycle, the people responsible for performing these tasks, the duration of these activities, and the deadline for completion. At GameCo, it was found that there was a low emphasis on collective planning efforts in the experimentation cycles of both teams because these tasks were likely to be performed independently, albeit at the cost of lower-quality output.

This emphasis on independent work was evident from the Alpha team's assessment of the workflow that would have been required to allow players to customize the height of their characters in the game. At issue was whether the team could implement this feature by stretching

the animations within the game. To explore the feasibility of this option, one of the software engineers wrote code to stretch some preliminary animations in the game that had already been created. This was a one-step process involving only one member on the team. In contrast, the regular procedure for integrating a piece of animation into the game is a three-step process involving the animator, the technical artist, and the software engineer.

The lower interdependence between team members in this phase is also evident from Table 3, which shows that only 6.6% and 5.0% of experimentation-related tasks in teams Alpha and Beta respectively were blocked – that is, obstructed from progressing – by the activities of other team members, compared to validation-related tasks, which formed 14.9% and 35.0% of total blocked tasks in Alpha and Beta, respectively.

When task interdependencies in experimentation cycles are low, as in the GameCo teams, coordination between team members is correspondingly simpler. Likewise, there will be a lower need for frequent, multidirectional communication among team members to coordinate effectively. I observed that communications between group members in the planning phase could be characterized into two forms, depending on whether the communication occurred within or between functional areas. Within functional areas, communications tended to involve collaborative problem-solving discussions to determine how ideas could be quickly implemented. Across functional areas, I observed more directive communication consisting of instructions from programmers to others on the team.

Table 3: Number of blocked tasks by task type

Project Phase	Team Alpha		Team Beta	
	Number of tasks	Percent of total tasks	Number of tasks	Percent of total tasks
Administration	10	8.3%	3	5.0%
Experimentation	8	6.6%	3	5.0%
Validation	18	14.9%	21	35.0%
Production	85	70.2%	33	55.0%

Enacting phase in experimentation cycles. Activities in the enacting phase of experimentation cycles directly relate to ideas decided upon in the planning phase. These activities are typically experiments that provide the team with insights into project requirements and technical constraints. These experiments manifest in the form of prototypes that emphasize a particular feature to be tested. In Alpha, for example, YI describes how the team explored the technical capabilities and limitations of the mobile devices on which the game would run:

We just made a quick-and-dirty build on the phone [where we] tried to port it and made sure that we could play an animation of the character and have it all run. So . . . it was just a prototype. Does it run? Just take whatever it is and push it on the phone. And, if it completely failed, we would've been in a bad place and if it ran, but it ran slow, we could probably make some adjustments to it.

Outputs of experimentation cycles are quick-and-dirty because these prototypes are built to represent a particular feature of the final product and are rarely intended to be a part of the final deliverable. Since the emphasis during enactment activities is on the speed of completion, rather than on technical quality, enacted outputs in experimentation cycles are usually improvised and less elegant or polished than the final deliverable. In the previous example given

for project Alpha, in which the customized height question was explored, the software engineer's use of animations that had already been created is an example of improvising a quick-and-dirty test to explore the feasibility of implementing this possible customization feature. It was also common for GameCo teams to use basic shapes and crude renderings of final art assets as placeholders in the virtual environment. For example, a prototype from Project Beta that was used to explore the feasibility of replicating the turtle's swimming motion contained simple two-dimensional renderings of the ocean environment and also lacked the rich texture and detail that would have made the environment look more realistic.

Reviewing phase in experimentation cycles. Activities in the reviewing phase of experimentation cycles involve evaluations of the group's output and the processes undertaken to produce this output in the enactment phase, followed by forming plausible interpretations of these evaluations.

Performance evaluations of the outputs produced by the team in experimentation cycles are usually exploratory, similar to proofs of concepts. For example, in project Alpha, the evaluation of the stretched animation was to determine whether the end result would satisfy quality requirements. Similarly, in project Beta, initial tests were conducted to verify that the movement of turtles in the ocean could be accurately represented in the game.

The workflow required to implement these ideas is also evaluated in the reviewing phase of experimentation cycles. These evaluations allow team members to better understand project constraints, which facilitates decision-making related to design specifications, and to more accurately anticipate resource needs such as staffing and process improvement tools. For example, once the number and type of ocean scenes that the turtles would swim through were confirmed, artists in the project Beta team could then begin producing concept art of various

graphics for the game. Concept art served two primary purposes: First, it allowed artists to verify their ideas with team leaders and the client. Second, it gave artists a better understanding of the resource requirements. This process was described by UE, the lead artist for project Beta, as such:

[What] we were doing with the concept art was visually saying “is this what you mean?” . . . That gives a clear picture . . . of how many assets we are really going to need for an area. [The lead designer] can say this area is a kelp forest, but until we really look at a lot of reference, and draw up from that reference what we would want it to look like, it’s not really clear how [many assets are] required for that.

Evaluations of group output and processes in experimentation cycles therefore inform decisions about project scope and specifications – specifically, which features to retain, abandon, or modify, as well as the tools and resources that are likely to be required at different points in the project’s lifecycle.

A feature of feedback from experimentation cycles is that it is ambiguous and does not always provide definitive answers to future actions. Feedback may only indicate that changes need to be made, or that an idea is good enough, but it offers limited insights into the correct response, or whether a course of action is the most optimal (Van De Ven & Polley, 1992). Consequently, a future course of action remains equivocal. In project Alpha, for instance, although evaluations of the stretched animations verified that this option would not satisfy quality requirements, the appropriate course of action – whether the team should explore other solutions to implement this feature, or to ask for an increase in the budget and development timeline, or to abandon this feature completely – was still unclear. This decision was made by

developing a plausible story of what reality might be (Weick, Sutcliffe, & Obstfeld, 2005) and deciding on a course of action consistent with this interpretation of reality.

The ambiguity of feedback is compounded by evaluations of group output in experimentation cycles that are usually derived from a small number of tests using prototypes which are quick and dirty representations of specific features of the end product. These tests are usually conducted on a small scale because of the unfinished, provisional nature of the output. For instance, playtest sessions at GameCo were usually conducted with no more than 10 participants. Consequently, the generalizability and validity of these tests are potentially limited (March, Sproull, & Tamuz, 1991). The extent of this limitation, however, is not apparent and may only be discovered much later. For example in project Beta, although the team was able to verify that the movement of turtles in the ocean could be accurately replicated in the game environment being tested, it was unclear that the same level of performance could not be maintained in a more graphics-intensive game environment. In fact, later in the project, serious performance issues were discovered and the team had to reduce the quality of graphic art assets to reduce the amount of computational processing resources required for the game to run.

In light of these equivocal options, the team's interpretation of feedback about their output from experimentation cycles and decisions about future actions also depends on prior information and predictions about the future. Activities in the review phase are thus similar to a sensemaking process involving Weick et al.'s (2005, p. 415) "continued redrafting of the story as it emerges."

Validation Cycles

Validation cycles refer to sequences of planning, enacting, and reviewing activities that enable teams to incrementally align their output with project requirements. Feedback obtained

from the review phase of validation cycles provides information about shortfalls in the performance or quality of the team's output relative to project requirements. For instance, YI describes how the team would receive feedback from its GameCo colleagues who had tried the basketball game with comments like, "I click this button and then this button and it crashed," or "I don't understand what these shoes do." Steps to address these shortfalls are then undertaken by the team in subsequent cycles. In response to the feedback, for instance, YI and the Alpha team would then look into fixing the bug that crashed the game or "[change] a little bit of the art to make things a little more noticeable." Similarly, UE from project Beta describes this sequence of activity in the team as follows:

There's this constant balancing act of adjusting something over here and making sure nothing else got messed up along the way. . . . There's a lot of cycles going back and forth between myself and [the] design [team members] until it was what they were envisioning.

Difference between validation and experimentation cycles. A key distinction between validation cycles and experimentation cycles pertains to the team's output. In validation cycles, team outputs are components of the team's final deliverable – not just quick-and-dirty tests as they are in the experimentation cycle. Consequently, the primary emphasis in the enactment phase in validation cycles is the technical quality of the team's output. Validation cycles can be considered to be correction-oriented, while experimentation cycles are discovery-oriented. Essentially, team actions in validation cycles involve modifying the value of known parameters, adding new features, or removing existing ones rather than building components from scratch.

The second difference between the cycles is the sense of permanence that encompasses validation cycles in contrast to the playful, provisional nature of experimentation cycles. If

experimentation cycles are analogous to dance rehearsals where the choreography has not been established, the analogous comparison for validation cycles will be to rehearsals in a symphonic orchestra with sheet music in hand. In this case, the parts to be performed by each musician is already defined and codified. The goal of rehearsals is to adjust specific parts to achieve a well-blended sound at a rhythm, volume, and style that is consistent with the conductor's interpretation of the piece. In the subsequent sections, the planning, enacting, and reviewing activities in validation cycles shall be elaborated upon by contrasting these activities with those in experimentation cycles.

Planning phase in validation cycles. A feature of the planning phases of validation cycles is the emphasis on coordination, which stems from the fact that team output in validation cycles are components of final deliverables rather than provisional prototypes. Consequently, team members need to actively coordinate their understandings of output specifications and the timing of completion during this phase to minimize errors and delays. The emphasis on coordination during the planning phase of validation cycles was evident in the daily scrums of both Alpha and Beta, where it was common for team members to openly ask what their next tasks were to be after completing a task. Although each member had a list of tasks to accomplish within a three-week sprint cycle, the priorities of these tasks often shifted during the course of the sprint and tasks were often added or removed to this list. These priorities were often not determined by a single person when the question was asked, but had to be discussed later in short, spontaneous meetings (or huddles) involving the team leads and the respective team member. In these huddles, members would discuss team priorities, the process and resources required to accomplish these priorities, and the team's capacity to accomplish these priorities.

These discussions then yielded a clearer answer about how team members would prioritize their tasks.

The greater emphasis on coordination in validation cycles also necessitated a greater requirement for communication between team members. In team Beta, for example, one of the ways that the team attempted to improve the performance of their game was by reducing the number and size of “collision bubbles” around objects. A collision bubble is a space that two objects in the virtual game environment cannot pass through at the same time, or else they would overlap (or collide) into one another. Reducing the number and size of collision bubbles improves game performance by reducing computational processing. However, this has to be balanced with maintaining the realism of the game so that objects “bounce” off one another in a realistic manner. Decisions about the location of these bubbles and how much to reduce the size of each bubble by were observed to involve a detailed discussion between the lead artist (who was responsible for implementing these changes) and the technical director (who was responsible for integrating various components into the main game artifact). This example illustrates the collaborative problem-solving communication between team members across different functional areas that is necessary for effective coordination in the planning phase of a validation cycle.

Enacting phase in validation cycles. As noted above, the main difference between validation and experimentation cycles is related to the teams’ output. That the team had shifted from experimentation to validation, essentially fine-tuning toward the finished product, was evident from the teams’ emphasis on fixing bugs in the days leading up to playtest sessions that involved members of the public and before a milestone deliverable to the client. The emphasis on the technical quality of outputs was also evident in their avoidance of short-cuts that would compromise the quality of their output in spite of time constraints. Instead of relying on short-

term fixes like they might have in the experimentation cycle, teams would commit resources to ensuring more robust and elegant solutions that would enable them to accomplish tasks faster without compromising on quality. For instance, YI described a pop-up messaging system in the Alpha team's product as being "ugly and just in there," with limited functionality since "it only worked in a battle" when this feature was first built for their game. After learning that the pop-up system would be used in other parts of the game, however, the programmers developed a more robust system that "with like three lines of code, [a software engineer] can add a new pop-up anywhere they want."

Another strategy to maintain the quality of their output in spite of time constraints was to reduce project scope. In project team Beta, UE described a meeting among the project leads where they "sat down and said we're not going to get all this done. We need to cut a couple of segments out." The decision about what aspects of the project to scale back on was based on a determination of "the story and the concepts we knew we needed," "[art assets] we could reuse," and whether that feature "was going to take a lot of scope to figure out."

When more extensive adjustments to the teams' outputs were needed during the validation cycle, the resulting changes were unlikely to involve modifications to the underlying architecture of the products, but were usually extensions of existing features to improve on them overall. In addition to the pop-up tutorial mentioned earlier in the Alpha team's basketball game, another example from this project is the implementation of leader boards showing players with the highest point totals, following a suggestion made by the team's client mid-way through the project. The team was able to quickly implement the software code to extract scoring information that was already being collected and stored in the database and to present it in a separate part of the game. The addition of this feature this did not involve deep-level

architectural changes to the relationship between components, but rather was a standalone feature that leveraged some existing components within the game's code.

Reviewing phase in validation cycles. Similar to activities in the reviewing phase of experimentation cycles, activities in the reviewing phase of validation cycles involve evaluations of team output. However, the emphasis in validation cycles is to verify that output performs to specifications, rather than to develop plausible interpretations of project goals from the feedback received during this phase. Because of the emphasis on verification, feedback content is therefore focused more on output quality and less on production processes.

Another feature of reviewing phases in validation cycles is that feedback is less ambiguous, especially in comparison to feedback during experimentation cycles. The greater clarity in feedback can be attributed to the fact that discrepancies between the quality of the team's output and the more concretely understood project requirements are more easily identified. Moreover, teams are likely to already be familiar with the actions required to address these discrepancies because these actions involve modifying the properties of components that have already been built, rather than building components from scratch.

An illustration of activities in the review phase of validation cycles are the weekly "run-throughs" in team Beta, where a few members of the team would play the game while the rest of the team observed and made notes of the parts of the game that could be improved upon. For example, software engineers might look out for art assets, such as rock, hooks, or other ocean creatures, that the turtles would pass through instead of collide with; artists might look out for artwork that needed to be retextured to improve the realism of the ocean environment in the game; and game designers might look out for parts of the game that were too easy or too difficult for players.

In light of this less ambiguous feedback and a greater familiarity with the actions needed to address issues, the communication requirements between team members were also lower in the review phase of validation cycles than the review phase of experimentation cycles. In project team Beta for instance, UE describes how he would review one of his artist's work at the end of the work day by "[stopping] by and [seeing] how things had gone for the day." During these informal review sessions, UE reported that his feedback to this artist was usually along the lines of, "you didn't take this far enough yet" rather than, "that's not working at all."

Due to the lower communication requirements in this phase, information may also be transmitted among team members through media that are less rich (Daft & Lengel, 1986). In project team Alpha, for example, it was observed that performance discrepancies in the team's output, such as technical bugs, could be listed by any team member in a shared database to which all team members had access.

Implications on the Temporal Characteristics of Activity Cycles

In my analysis of activity cycles in project teams Alpha and Beta in GameCo, I identified experimentation and validation cycles as two distinct cycles, each with its own unique configuration of planning, enacting, and reviewing activities. Differences in how these various activities manifest in each type of cycle can be applied to draw inferences about how the mapping of teams' activities along the temporal continuum can affect their outcomes. In this section, I draw on these findings to explore, and posit upon, the effects that different durations of planning, enacting, and reviewing activities can have on the quality and innovativeness of team outcomes.

Of the multiple dimensions of time that have been proposed by organizational scholars (e.g., Ancona et al., 2001; Bluedorn & Denhardt, 1988; McGrath & Rotchford, 1983), I focus on

the duration of phases because duration has implications for how tasks are to be temporally segmented. As time is a scarce, non-renewable resource, a team's ability to effectively allocate time across its multitude of activities can be critical to gaining a time advantage over its peers in terms of "cycle time, time to market and turn-around time" (Gibson, Waller, Carpenter, & Conte, 2007).

Duration bears a complex relationship to other important characteristics, such as pace and frequency. Pace refers to the tempo or rate of activity within a unit of time (Levine, 1988; McGrath & Kelly, 1992). A shorter duration of phases will imply a higher pace of activity (holding the frequency of activity constant). Similarly, if the pace of activity is held constant, then a shorter duration will allow for a lower frequency of activities within that phase. It is in this way that "[d]uration surrounds – embeds and is embedded within – rate and frequency" (McGrath & Kelly, 1992, p. 414). An underlying assumption in the propositions presented here is that shorter intervals can lead to an increase in the rate of performance, a lower frequency of activities, or both (Karau & Kelly, 1992).

Duration of Planning Phases

In planning phases, teams faced with shorter durations are likely to rely more on in-process planning (Weingart, 1992), improvisation (Vera & Crossan, 2005), and greater simplification of complex tasks. In experimentation cycles, where team outputs are prototypes, relying on in-process planning and improvisation is not likely to have a negative impact on performance. In fact, it may even have a positive impact, as it allows teams to rapidly gain an intuitive understanding of the solution at hand (Eisenhardt & Tabrizi, 1995). On the other hand, in validation cycles where teams are building the final output, it is important for them to plan in advance as their outputs are final deliverables and therefore are more complex with less room for

compromising on output quality. Coordinating team action during the validation phase by using in-process planning and improvisation is therefore more likely to result in delays, which will adversely affect team performance.

Proposition 1a: The duration of planning phases in experimentation cycles is negatively related to the quality and innovativeness of team outcomes.

Proposition 1b: The duration of planning phases in validation cycles is positively related to the quality and innovativeness of team outcomes.

Duration of Enacting Phases

In enacting phases, the higher pace of task performance associated with shorter durations for these activities is likely to result in a greater incidence of errors and correspondingly lower output quality. The higher incidence of errors could be caused by team members being less careful in implementing work, as well as fatigue due to team members working harder for longer periods of time and reducing the number of breaks. Other likely responses are to simplify the output to be produced so that fewer tasks are required, or to take shortcuts to accomplish their tasks.

In experimentation cycles, these responses to shorter durations of enactment phases will have less far-reaching consequences on the quality and innovativeness of team outcomes. Since team output in experimentation cycles is provisional, output that is simplified and of a lower quality is more acceptable than if the team was producing output that was to be final. Errors committed during experimentation cycles can even be beneficial to team performance, as these allow team members to discover potential problems earlier rather than later when production of the team's final output has already begun.

In contrast, low-quality output during the enacting phase of validation cycles has more immediate consequences on team performance. Because team activities are directed towards completing the team's final output, output quality is a high concern and errors will need to be rectified. Errors thus result in delays as work is replicated to rectify these errors, which in turn compresses the time available for future activities, increasing the chances of more errors and even further delays. Furthermore, project requirements of output quality constrain the degree to which its work can be simplified.

Proposition 2a: The duration of enacting phases in experimentation cycles is negatively related to the quality and innovativeness of team outcomes.

Proposition 2b: The duration of enacting phases in validation cycles is positively related to the quality and innovativeness of team outcomes.

Duration of Reviewing Phases

In review phases, shorter review durations will be associated with less in-depth processing of information (Kelly & Loving, 2004). This approach to information processing is partly influenced by the scarcity of temporal resources, but also by the corresponding psychological effects of this scarcity. Shorter durations will increase team members' need for cognitive closure (Kruglanski & Freund, 1983; Kruglanski & Webster, 1996), which increases their preference for unambiguous outcomes even if these are not optimal.

In experimentation cycles, the tendency for teams to engage in less in-depth information processing is likely to result in the team deciding on sub-optimal solutions, resulting in poorer outcomes for the team (West, 2002). This is because interpreting the implications of feedback in these cycles is a complex decision-making process that benefits from more in-depth information processing due to the equivocality of choices available to the group.

In contrast, the negative impact on performance from less in-depth information processing during the review phases of validation cycles will be weaker. This is because information processing requirements in the review phases of validation cycles are lower. As discrepancies between the quality of the team outcomes and project requirements (which are less ambiguous at this point) are more easily interpreted, feedback and the corresponding implications about subsequent actions required to improve outcome quality are more concrete and less equivocal. Additionally, teams are also likely to be familiar with the actions required to address these discrepancies because these actions involve modifying the properties of components that have already been built rather than building a component from scratch.

Proposition 3a: The duration of reviewing phases in experimentation cycles is positively related to the quality and innovativeness of team outcomes in both experimentation and validation cycles.

Proposition 3b: This positive relationship between the duration of reviewing phases and team performance will be stronger in experimentation cycles than validation cycles.

Discussion

In this research, I examined cycles of planning, enacting, and reviewing activities in case studies of two IMD teams in order to develop insights into team innovation processes. Models of team innovation in the extant literature do not sufficiently account for the iterative, dynamic nature of team innovation processes. This gap in our theoretical models of team innovation is problematic because innovation processes in teams do not unfold in a smooth, predictable manner and need to be actively managed. Without an understanding of how these processes unfold to inform theory, evidence-based prescriptions to managers about how the chaotic and messy process of innovation can be more effectively managed will be limited.

My analysis of the activity patterns in two IMD teams revealed two distinct activity cycles consisting of unique configurations of planning, enacting, and reviewing activities. The first, experimentation cycles, were utilized by the teams to discover project requirements, scope, and constraints through trial and error. The second type of cycle identified, validation cycles, enabled the teams to align their final outputs with project requirements through incremental modifications. The manner in which the planning, enacting, and reviewing activities manifested in each type of cycle were elaborated on in detail.

I then drew on these findings to develop a number of testable theoretical propositions about the effects that different durations of planning, enacting, and reviewing activity phases in each type of cycle will have on team performance. These propositions illustrate how findings from the longitudinal study of iterative processes can deepen theoretical models of team innovation, and they can be used to inform future research to extend these models further.

One implication of the relationships between the duration of activity phases and team performance that can be inferred from the findings in this study is that there is an ideal-type rhythm for each cycle based on the activities that team members are performing. Experimentation cycles would be ideally characterized by short intervals of planning and enacting phases punctuated by longer intervals of reviewing phases, whereas validation cycles would be characterized by longer intervals of planning and enacting phases and shorter intervals of reviewing phases. This idea could be tested in future research.

Another implication extends to the literature on temporal entrainment in teams. Teams have been found to be barraged by multiple rhythms that stem from organizational pacers, such as project deadlines, customer schedules, and external shocks (Ancona & Chong, 1996; Ancona & Waller, 2007). While the prior research has largely focused on exogenous rhythms, this

research emphasizes the endogenous rhythms that are generated internally by the activities required to accomplish project goals. Emphasizing these endogenous or internal rhythms reinforces the idea of teams having to perform a “dance of entrainment” (Ancona & Waller, 2007, p. 117) in order to be effective. It also raises further questions about the repertoire of steps available for teams performing this dance. For instance, teams tend to be conceptualized as being engulfed by, and having to adjust project schedules to keep pace with, varying exogenous rhythms. When one recognizes that team activities also generate endogenous rhythms that can affect team performance, the question then becomes one of how they are able to keep both exogenous and endogenous rhythms in sync. What are the strategies available to them? Which strategies are more or less effective and when? These questions can also be examined in future research.

From a practical standpoint, propositions about the relationship between the duration of activity phases and team performance can remind managers about the potential tradeoffs when making decisions about allocating scarce temporal resources across different activities. As organizations and teams are increasingly faced with having to develop and sustain a time advantage in order to survive (Gibson et al., 2007), this research suggests that teams should not blindly operate at a higher pace across all kinds of activities, but that greater discernment about what activities to speed up, maintain, and slow down can be beneficial to overall project team performance.

A limitation of this research is that the sequences of planning, enacting, and reviewing activities were not captured as they occurred. Since the exact moments when transitions from one activity phase to another occurred were not recorded, recursive patterns within cycles, interruptions, and incomplete cycles could not be represented. In order to do so, activities of

team members would have needed to be captured on a more granular time-scale, which was impractical in the field setting. Future research could investigate these aspects of activity cycles in more controlled settings (e.g., Brett et al., 2004; Stachowski et al., 2009) and with a greater emphasis on their temporal configurations.

Another concern might be that the generalizability of findings in this research to broader theory might be limited by the idiosyncratic product development process (i.e., scrum methodology) adopted by the focal teams. This concern would be valid if this research attempted to draw conclusions about *when* certain activities occurred, since different development processes in various fields would affect the timing of these activities. However, as this research was focused on *what* and *how* the studied activities occurred, the generalizability of findings in this research to theory is not adversely affected by the unique development process adopted by the teams in this case study.

In summary, this research reveals two different pathways by which planning, enacting, and reviewing activities in team innovation processes unfold. Discovery-oriented experimentation cycles are characterized by a lower need for collective planning, an emphasis on the speed of completion over the quality of outputs, and a greater need for interpreting ambiguous feedback. Correction-oriented validation cycles, in contrast, are characterized by a higher need for collective planning, an emphasis on the quality of outputs over the speed of completion, and review phase activities involving verification that team outputs meet project requirements.

Although prior research shows that team processes are critical to team innovation (Hulsheger et al., 2009), these dynamic processes are still enclosed in a black box because prior research tends to conceptualize these as static phenomena (Cronin et al., 2011). By

conceptualizing team innovation processes as dynamic and examining the activity patterns that underlie these processes, this research sheds light on the underlying patterns of planning, enacting, and reviewing activities that teams engage in to produce innovative outcomes. These findings are an initial but necessary step towards developing theories that account for how temporal variables that relate to the different ways of structuring team processes (Ancona et al., 2001) can affect innovation outcomes. This contribution is illustrated in the theoretical propositions presented about the effects that the duration of planning, enacting, and reviewing activity phases have on the innovativeness and quality of team outcomes.

CHAPTER 3: AN EMPIRICAL TEST OF THE TEMPORAL CHARACTERISTICS OF ITERATIVE PROCESSES ON THE PERFORMANCE OF CREATIVE PROJECT TEAMS

In Chapter 2 of this dissertation, I introduced the idea of an ideal rhythm of plan-enact-review phases for experimentation and validation activity cycles as creative project teams iterated. The second study of this dissertation explores this idea further by examining the relationship between temporal characteristics of the iterative process, prototyping performance, and team outcomes. These aspects of the iterative process are examined together with the mediating effects of team interactions, team emergent states, and the quality of coordination. Because experimentation cycles are crucial in orienting teams through the “fuzzy front end” of creative tasks, I have selected to focus first on these cycles instead of validation cycles. The objective of this research is twofold. First, I aim to investigate how structuring the duration of transition phases affect iterative performance in terms of improvements in prototype quality. Time is a finite resource that can neither be stored nor replenished (Bluedorn, 2002). A deeper understanding of how different ways of allocating time across the multitude of team activities affects team functioning can inform how teams can gain a time advantage over their competitors. My second objective is to examine how this rate of improvement in prototype quality over time affects team output quality on a creative task.

To investigate these effects, a lab experiment was conducted where groups of participants performed a creative, open-ended task in which they were to build a floating vessel from Lego pieces according to certain specifications. Participants were instructed to iterate on their designs before collaborating to design and build their group’s vessel.

Although group activities were categorized according to a plan-enact-review framework in the first study, an action-transition framework (Marks, Mathieu, & Zaccaro, 2001) is adopted in this study because activities in ad-hoc groups often do not follow an ideal sequence of planning, enacting and reviewing (Tschan, 2002; Weingart, 1992) – teams may iterate between review and planning activities such that they blend into one combined phase, or activities may occur out of sequence. Structuring the iterative process in terms of action-transition phases allows for the fluid interchange between reviewing and planning activities so that team interactions still retain an element of realism from the perspective of experimental participants. At the same time, this framework allows for these iterative processes to be replicated and systematically studied in the behavioral lab.

The concept behind this framework is that groups perform in temporal cycles of goal-directed activity called “episodes” (Weingart, 1992; Zaheer, Albert, & Zaheer, 1999). Episodes are distinct segments of time in which performance accrues and feedback is available (Mathieu & Button, 1992). Within performance episodes, teams may be engaged in different types of taskwork at different phases of task accomplishment. In some phases, they are focused on activities related to accomplishing goals, while in others they are focused on reviewing past performance and planning for future action. These phases are referred to as “action” and “transition” phases respectively. The iterative process that creative project teams adopt as they are prototyping can therefore be considered as recurring sequences of action-transition phases.

Three conditions are examined: the first condition consists of structured transition phases with long durations; the second condition consists of structured transitions with short durations; and the third condition is a control condition where the duration of transition phases are unstructured and participants are free to decide how much time to spend on action and transition.

Literature Review and Hypothetical Model

The emphasis in this study is the effect of temporal characteristics of iterative processes on prototyping performance and the subsequent effects on team output quality on a creative task. Examined through the lens of an input-process-output (IPO) model of team performance (Hackman, 1987; McGrath, 1984; Steiner, 1972), related research on the performance of such teams in the team innovation literature has largely focused on the role of inputs such as norms (Caldwell & O'Reilly, 2003), group composition (West & Anderson, 1996; Woodman, Sawyer, & Griffin, 1993), and diversity (Cady & Valentine, 1999; Dahlin, Weingart, & Hinds, 2005; Gibson & Gibbs, 2006). However, mediating processes are also a critical influence on team performance (Marks et al., 2001; Woodman et al., 1993). These mediating processes include team emergent states and team members' interdependent acts that convert inputs into outputs (Marks et al., 2001). Emergent states refer to the cognitive, motivational, and affective states such as team cohesion and team climate that emerge from the interaction processes in teams. For example, studies have found vision, participative safety, support for innovation, and task orientation to be positively related to innovation (N. R. Anderson & West, 1998; Mathisen, Einarsen, Jorstad, & Bronnick, 2004; Ragazzoni, Baiardi, Zotti, Anderson, & West, 2002).

The interdependent acts that convert inputs into outputs refer to both taskwork as well as the interactions that enable work to be performed smoothly. These processes have been characterized both as interactions between team members, such as communication (Ancona & Caldwell, 1992; Keller, 2001), as well as the quality of teamwork (Hoegl & Parboteeah, 2007; Hoegl, Weinkauff, & Gemuenden, 2004) and coordination (Taggar, 2002).

Static concepts of process are adequate in many circumstances, especially when the process is relatively invariant over time. In the case of creative project teams, however,

mediating processes follow an unpredictable trajectory because the ambiguity inherent in their projects needs to be resolved over time. For example, the IMD teams discussed in the earlier chapters of this dissertation had to go through a process of trial-and-error in order to clarify project goals and specifications. Hence, the behaviors, activities, and emergent states are difficult to predict at the onset of team performance. The process of transforming inputs to outcomes in such contexts thus cannot be adequately represented as a static phenomenon, but as a dynamic process that unfolds over time (Mohr, 1982).

Iterative Processes in Creative Project Teams

Tasks in creative project teams are typically accomplished in an iterative fashion. As discussed earlier, teams iterate as a way to experiment, engage in trial and error, or introduce incremental improvements to their outputs. While these processes are conceptually distinct, they can be collectively represented as recurring action and transition phases. According to Marks and colleagues (2001), action phases are periods of time when teams are engaged in acts that contribute directly to goal accomplishment (i.e., taskwork). Transition phases are periods of time when teams focus on evaluation and/or planning activities to guide their accomplishment of team goals. This representation of iterative processes as recurring phases of action and transition phases can be contrasted to processes that unfold in a more ordered and linear fashion where actions are performed according to a pre-determined plan with infrequent changes over time.

The crucial role of iterative processes in innovating teams has been documented in this dissertation and other work (Buxton, 2007; Dow, Heddlestone, & Klemmer, 2009; Schrage, 1999). As shown in the first part of this dissertation, project teams iterate to gather insights into project requirements, constraints, and design specifications, explore the feasibility of solutions through provisional outputs (e.g., prototypes), and incrementally adjust their output to meet

project requirements. Furthermore, the prototypes produced by teams while iterating act as boundary objects (Carlile, 2002) which help to reduce ambiguity and develop shared mental models with team members and stakeholders. Additionally, the experience gained from producing these prototypes also enhances team members' intuitive understanding of the solution under development (Eisenhardt & Tabrizi, 1995).

Consistent with the purpose served by these iterative processes, researchers have found the frequency of iteration to be positively associated with innovative performance both at the individual (Dow et al., 2009) and team levels (e.g., Dow, Fortuna, Schwartz, Altringer, & Klemmer, 2011; Eisenhardt & Tabrizi, 1995). However, this is likely to be an inverted U-shaped relationship because excessive iterations can be costly, not to mention frustrating and demoralizing to team members (Eppinger, 2001), leading to delays and a higher frequency of errors. Research on iterative processes by management scholars have therefore primarily focused on the efficient organization of this process in terms of the optimal frequency and timing of iterations (e.g., Thomke, 2003) by developing models that account for the benefits of timely information against the cost of acquiring it.

In this paper, I examine these iterative processes by first investigating how structuring the duration of transition phases affect the rate of improvements in prototype quality during the prototyping phase. Specifically, I propose that transition phases with longer transitions structured will lead to steeper rates of improvement in prototype performance. In addition, I shall test the mediating role of error statements in this relationship (Figure 1).

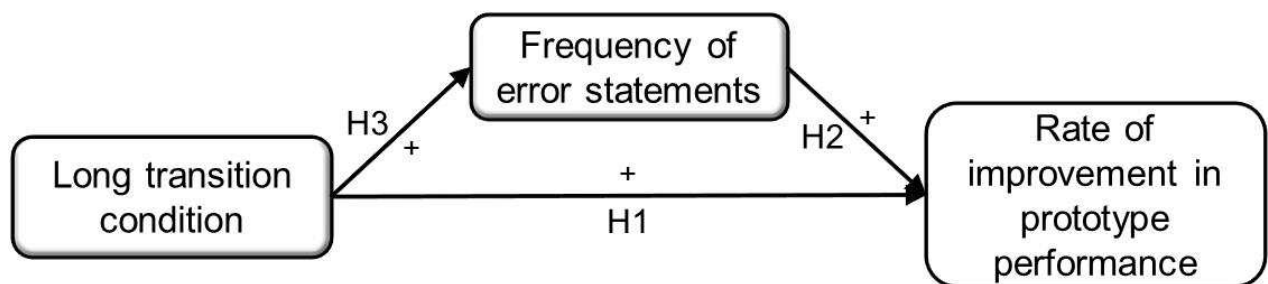


Figure 1: Hypothesized relationships between transition phase duration, frequency of error statements, and the rate of improvement in prototype performance.

The second model examines how trajectories of prototype performance affect team performance in terms of the quality of team output. Specifically, I propose that steeper rates of improvement in prototype performance will lead to higher quality outputs via a more positive group atmosphere and better quality of coordination (Figure 2).

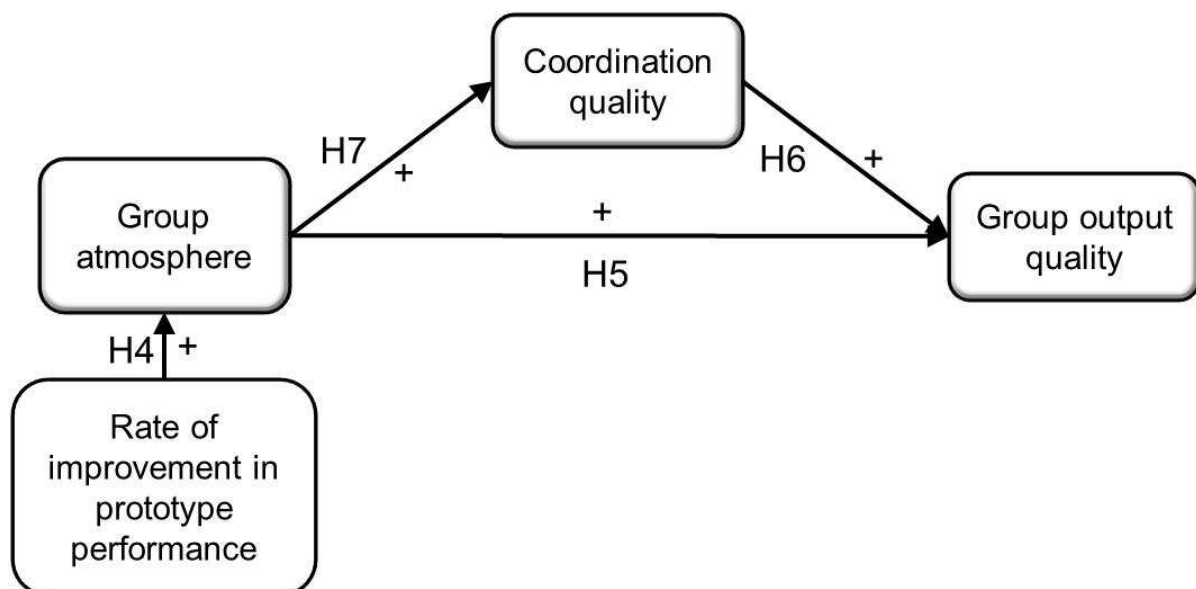


Figure 2: Hypothesized relationships between the rate of improvement in prototype performance, group atmosphere, coordination quality, and team output quality.

Effect of Structured Transitions on Prototype Performance

Despite the attention to iterative processes in the management and engineering design literature (Dow et al., 2011; Erat & Kavadias, 2008; Loch, Terwiesch, & Thomke, 2001; Thomke, 2003; Thomke & Bell, 2001), this body of work, with a few exceptions (e.g., Dow et al., 2011; Dow et al., 2010), does not consider how prototyping performance can be improved upon. In this section, I examine the importance of discussing errors for prototyping performance, and the role that the duration of transition phases has in facilitating or hindering such interactions.

When working under time scarce conditions, prior research has shown that groups become more focused on task completion. For example, researchers have found that in comparison to groups with a greater abundance of time, groups under time scarce conditions worked at a faster rate, engaged in more task-oriented interactions, and correspondingly less interpersonally-oriented interactions (Karau & Kelly, 1992; Parks & Cowlin, 1995). Thus in the context of prototyping under time scarce conditions, teams would exhibit a tendency to commit more time to activities related to building up their prototypes at the expense of transition activities such as planning and reviewing.

Unfortunately, this preference for task completion can be detrimental to prototyping performance. During prototyping, even though feedback from testing informs team members about the viability of an idea, this information does not necessarily lead to clear choices about future actions. The tests may indicate that an idea does not work, but it neither reveals why nor how the problem could be resolved. These insights emerge through interactions with one another such as brainstorming, sharing and combining knowledge, drawing on tacit knowledge, framing

and reframing perspectives, and correcting errors. Without sufficiently engaging in these interactions, improvements in prototype performance are likely to involve superficial modifications, rather than more fundamental changes that affect how components are configured and interrelated.

This preference for task completion over interpersonal interactions exhibited by groups can be mitigated by structuring the duration of action and transition phases to protect the temporal space for groups to engage in reviewing and planning activities. However, the effectiveness of such an intervention is also contingent on the duration of these transition phases.

Longer transitions will afford teams more opportunities for interaction. Such teams will subsequently be more likely to brainstorm, share and combine knowledge, draw on tacit knowledge, reframe perspectives, identify and correct errors. These interactions contribute to a higher likelihood of experiencing radical improvements in prototype performance rather than incremental improvements. In contrast, teams with shorter transition times will not have as many opportunities for team members to interact, resulting in incremental rather than radical improvements.

H1a: Rates of improvement in prototype performance will be steeper in teams with longer transitions structured than those with unstructured transitions.

H1b: Rates of improvement in prototype performance will not be different between teams with shorter transitions structured and those with unstructured transitions.

Mediating Role of Discussing Errors

There is widespread consensus that learning is instrumental to success for both groups and organizations (Argote & Miron-Spektor, 2011; Edmondson, 2002). While learning can occur

through various sources (c.f. Argote & Kane, 2003), an important source of learning is from errors, mistakes, and failures which is critical to success, particularly in the context of innovation. Indeed, a common theme in the innovation literature is that failures can be more important than success because these experiences are the fodder for successful innovation (Leonard-Barton, 1995; Nonaka & Takeuchi, 1995; Sitkin, 1992; Starkey, 1998). By discussing errors, in product development for example, Dougherty (1992) found that the inability to discuss errors in a constructive fashion led to failed products. When errors are discussed, Edmondson (1999) argues that mistaken assumptions are allowed to be surfaced, brainstorming is invited which leads to more ideas, and the chances of unique information being shared are increased. In contrast, focusing on “*what went right*” instead of “*what went wrong*” reinforces rather than correct biases (Houghton, Simon, Aquino, & Goldberg, 2000; Schwenk, 1984; Van Knippenberg, Van Knippenberg, & Van Dijk, 2000).

Discussing errors therefore allows teams to engage in more in-depth information processing directly related to the problem at hand. Teams that discuss errors more frequently will also be more likely to address major design flaws in their prototypes that can lead to significant improvements in prototype performance. In contrast, teams that do not process information with the same depth and rigor are more likely to focus on incremental improvements without addressing major flaws, resulting in less significant improvements in prototype performance.

H2: The number of error statements is positively associated with the rate of improvement in prototype performance.

The model predicts that the number of error statements discussed will be higher in teams with longer transitions structured than those without transitions structured. However, this

relationship is not due to the greater availability of time because the fear of embarrassment causes people to be averse to discussing errors (Edmondson, 1999). Rather, this relationship between the availability of time and how people interact is attributed to people's psychological need for closure.

The need for cognitive closure refers to people's "desire for a firm answer to a question and an aversion toward ambiguity" (Kruglanski & Webster, 1991, p.264). This need will "prompt activities aimed at the attainment of closure, bias the individual's choices and preferences toward closure-bound pursuits". People who experience a high need for closure will therefore display considerable cognitive impatience characterized by judgment leaps on the basis of inconclusive evidence and rigidity of thought. When people have a high need for closure, they are less likely to discuss errors because doing so challenges the validity of existing assumptions and also threatens the relevance of existing plans and mental models without necessarily providing a solution (Edmondson, 1999). They will instead be more focused on their successes (e.g., what went right), or they could engage in conversations that are non-task related (e.g., the weather, sports, current events, common friends).

Prior research has found that time pressure increases the need for cognitive closure (Kruglanski & Freund, 1983). Therefore, structuring transition phases with longer durations decreases experienced time pressure and correspondingly reduces the need for cognitive closure. The lower need for closure coupled with the creation of an environment dedicated to reviewing and planning is likely to reduce people's general aversion to discussing errors and increase their propensity for discussing errors.

On the other hand, structuring short durations of transition phases heightens the need for cognitive closure due to the higher time pressure experienced. People in these teams will

therefore be more likely to engage in activities aimed at attaining closure, such as honing in on a solution even if they know that solution to be flawed. Compared to teams with unstructured transition phases, they will be just as unlikely to discuss errors.

H3a: The number of error statements will be higher in teams with longer transitions structured than those without transitions structured.

H3b: The number of error statements will not be different between teams with shorter transitions structured and those without transitions structured.

Effect of Prototype Performance on Team Outcomes

Although researchers have focused on the benefits of iterative processes particularly in the domain of innovation, one aspect of this process that has not received as much attention is the effect of these processes on team functioning². Even though prototypes are provisional team outputs produced as part of the iterative process, their performance also affects emergent states which represents members' attitudes about their work group environment (Jehn, Rispens, & Thatcher, 2010).

The emergent state that this study focuses on is the group's atmosphere which reflects the positive attitudes and cognitions of a group's members about levels of trust, respect, and commitment in their group (Jehn & Mannix, 2001; Jehn et al., 2010). Drawing on the idea of efficacy-performance spirals (Lindsley, Brass, & Thomas, 1995), I argue that the rate of improvement in prototype performance provides feedback about the team's prospects which then affects levels of trust, respect, and commitment to the group. Steeper improvements in prototype

² Gerber & Carroll (2012) is a notable exception.

performance are positively associated with group atmosphere because the positive feedback increases self- (Shea & Howell, 2000) and collective-efficacy (Katz-Navon & Erez, 2005), team members' identification with the team (Ashforth & Mael, 1989; Tajfel & Turner, 1979) and their commitment to the team's success (Locke, Latham, & Erez, 1988). Increases in these positive states will therefore be reflected in corresponding improvements in group atmosphere.

Although the relationship between the rate of improvement in prototype performance and group atmosphere is likely to be reciprocal (Lindsley et al., 1995), I consider the directional relationship of improvements in prototype performance on group atmosphere because the phenomena of interest in this study is group atmosphere prior to final performance rather than its development over time.

H4: Steeper rates of improvement in prototype performance increases group atmosphere.

The body of research on the link between team emergent states and performance has consistently demonstrated a positive relationship between the two. For instance, studies have shown team performance to be positively associated with collective efficacy (Lindsley et al., 1995), trust (Salas, Sims, & Burke, 2005), cohesion (Dailey, 1980; Mullen & Cooper, 1994), and team identification (Van Der Vegt & Bunderson, 2005). Although these states are theoretically distinct, they generally reflect people's emotional attachment to the collective. This emotional attachment motivates people to engage in the behaviors and interactions that are otherwise effortful, but contribute to the performance of the collective (Bergami & Bagozzi, 2000). Similarly, a more positive group atmosphere, in the form of higher levels of trust, respect, and commitment between team members, will improve team performance because of a higher incidence of these functional behaviors and interactions.

The form of team performance that is considered in this study is the quality of the team's output in terms of the acceptability of this output to those who will receive and review it. Because of the multi-faceted nature of this criterion for creative project teams that are responsible for outcomes that are both novel and useful (Amabile, 1996), team output quality in this study is considered in terms of novelty, functional performance, and aesthetic appeal.

H5: Higher levels of group atmosphere increases team output quality.

Mediating Role of Coordination Quality

I propose that the positive relationship between group atmosphere and team output quality is mediated by the quality of coordination in the team. Coordination is the management of interdependencies between participants (Malone & Crowston, 1994) such that individual contributions are harmonized and synchronized (Brannick, Prince, Prince, & Salas, 1995; Larson & Schaumann, 1993; Tannenbaum, Beard, & Salas, 1992). The importance of coordination quality on team performance on interdependent tasks is widely acknowledged (Steiner, 1972). Specific to teams engaged in creative projects where there is a high degree of ambiguity and uncertainty, prior research on software teams found coordination breakdowns to be a key factor in project outcomes (e.g., Curtis, Krasner, & Iscoe, 1988; Faraj & Sproull, 2000; Kraut & Streeter, 1995; Walz, Elam, & Curtis, 1993). Similarly, Hoegl and Gemuenden (2001) found teamwork quality, of which coordination is a key component, to be related to team performance.

Given the interdependent tasks that team members are engaged in, it is not surprising that coordination quality plays a crucial role in influencing team outcomes. Poor coordination can result in delays from team members having to wait on one another, or having to redo work if one or more components of the team's output is misaligned with the other parts. In contrast, a well-

coordinated team will face fewer delays and can spend more time refining the quality of their output and ensuring that it meets project requirements. Based on this reasoning and consistent with the findings from prior research, I hypothesize that coordination quality will be positively associated with the quality of team outputs.

H6: Higher quality of coordination quality will increase the quality of team outputs.

Although managing interdependencies between team members can be facilitated by certain design elements such as routines, protocols, and schedules (c.f., Okhuysen & Bechky, 2009), coordination also occurs spontaneously as mutual adjustment (Thompson, 1967) and teamwork (Hoegl & Gemuenden, 2001; Van de Ven, Delbecq, & Koenig, 1976). This process of coordination is characterized by spontaneous interaction amongst participants and depends on the frequency, timeliness, accuracy, and problem-solving nature of communication (Gittell, 2002) rather than scripted protocols for action. In creative projects where tasks are interdependent, and where outcomes and the means of producing these outcomes are also uncertain, this spontaneous form of coordination is expected to be effective because participants are afforded greater flexibility and adaptability in responding to unknowns (Gittell, 2001, 2002), whereas routines and protocols rely on standardization.

Because of the highly social nature of this form of coordination, group emergent states, such as a positive group atmosphere, play an important role in facilitating coordination in situations where interdependencies are high by increasing cooperative behaviors (e.g., help giving) amongst members while decreasing dysfunctional group behaviors such as social loafing (Latané, Williams, & Harkins, 1979). The positive attitudes and cognitions in question can be represented using Jehn and colleagues (Jehn & Mannix, 2001; Jehn et al., 2010) positive group

atmosphere construct which captures members' levels of trust, respect, and commitment to the team.

Commitment to a group is a motivational attitude regarding the group that positively influences members' satisfaction with the group and performance (Mannix & Jehn, 2004; Marks et al., 2001). When members are committed to a group, they are motivated to act in the broader interests of the group rather than just their own. This prioritization of collective goals over individual sub-goals will lead to a higher willingness amongst members to engage in cooperative behaviors instead of those that are more self-serving (Brief & Motowidlo, 1986; Mowday, Porter, & Steers, 1982; O'Reilly & Chatman, 1986). The higher degree of cooperative behaviors and lower incidence of selfish behaviors will in turn improve coordination quality in the team.

A high level of trust for one another will also increase cooperative behaviors in the team even if the benefits to themselves are not immediately clear because there is a high expectation of future reciprocity (De Cremer & Van Lange, 2001; Jones & George, 1998). Cooperative behaviors will also be spurred when trust is high because team members will not feel inadequate or threatened to be indebted another person when they seek help (Brehm, 1966; Greenberg, 1980; Hatfield, Walster, & Berscheid, 1978; Nadler, 1991). This supportive environment for help-seeking subsequently increases other members' awareness of opportunities for cooperative behavior (S. E. Anderson & Williams, 1996). Additionally, team members will also be more willing to accede to requests for help when trust is high because such requests are more likely to be perceived as genuine rather than as attempts at free-riding.

In contrast, when team members do not have a high level of trust for one to infer, they are more likely to infer that other members have sinister intentions especially in uncertain situations, such as when goals are ambiguous (Simons & Peterson, 2000). To protect themselves, they are

likely to behave in a way that benefits themselves at the expense of the group resulting in less cooperative behavior, a higher propensity for social loafing, and thus poorer coordination.

Finally, a high level of respect is also expected to increase cooperative behaviors amongst group members. Respect, in this study, is the extent to which group members hold one another in high regard. It stands to reason that people are likely to reciprocate with respect when they themselves feel respected by others. To the extent that respect communicates symbolic information about people's standing within the group (Smith & Tyler, 1997; Tyler & Smith, 1999), high levels of respect will indicate that group members feel included and accepted by the group. Such feelings of inclusion subsequently engender higher levels of commitment to group goals and cooperative behaviors (De Cremer, 2002) which improve the quality of coordination.

In addition to increasing peoples' propensity for cooperative behaviors, a positive group atmosphere also improves coordination by reducing social loafing. Social loafing refers to the withholding of individual effort when performing in groups as compared to when performing alone (Latané et al., 1979), and is related to concepts such as shirking and free-riding (Kidwell & Bennett, 1993). In interdependent groups where the synchronicity of contributions is critical, such behaviors will have an adverse impact on coordination. This coordination loss was first documented by Ringelmann (Kravitz & Martin, 1986) in groups performing an additive task (i.e., pulling a horizontal load), and more recently by Marotto, Roos, and Victor (2007) in an orchestra where musicians are reciprocally interdependent.

High interdependencies in groups has been found to result in a greater extent of social loafing (Liden, Wayne, Jaworski, & Bennett, 2004; Pearce & Gregersen, 1991) because individual contributions are less identifiable (Harkins & Petty, 1982; Weldon & Gargano, 1985; K. D. Williams & Karau, 1991) and also because of the corresponding difficulty in evaluating

individual contributions (Harkins, 1987; Karau & Williams, 1993). This difficulty in identifying, monitoring, and measuring performance is exacerbated the more unstructured or ambiguous the task is (Jones, 1984), which is typically the case in creative projects.

As a case in point, delays in the Interactive Media Development setting that was observed in the first study of this dissertation could be caused by a lack of effort on the part of the software engineer or by uncooperative team members who did not proactively provide important information that could have reduced the number of revisions the software engineer had to make in coding. While it may be possible to identify the parties involved in the task, having to assign blame for the delay is more difficult because the complex interdependencies between these parties complicates performance measurement and monitoring.

A positive group atmosphere consisting of trust, respect, and liking is likely to mitigate the higher propensity for social loafing attributed to higher task interdependencies because members will be more committed to the group's success. The lower propensity for social loafing subsequently reduces coordination losses amongst group members.

H7: Higher levels of group atmosphere will increase coordination quality.

Method

Participants and Design

A total of 195 participants forming 65 groups were recruited from the general population surrounding a mid-Atlantic university in the United States. Of these 65 groups, 3 groups were removed for not following the instructions and 3 groups were removed because of technical problems with the recording equipment. The final sample thus contained 59 groups. Of these, 42.56% of the participants described themselves as Caucasian, 33.33% described themselves as

Asian, 13.85% described themselves as African American, 8.21% described themselves as Hispanic or belonging to another ethnic group, and the remaining 2.05% did not disclose their ethnicity. Participants were each paid \$15 for the 90-minute experiment, and the best performing team earned an additional \$50 gift card per person.

Teams of three were formed by random assignment of participants in each session to a team. These teams were then randomly assigned to one of three conditions. The experimental task consisted of two parts. The first part involved team members building prototypes of a floating vessel, testing these prototypes, and discussing the performance of these prototypes, while the second segment involved the team collaborating to build their final design.

Across conditions, teams were allotted a total of 36 minutes to complete three prototypes (Table 4). Teams in the Short Transition (ST) condition had 10 minutes for building and 2 minutes for discussing; teams in the Long Transition (LT) condition each had 8 minutes for building and 4 minutes for discussing; finally, teams in the Control (CT) condition were free to determine how much time to spend on three cycles of building and discussing as long as these were completed within 36 minutes. The duration for discussion was determined from pre-tests where teams without transitions structured spent an average of 2 minutes for discussion. Similarly, teams in the CT condition in this sample spent an average of 1.95 mins on discussion. Hence, for longer transitions, the duration for discussion in the LT condition was doubled to 4 mins. Participants went through 3 iterations because it was found during pre-testing that participants began to become disengaged after the third iteration.

Table 4: Durations of Building and Discussion Phases Across Experimental Conditions

Conditions	Prototyping Round 1		Prototyping Round 2		Prototyping Round 3		Final Design
	Build	Discuss	Build	Discuss	Build	Discuss	Build
Long Transition	8 mins	4 mins	8 mins	4 mins	8 mins	4 mins	9 mins
Short Transition	10 mins	2 mins	10 mins	2 mins	10 mins	2 mins	9 mins
Control	36 mins to complete 3 prototypes						9 mins

Experimental Task

The experimental task involved participants working in groups of three to design and build a floating vessel with Lego blocks during a ninety-minute laboratory session (Appendix A). This was an open-ended, creative task where designs were scored according to a set of complex scoring criteria (see Appendix B). The criteria consisted of functional characteristics that includes the number of stainless steel ball bearings that vessels can contain without sinking and the height that vessels can withstand in a vertical drop; structural characteristics that includes the weight, height, and shape of vessels; aesthetic appeal that includes color patterns and symmetry; and the overall novelty of the design.

The scoring criteria were complex in that scoring high on one criterion involved making trade-offs on others. For example, a vessel designed like a box was likely to fare well on the vertical drop test, but would score poorly on aesthetics. Although it was possible for teams to simultaneously maximize their points on multiple criteria, such solutions were not obvious and were difficult to obtain.

This task was appropriate for examining my hypotheses for the following reasons. First, multiple indicators of both objective (e.g., number of ball bearings contained, drop height,

weight) and subjective performance (e.g., symmetry, attractiveness) were used. Second, this was an open-ended task for which there can be multiple ways of accomplishing outcomes. Third, even though there were objective criteria of performance, it was not obvious to participants how a proposed design might have met these criteria without actually producing and testing the design. In this respect, these three features of the task replicated key characteristics of creative group tasks. Another reason for selecting this was that no special technical expertise or training was required to accomplish the goals of these tasks. Although having a member with a strong technical background or familiarity with Lego blocks might have conferred an advantage, this advantage would have been attenuated by the subjective criteria of performance. Finally, the task was a team activity since there were both task and outcome interdependence amongst group members as each person's outcomes was dependent on the contributions of other team members. This task was thus similar to those used by researchers to simulate the open-ended tasks faced by knowledge workers without requiring the application of specialized expertise (c.f., Woolley, 2009) allowing for the use of ordinary participants in a laboratory.

Procedure

Each team worked alone in a private room set up with a table, three chairs, three sets of Lego blocks with the same type and number of pieces, and a timer. All teams were videotaped with the knowledge and consent of all participants, and conversations were transcribed for the purposes of coding and analysis. An overview of this sequence of building, testing, and discussion is shown in Figure 3.

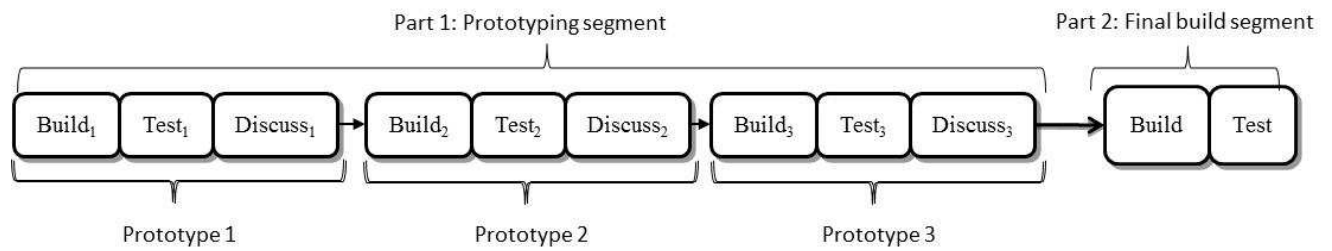


Figure 3: Overview of building, testing, and discussing phases in experimental procedure

The task was completed in two segments. The first segment involved prototype-building, where participants would sequentially build, test, and discuss the performance of their prototypes. For the first segment, teams were briefed about the point scoring system and the sequence of activities for the experiment. Verbal communication between participants during the building phase was prohibited. However, those in the CT condition were allowed to discuss when to end the building phase. This restriction on communication was reinforced by having participants wear medical face masks while building, under the pretext of simulating a manufacturing clean room environment. They then began the first phase of building after this briefing was completed.

For teams in the ST and LT conditions, the timer was set to 10 minutes and 8 minutes respectively. For teams in the CT condition, the timer was set to 36 minutes. These teams were also instructed to stop the timer and alert the experimenter by knocking on the wall partition when they were ready to test their prototypes. In addition, the experimenter also informed teams in the CT condition of the time remaining in 5 minute intervals by monitoring the amount of time elapsed with a second timer kept by the experimenter.

The testing procedure for prototypes built by each member in the preceding phase was carried out in the following sequence. The height and weight of each design were first measured

and then filmed from different angles. Each vessel was then placed in a container of water to test their buoyancy. If the vessel did not sink, half-inch stainless steel ball bearings were added until water seeped into the vessel and the balls were wet. The vessel was then removed from the container of water and dried. This procedure for testing buoyancy was then repeated for the second and third vessels. After the buoyancy test was conducted for each member's design, the experimenter then proceeded to conduct the drop test on the design.

The drop test was conducted by dropping prototypes head first starting from a height of 1 foot. If it survived the fall, it was redropped at consecutively higher height in increments of 1 foot up to 6 feet or until it broke apart. The pieces were then collected in a container and placed in front of each participant.

After these tests were completed, the experimenter then announced the performance of each prototype on each of these tests and briefed participants on the instructions for the discussion phase. After this briefing, the timers were reset to 2 minutes and 4 minutes for the ST and LT condition respectively. Participants were then instructed to remove their face masks for the discussion phase. After the allotted time for discussion was over, the experimenter then entered the room and instructed participants to begin building the second prototype under the same rules as before. In the CT condition, the time remaining was not reset and the timer was restarted from when it was stopped during the building phase. Unlike the ST and LT conditions, participants in the CT were instructed to raise their face masks and begin building when they had completed the discussion phase. This sequence of building, testing, and discussion were completed twice more for a total of 3 cycles.

To ensure that teams in the CT condition completed 3 cycles, reminders were given at the start of the first two discussion phases that they should allocate enough time for 3 rounds of

discussion. They were also told that it was mandatory for them to stop building by the final minute in order to have sufficient time for the third round of discussion.

After the third round of discussion, participants were informed that they had completed the first segment of the experiment and were to begin the second segment where they were required to collaboratively build the final design of their vessel. They were then instructed to complete the first survey. In the meantime, the experimenter replaced the three sets of Lego pieces in the room with one new set that contained the same types and number of pieces as before. After completing the first survey, participants were informed that they had 9 minutes to work together to complete their final design and the timer was reset and started to begin the second segment of the experiment. When time was up, the experimenter returned to the room and instructed participants to complete the second survey. When the survey had been completed, the same testing procedures as in the prototyping segment was conducted by the experimenter to determine the weight, height, buoyancy, and sturdiness of the vessel designed by the team

Measures

Error-related statements. Videotapes were transcribed and coded for error-related statements. The coding procedure followed the steps outlined by Weingart, Olekalns, and Smith (2004) where the unit of analysis for coding is identified from the data prior to applying codes. To code for these statements, three research assistants, blind to the original hypotheses, were trained to unitize these transcripts into speaking units which consist of statements that contain a subject-verb-object. Their reliability in unitizing was then calculated by having them unitize 10 transcripts selected at random. Unitizing reliability on these transcripts was satisfactory with values of Guetzkow's U ranging from .005 to .034. The transcripts were then divided between

the research assistants and individually unitized. A total of 22,784 units from 177 individual transcripts were identified.

Error-related statements were identified by myself using the “Problem-focused statements” dimension in the Act4Teams coding scheme (Kauffeld, 2006). Specifically, statements that related to defects, deficiencies, flaws, and errors with their output were coded as error-related statements. Examples of these are “clearly mine was too tall compared to how it was wide because it tipped over” (Group 12, Round 2); “[the water] probably is coming in immediately because you can probably look and see where the seams are on the bottom (Group 16, Round 2); and “The bit that broke off was this bit here. I didn't put any reinforcement” (Group 28, Round 1). Coding reliability was determined by a second rater who rated a random selection of 30 transcripts. The reliability of ratings was found to be high with Cohen’s kappa (1960) for these transcripts ranging from .83 to .98. The total number of error-related statements in each round was determined by summing up the total number of these statements identified per transcript and were labeled as Errors₁, Errors₂, and Errors₃, respectively.

Group atmosphere. Perceptions of group atmosphere (i.e., positive attitudes and cognitions of group members about their group) were measured using a 10-item composite measure from Jehn and colleagues (2010) (see Appendix C). This measure contained questions about respect, trust, and commitment. Items were found to load on one factor and the Cronbach’s alpha coefficient for the composite scale was .95, which was similar to values found in past research (e.g., Jehn & Mannix, 2001; Jehn et al., 2010). The basis for using the composite measure was due to the theory on combined aspects of group atmosphere (Jehn & Mannix, 2001), the factor analysis results, Cronbach’s alpha, and past conceptualizations of group states and processes (e.g., Jehn, Greer, Levine, & Szulanski, 2008; Jehn et al., 2010). Responses

showed satisfactory inter-rater agreement within groups ($rwg_j = .98$) which justified aggregating responses amongst group members. Group atmosphere was measured in the first survey that was conducted after the third discussion phase, prior to beginning the final build segment of the experiment.

Coordination quality. Coordination quality was measured using a 5-item scale from the coordination dimension of Lewis' (2003) transactive memory systems measure. Items for this measure can be found in Appendix C. This measure of coordination was found to load on one factor and the Cronbach's alpha coefficient for this scale was .90. Aggregation of responses within groups was justified by adequate inter-rater agreement ($rwg_j = .89$). Coordination quality was measured in the second survey during the final build segment, after the team's final design had been built but prior to testing the performance of the team's output.

Average prototype scores. Average prototype scores for Rounds 1 (APS_1), 2 (APS_2), and 3 (APS_3) were determined by averaging the cumulative points scored by each vessel built during that round in the prototyping segment. In the prototyping segment, points were scored along the dimensions of height, weight, the number of ball bearings they could carry, and the height that they could be dropped before it broke. The point values associated with these dimensions can be found in Appendix B.

Team output quality. Similar to the prototype performance scores, team output quality was calculated from the height and weight of the final design, the number of ball bearings it could carry, and the height that they could be dropped before it broke.

Final designs were also rated in terms of aesthetics by two research assistants who were blind to the research hypotheses. Ratings for each criterion were assigned in separate sessions. For each criterion, rating rubrics were explained to the raters with pictures of exemplary designs

shown (Appendix D). 10 designs were then selected at random for the raters to assign scores based on these rubrics. Any discrepant scores were discussed to clarify the criteria for evaluation. After their scores on this trial rating were calibrated, they then independently rated the population of designs. This procedure was repeated for each criterion in the aesthetics dimension. Cronbach's alpha for these ratings ranged from .89 to .99, which justified aggregating scores between raters.

Data Analysis

The analysis was conducted in two parts. The first analysis examined the change in prototype performance as a function of the duration of transition phases, while the second analysis examined the quality of the team's final output as a function of intragroup change in prototype performance. In the first analysis, the three conditions were coded with two dummy variables. Teams in the short transition condition were coded as 1 on the ST variable and zero on the LT variable. Teams in the long transition condition were coded as 1 on the LT variable and zero on the ST variable. Finally, teams in the control condition were coded as zero on both ST and LT variables.

The models in both analyses were fitted using the MPlus computer program, Version 7 (Muthén & Muthén, 1998-2012). For both analyses, latent growth curve analysis was used to model intergroup change in prototype performance between Rounds 1 to 3. This technique was chosen because two growth parameters are estimated by latent growth curve models – in this case, prototype performance in Round 1, and the change in APS over time. These estimates allow for performance over time to be modeled as both a predictor of future outcomes as well as an outcome itself.

The first analysis examined the factors that predicted differences in prototype performance over time across groups. An unconditional growth model was first fitted to reveal differences in prototype performance over time across groups (Duncan, Duncan, & Strycker, 2006; L. J. Williams, Vandenberg, & Edwards, 2009). On the right side of Figure 4, a two-factor measurement model is specified with factor loadings that are fixed and equal to either a constant value of 1 or to the rounds that prototype performance was measured at, “centered” at the first round. This model parameterization yielded two latent factors representing estimates of prototype performance in Round 1 (the Intercept) and the linear change in prototype performance, corrected for measurement error (the Rate of Improvement).

On the left of this measurement model in Figure 4, a set of structural paths by which experimental conditions are hypothesized to affect $Errors_1$, $Errors_2$, and the growth parameters are shown, controlling for the number of speaking units in each round (not shown in Figure 4). As shown in Figure 4, β_1 and β_2 represents the respective direct effects of the LT and ST conditions on the rate of improvement; β_3 and β_4 represents the respective effects of the number of error statements in Rounds 1 and 2 on the Rate of Improvement in APS; β_5 and β_6 represents the respective effects of the LT condition on $Errors_1$ and $Errors_2$; and β_7 and β_8 represents the respective effects of the ST condition on $Errors_1$ and $Errors_2$.

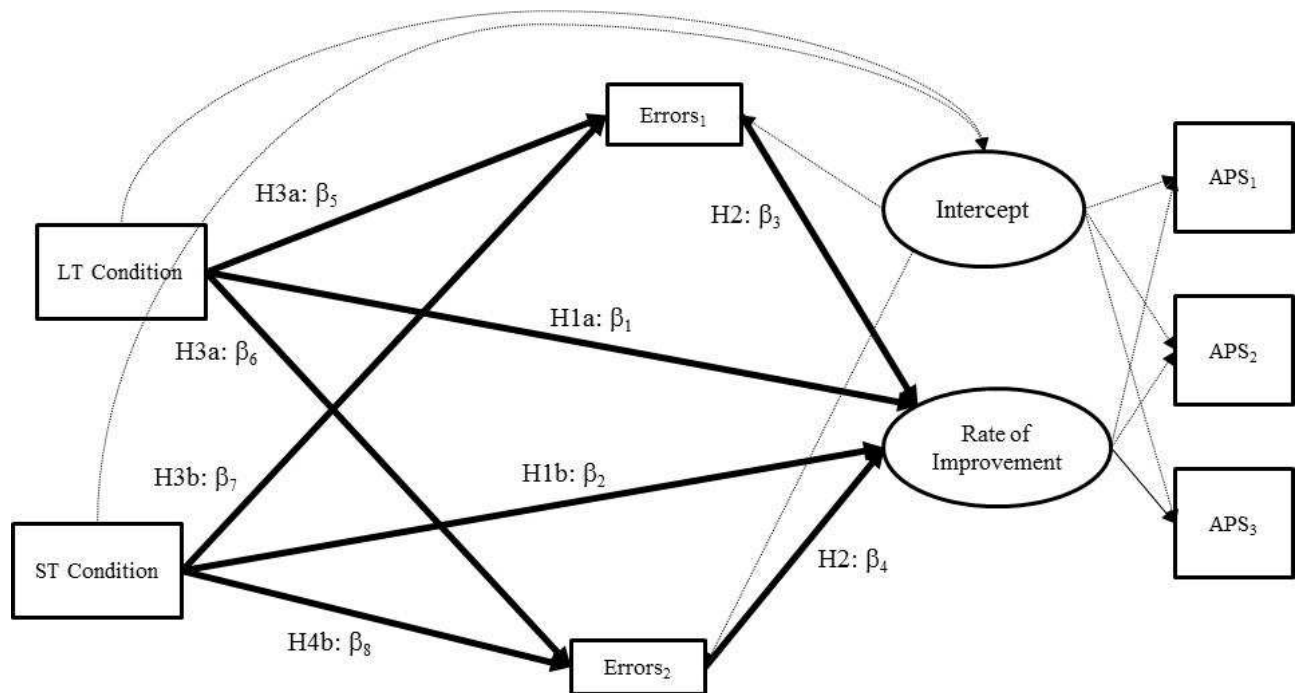


Figure 4. Latent growth curve structural model depicting associations between experimental conditions, the number of error statements, and growth parameters of average prototype scores from Rounds 1 to 3.

The second analysis examined the relationship between the Rate of Improvement in APS with Group Atmosphere, Coordination Quality, and Team Output Quality. A latent growth curve model that accounted for the hypothesized relationship between these variable was specified and fitted as shown in Figure 5.

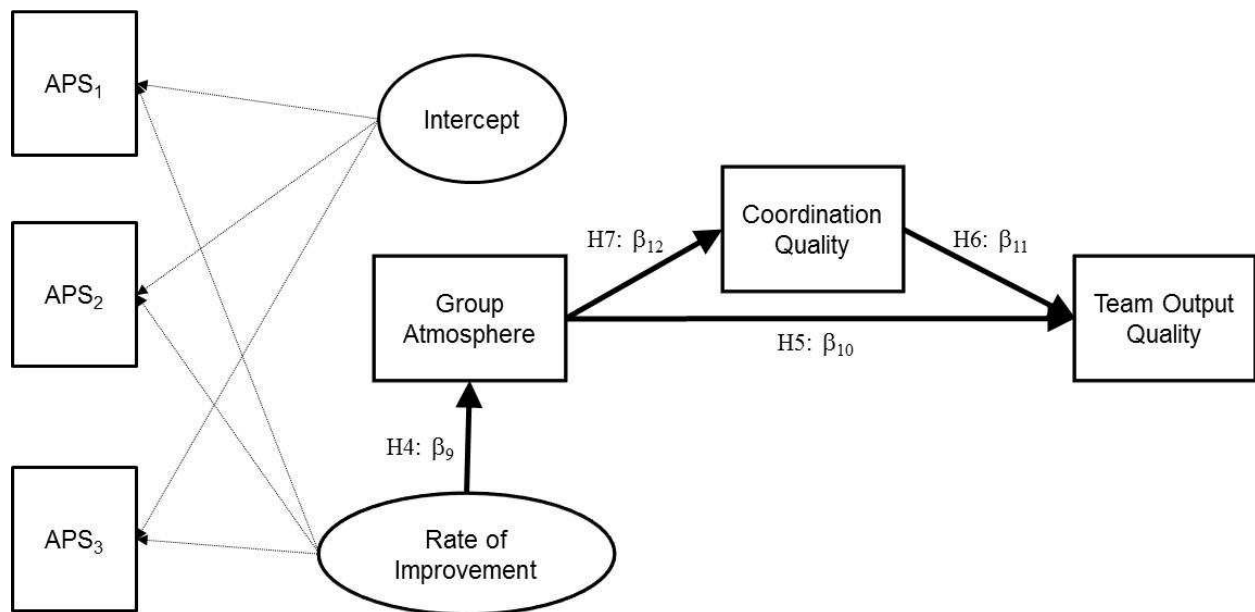


Figure 5. Latent growth curve structural model depicting associations between growth parameters of average prototype scores from Rounds 1 to 3, group atmosphere, coordination quality, and team output quality.

Similar to the first analysis, the left side of Figure 5 shows the two-factor measurement model containing estimates of the Intercept and the Rate of Improvement in APS. The right side of Figure 5 shows the structural paths by which the Rate of Improvement is hypothesized to predict Group Atmosphere, Team Output Quality, and the mediating role of Coordination Quality. The structural parameter β_9 represents the relationship between Rate of Improvement in APS on Group Atmosphere, controlled for estimates of APS_1 ; β_{10} represents the direct effect of Group Atmosphere on Team Output Quality; β_{11} represents the effect of Coordination Quality on Team Output Quality; and β_{12} represents the effect of Group Atmosphere on Coordination Quality.

Results

Sample means and standard deviations for outcomes and predictors are shown in Table 5.

On average, teams in the control condition spent 2.57 mins, 1.75 mins, and 2.93 mins for discussion in Rounds 1, 2, and 3 respectively. The average amount of time for discussion each round was thus 1.95 mins, which was slightly less time than what teams in the ST condition were given.

Table 5: Univariate Descriptive Statistics on Outcome and Predictor Variables ($n = 59$)

Variable	Control ($n = 19$)		Long Transition ($n = 20$)		Short Transition ($n = 20$)		Overall ($n = 59$)	
	M	SD	M	SD	M	SD	M	SD
Errors ₁	4.50	2.81	7.84	4.94	5.11	4.27	5.85	4.31
Errors ₂	3.39	2.79	10.53	8.83	5.89	5.13	6.67	6.77
Units ₁	54.94	19.31	91.00	34.57	47.06	11.73	64.82	30.63
Units ₂	37.28	17.875	101.47	26.42	48.00	9.53	62.96	34.32
APS ₁	42.63	21.67	30.00	12.18	35.05	17.50	35.78	17.94
APS ₂	66.74	26.76	50.02	15.23	56.00	25.75	57.43	23.74
APS ₃	69.50	29.46	73.65	22.88	72.40	28.73	71.93	26.68
Output Quality	93.89	39.62	95.18	36.72	89.63	44.63	92.88	39.84
Coordination	3.67	0.58	3.56	.61	3.73	.77	3.65	.65
Group Atmosphere	5.10	0.67	5.17	0.52	5.23	0.41	5.17	0.54

In terms of the average prototype performance across rounds, there was a general upward trend in prototype performance over time (Figure 6). Across conditions, differences in prototype performance in each round were marginally significant for Round 1, $F(2, 56) = 2.57$, $p = .085$, and Round 2, $F(2, 56) = 2.61$, $p = .083$, but not for Round 3, $F(2, 55) = .116$, $p = .891$. Teams also did not differ in Group Atmosphere, Coordination Quality, and Team Output Quality across

conditions, suggesting that variance in these constructs are better explained by intermediate processes rather than the experimental conditions.

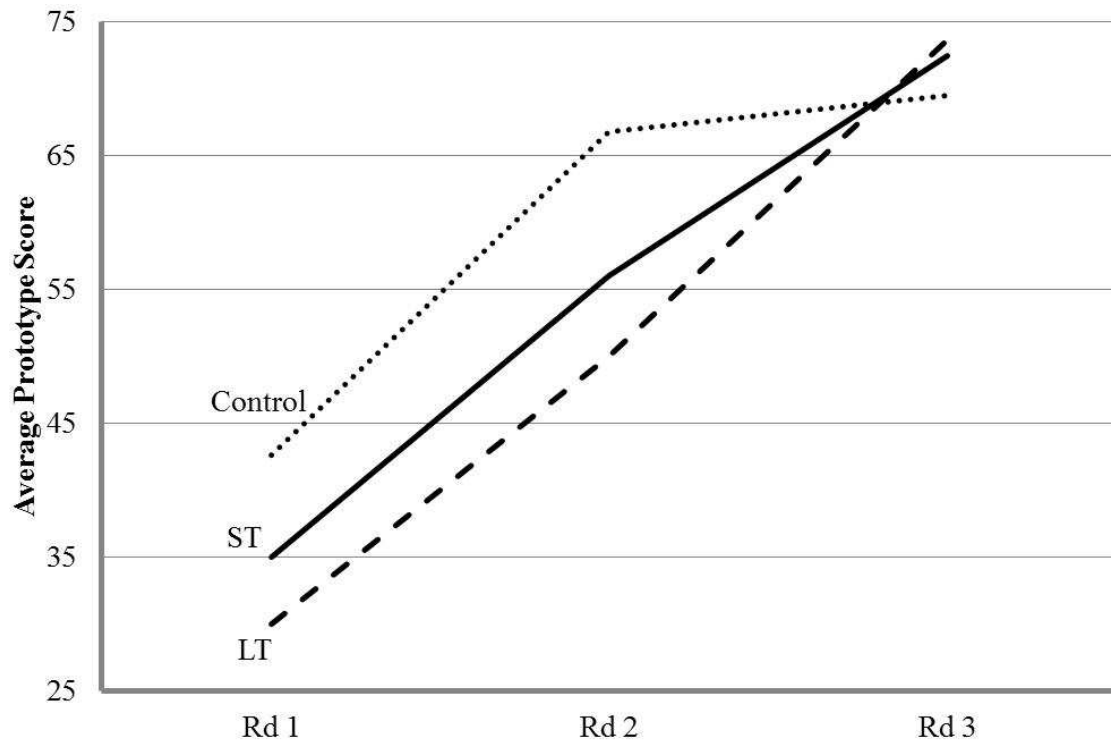


Figure 6. Change in APS across rounds.

In terms of how teams interacted across conditions, differences in the number of speaking units were found to be significant for Round 1, $F(2, 56) = 21.19, p < .01$, Round 2, $F(2, 56) = 66.38, p < .01$, and Round 3, $F(2, 54) = 10.72, p < .01$. Differences in the number of error statements were also evident in Round 1, $F(2, 56) = 4.02, p = .03$, and Round 2, $F(2, 56) = 7.76, p = .001$, but only marginally so in Round 3, $F(2, 54) = 2.72, p = .08$.

Planned contrasts revealed that compared to teams with unstructured transitions, those with longer transitions structured displayed a higher number of speaking units (Round 1, $t(56) = 4.97, p < .01$; Round 2, $t(56) = 10.73, p < .01$; Round 3, $t(54) = 3.00, p = .04$) and number of

error statements (Round 1, $t(56) = 2.59, p = .012$; Round 2, $t(56) = 3.86, p < .01$; Round 3, $t(54) = 2.27, p = .03$). Similarly, in comparison to teams with shorter transitions structured, those with longer transitions structured displayed a higher number of speaking units in every round (Round 1, $t(56) = 6.11, p < .01$; Round 2, $t(56) = 8.94, p < .01$; Round 3, $t(54) = 4.53, p < .01$). The number of error statements was also higher for long transition teams for Round 1, $t(56) = 2.29, p < .03$, and Round 2, $t(56) = 2.60, p = .01$, but not for Round 3, $t(54) = 1.55, p = .126$).

Despite the different amounts of time spent discussing, the rate of communication (i.e., number of units per second), the rate of errors discussed (i.e., number of error statements per second), and the proportion of errors discussed (i.e., number of error statements per unit) did not differ across conditions. These results therefore show that teams in the LT condition had more communications and discussed errors more frequently compared to teams in the ST and control conditions. However, teams neither differed on the pace of communication nor on the proportion of errors discussed across conditions.

Effect of Structured Transitions on Prototype Performance Over Time

The first analysis examines the relationship between experimental conditions and team interactions within transition phases on the rate of improvement in APS. Parameter estimates and goodness-of-fit indices for the model in Figure 4 are shown in Table 6, Model 1 ($\chi^2(16) = 41.31$, AIC = 1484.46, CFI=.88, SRMR = .084). The fit indices for this model indicated poor overall model fit with the data. Two alternative models were explored. In Model 2, the correlation between Errors₁ and Errors₂, and the correlation between the number of were units in Rounds 1 and 2 were constrained to equality ($\chi^2(14) = 33.02$, AIC = 1480.16, CFI=.91, SRMR = .077). In Model 3, correlations between Errors₁ and Errors₂ and the number of units for each round were constrained to equality ($\chi^2(14) = 24.79$, AIC = 1471.93, CFI=.95, SRMR = .064). Model 3 was

selected as the final model from which results are reported from because of the satisfactory model fit and the significantly better fit compared to Model 1 ($\Delta\chi^2 = 16.52, p < .01$). Coefficients of the paths corresponding to Hypotheses 1 to 3 are shown in Figure 7. Estimates of the paths from the ST condition to Errors₁ (β_7) and Errors₂ (β_8) were not significant and are not shown in Figure 7.

Table 6: Selected Parameter Estimates From a Taxonomy of Fitted Latent Growth Curve Models Predicted by Experimental Condition and Frequency of Error Statements (n = 59)

Parameter	Model 1		Model 2		Model 3	
	Unstandardized	Standardized	Unstandardized	Standardized	Unstandardized	Standardized
LT → Rate of Improvement (β_1)	2.146	.197	2.166	.200	1.949	.183
ST → Rate of Improvement (β_2)	2.196	.202	2.171	.201	2.330	.219
Errors ₁ → Rate of Improvement (β_3)	10.327 ^{*a}	.307 [*]	10.101 ^{*a}	.302 ^{*a}	9.932 ^{*a}	.301 ^{*a}
Errors ₂ → Rate of Improvement (β_4)	1.311	.037	2.018	.058	1.224	.036
LT → Errors ₁ (β_5)	.229 ^{**}	.709 ^{**}	.231 [*]	.712 [*]	.220 [*]	.683 [*]
LT → Errors ₂ (β_6)	.402 ^{***}	1.298 ^{***}	.397 ^{***}	1.284 ^{***}	.409 ^{***}	1.325 ^{***}
ST → Errors ₁ (β_7)	-.009	-.027	-.008	-.026	.013	-.041
ST → Errors ₂ (β_8)	.190 [*]	.613 ^{**}	.186 [*]	.601 [*]	.194 [*]	.626 [*]
LT → Units ₁	.216 ^{***}	1.170 ^{***}	.215 ^{***}	1.166 ^{***}	.214 ^{***}	1.158 ^{***}
LT → Units ₂	.452 ^{***}	1.997 ^{***}	.453 ^{***}	1.999 ^{***}	.452 ^{***}	1.997 ^{***}
ST → Units ₁	-.052	-.284	-.053	-.289	-.055	-.299
ST → Units ₂	.143 ^{***}	.630 ^{***}	.144 ^{***}	.634 ^{***}	.143 ^{***}	.630 ^{***}
Units ₁ → Rate of Improvement	-13.529	-.230	-13.105	-.224	-11.247	-.195
Units ₂ → Rate of Improvement	14.100	.293	13.271	.278	13.552	.289
LT → APS ₁	-14.392 ^{**}	-.436 ^{**}	-14.405 ^{**}	-.922 ^{**}	-14.454 ^{**}	-.927 ^{**}
ST → APS ₁	-8.736	-.265	-8.744	-.560	-8.776	-.563
APS ₁ → Errors ₁	.003	.155	.003	.160	.002	.111
APS ₁ → Errors ₂	-.001	-.053	-.001	-.061	.000	-.019
Goodness-of-fit statistics						
AIC	1484.455		1480.163		1471.925	
χ^2	41.314, 16 d.f., p = .0005		33.023, 14 d.f., p = .0029		24.785, 14 d.f., p = .0368	
CFI	.875		.906		.947	
SRMR	.084		.077		.064	

* p < .05. ** p < .01. *** p < .001. a one-tailed test

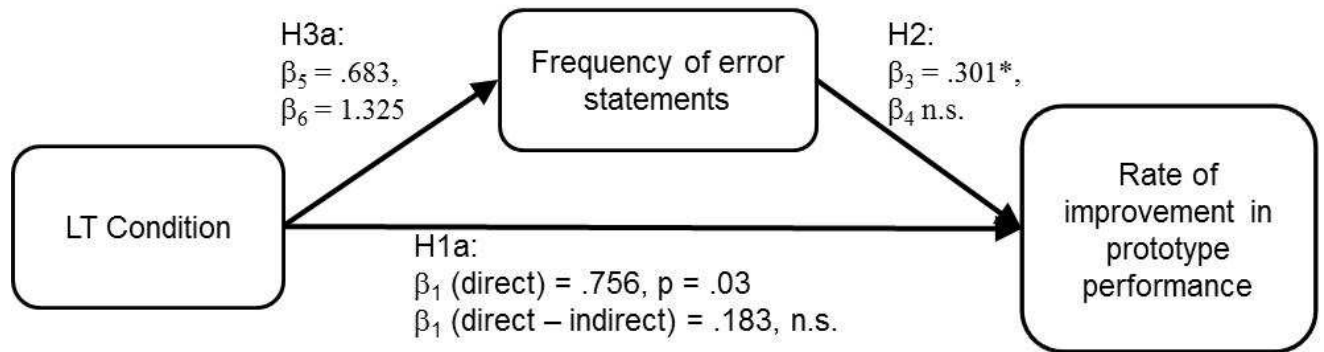


Figure 7: Path coefficients between experimental conditions, frequency of error statements, and the rate of improvement in APS.

The first hypothesis predicted that in comparison to teams with unstructured transitions, teams with longer transitions structured would have steeper rates of improvement (H1a), but not teams with shorter transitions structured (H1b). This hypothesis was supported by the positive and significant direct effect between LT and the Rate of Improvement (β_1 (direct) = .756, $p = .03$) but the direct effect between ST and the Rate of Improvement was not found to be significantly different from the control.

Hypothesis 2 predicted that the frequency of error statements exhibited would be positively associated with the rate of improvement in prototype performance. The $\text{Errors}_1 \rightarrow \text{Rate of Improvement}$ coefficient was found to be positive and significant ($\beta_3 = .301$, $p = .037$, one-tailed), but not for Errors_2 , indicating that Hypothesis 2 was supported for error statements made in Round 1.

Hypothesis 3 predicted that the number of error statements would be higher in teams with longer transitions structured relative to teams without transitions structured. However,

differences in the number of error statements would not be significantly different between teams with shorter transitions structured and those without transitions structured. This hypothesis was supported by the positive and significant coefficient of the $LT \rightarrow Errors_1$ ($\beta_5 = .683, p = .03$) and $LT \rightarrow Errors_2$ ($\beta_6 = 1.325, p < .001$) pathways, while the coefficient for the $ST \rightarrow Errors_1$ and $ST \rightarrow Errors_2$ pathways were not significant.

The results also support the claim that the positive effect of longer transitions on the rate of improvement in prototype performance is mediated by the frequency of error statements. Following Baron and Kenny's (1986) causal step approach, support for this claim of mediation stems from the fact that accounting for the effect of error statements (the mediator) reduces the significance and the strength of the $LT \rightarrow Rate\ of\ Improvement$. Furthermore, MacKinnon and colleagues (2002) also argue that the joint significance of the paths from the predictor to the mediator (i.e., $LT \rightarrow Errors_1$) and from the mediator to the dependent variable (i.e., $Errors_1 \rightarrow Rate\ of\ Improvement$) is a valid test of mediation with low Type 1 error rates.

Effect of Prototype Performance on Final Performance

Goodness-of-fit indices and parameter estimates for the path model in Figure 5 are shown in Table 7, Model 1. The model fit indices showed an appropriate fit with the data ($\chi^2(7) = 8.71$, $AIC = 2335.53$, $CFI = .98$, $SRMR = .041$). An alternative model in which pathway between the rate of improvement and group atmosphere was removed was also examined ($\chi^2(8) = 14.69$, $AIC = 2242.355$, $CFI = .93$, $SRMR = .065$). However, the results from the first model were reported because of its satisfactory and better fit compared to the alternative model ($\Delta\chi^2 = 5.98$, $p = .01$). Coefficients of the paths corresponding to Hypotheses 4 to 7 are shown in Figure 8.

Table 7: Selected Parameter Estimates From a Taxonomy of Fitted Latent Growth Curve Models That Predict Final Design Scores by True Initial Scores, True Rate of Change in Prototype Performance Between Rounds 1 to 3, Group Atmosphere, and Coordination Quality ($n = 59$)

Parameter	Model 1		Model 2	
	Unstandardized	Standardized	Unstandardized	Standardized
Rate of Improvement $\rightarrow$ Group Atmosphere (β_9)	.019*	.370**		
Group Atmosphere $\rightarrow$ Output Quality (β_{10})	4.842	.065	5.913	.081
Coordination $\rightarrow$ Output Quality (β_{11})	20.707**	.339**	20.489**	.343**
Group Atmosphere $\rightarrow$ Coordination (β_{12})	.593***	.487***	.593***	.487***
Intercept $\rightarrow$ Output Quality	1.009***	.397***	1.009**	.400***
Rate of Improvement $\rightarrow$ Output Quality	1.144	.295*	1.238	.305
Goodness-of-fit statistics				
AIC	2335.527		2242.355	
χ^2	8.710, 7 d.f., $p = .274$		14.685, 8 d.f., $p = .065$	
CFI	.98		.93	
SRMR	.041		.065	

* $p < .05$. ** $p < .01$. *** $p < .001$.

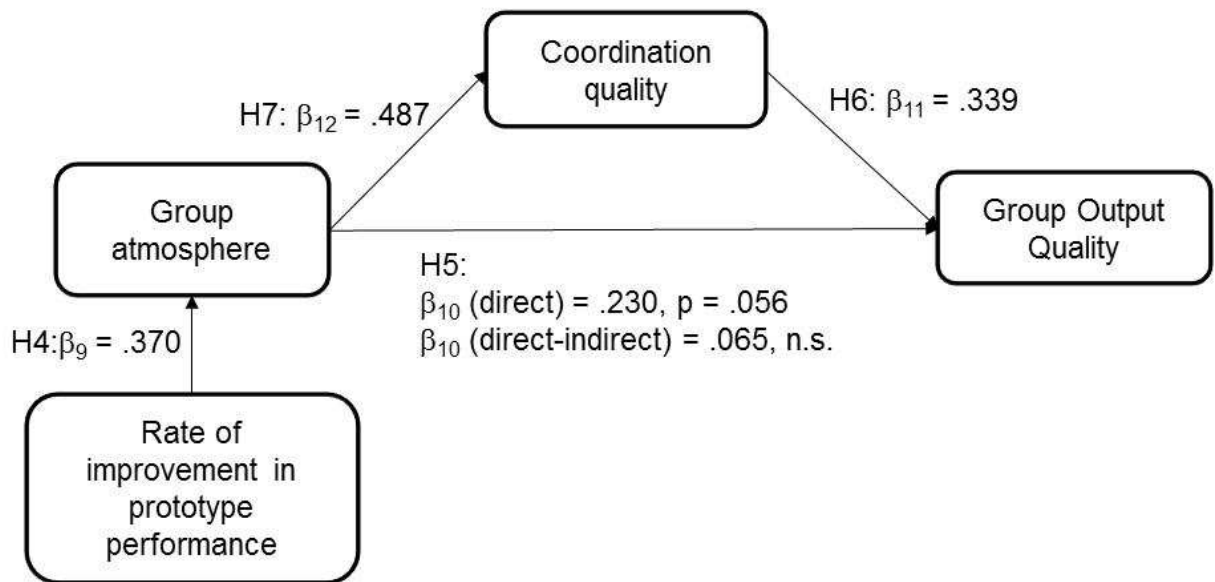


Figure 8: Path coefficients between the rate of improvement in APS, group atmosphere, coordination quality, and team output quality.

Hypothesis 4 predicted that the steeper the Rate of Improvement in APS, the higher Group Atmosphere will be. This relationship was found to be positive and significant ($\beta_9 = .370$, $p = .008$), indicating that a 1 standard deviation increase in the Rate of Improvement in APS led to a .370 standard deviation increase in Group Atmosphere. Hypothesis 4 was thus supported.

Hypothesis 5 predicted that higher levels of Group Atmosphere would increase the Team Output Quality. Support for this hypothesis was found by the positive and significant direct effect of Group Atmosphere on Team Output Quality ($\beta_{10}(\text{direct}) = .230$, $p = .028$, one-sided).

Hypothesis 6 predicted that Coordination Quality would be positively associated with Team Output Quality. Support for this hypothesis was found as evidenced by the positive and statistically significant coefficient between Coordination Quality and Team Output Quality ($\beta_{11} = .339$, $p < .001$).

Finally, Hypothesis 7 predicted that higher levels of Group Atmosphere will increase Coordination Quality. This hypothesis was also supported given the positive and significant pathway between Group Atmosphere and Coordination Quality ($\beta_{12} = .487$, $p < .001$).

The results also support the claim that Coordination Quality mediates the positive relationship between Group Atmosphere and Team Output Quality. Following the causal step approach (Baron & Kenny, 1986), the direct effect of Group Atmosphere on Team Output Quality became insignificant after accounting for the effect of Coordination Quality. Furthermore, the indirect effect consisting of the combined Group Atmosphere $\rightarrow$ Coordination $\rightarrow$ Team Output Quality pathway was found to be significant ($\beta_{12}\beta_{11} = .165$, $p = .014$) even after controlling for the effect of APS₁ and the Rate of Improvement.

Full model

The full model combined models from both analyses and included variables from the prototyping and final build phases. This model showed satisfactory fit with the data ($\chi^2(39) = 49.793$, AIC = 2253.904, CFI=.957, SRMR = .066). An alternative model was tested in which paths from LT, ST, Errors₁, and Errors₂ in the first segment to Team Output Quality in the second segment of the experiment were added. This model also showed satisfactory fit ($\chi^2(35) = 46.813$, AIC = 2258.924, CFI=.953, SRMR = .064), but was not a significant improvement in the fit over Model 1 ($\Delta\chi^2 = 2.98$, 4 d.f., $p = .56$). The significant path coefficients in the final model are consistent with those in the first and second analysis. Specifically, the LT $\rightarrow$ Errors₁, Errors₁ $\rightarrow$ Rate of Improvement path, Rate of Improvement $\rightarrow$ Group Atmosphere path, Group Atmosphere $\rightarrow$ Coordination Quality path, and the Coordination Quality $\rightarrow$ Team Output Quality path were found to be significant. Results from this analysis therefore lend further support to the hypothesized model.

Discussion

The goal of this study was twofold. The first was to examine how structuring the duration of transition phases in the iterative process affects differences in prototype performance. The second was to examine the effect of dynamic iterative processes on the quality of outputs in creative project teams.

A model was proposed where structuring longer transition phases would encourage teams to discuss errors more. Such discussions would subsequently enable team members to identify mistaken assumptions, share knowledge, and explore new ideas. This more in-depth information processing would in turn lead to improvements in prototype performance over time. The results show that the greater improvements in prototype performance led to a more positive group atmosphere. A more positive group atmosphere subsequently improved the quality of

coordination amongst team members, which led to higher quality outputs that better met desired ends. Results from an experiment which simulated the iterative, prototyping process typically adopted by teams engaged in performing creative work supported this model.

Temporal characteristics of activity cycles

This research contributes to a deeper understanding of how temporal characteristics of activity cycles in teams can affect team outcomes. The results support the idea that a rhythm consisting of short action phases and long transition phases during the initial stages of team performance can have beneficial outcomes for teams performing creative tasks. Although scholars have recognized that different activity rhythms exist in teams (e.g., Ancona, Okhuysen, & Perlow, 2001; Gersick, 1988, 1989), the effects of different rhythms on team outcomes has, thus far, been limited. This study thus provides preliminary evidence for investigating these effects in greater depth. For example, as mentioned in Chapter 2 of this dissertation, it is possible that a rhythm consisting of long action phases and short transition phases might be more desirable when teams are engaged in validation-related activities. Rhythms can also vary in terms of the predictability and regularity of the beat or tempo, which could translate into an examination of the regularity and predictability of transition phases on team outcomes. Addressing these questions goes beyond documenting that variations in rhythm occurs, but sets the stage for offering evidence-based prescriptions about how creative project teams can deliberately manipulate these rhythms to perform more effectively.

Iterative performance and team emergent states

Although scholars acknowledge the importance that team emergent states (N. R. Anderson & West, 1998; Milliken, Bartel, & Kurtzberg, 2003; West & Anderson, 1996) and coordinated activities (Hoegl & Gemuenden, 2001) have in attaining creative outcomes, most of

this work has conceptualized these processes as static rather than dynamic phenomena. However, this shortcoming in research on team innovation by group researchers persists in the broader literature as well (Cronin et al., 2011). Hence, there is little research that directly examines the different ways that processes unfold affect team outcomes in a creative setting. Additionally, although scholars have hypothesized about the dynamic interplay between performance feedback and team states in creative teams (e.g., Milliken et al., 2003; West, 2003), such a model has not been explicitly tested.

In this study, the dynamic process was replicated in the lab by imposing recursive cycles of action and transition phases onto participating teams. These recurring phases of action-transition phases are commonly adopted by creative project teams as they perform their tasks as a form of learning and adaptation and have been documented in teams including the interactive media development teams that I studied in the first part of this dissertation, TV production crews (Carter & West, 1998), as well as product development teams in the computer (Eisenhardt & Tabrizi, 1995) and auto industries (Nonaka & Takeuchi, 1995).

Although scholars in the operations management field have examined these dynamic processes in terms of the frequency of iterations (e.g., Erat & Kavadias, 2008; Thomke & Bell, 2001), this body of work is primarily concerned with optimizing the information benefits of frequent iterations with the associated costs and do not account for the psychological effects that such a process can have on team member interactions. This research thus departs from these traditional approaches of studying innovation processes in teams by investigating the effect of structuring the duration of transition phases in the iterative process on team interactions, team emergent states, and the quality of team outcomes. By doing so, it informs theory on how the innovation process can be more effectively organized to foster team interactions and

psychological states that are more productive, rather than simply to optimize the informational benefits.

A key aspect of this theory is the role of intermediate performance feedback, in the form of prototype performance, on team emergent states and the quality of team outputs. I hypothesized and found that it is not just the absolute performance of these intermediate outcomes that matters, but rather the performance trajectory that occurs over time. The steeper this trajectory, the more positive the group's atmosphere, which leads to higher quality outcomes through improved coordination.

Balancing learning from errors with intermediate successes

This research reinforced the critical role that learning from errors and intermediate successes have on team performance. However, it also raises the question of how teams can balance between these contradicting priorities. On one hand, overemphasizing errors may have the adverse effect of lowering team morale and group atmosphere resulting in a downward performance spiral (Lindsley et al., 1995); on the other hand, overemphasizing intermediate successes may stifle learning and radical innovation (March, 1976) because success can serve as a filter for interpreting new information in a way that confirms previous success (Ashford, 1989). Unfortunately, this dilemma is not addressed by this research but could be the basis for future studies.

Other contributions and implications

A final contribution from this research is that it adds to our understanding of what it means to iterate effectively. Effective iteration is currently conceptualized in terms of optimizing the benefits of information against the cost of obtaining this information (Erat & Kavadias, 2008; Loch et al., 2001; Thomke & Bell, 2001). This research enhances this understanding by

highlighting the importance of structuring this process to facilitate critical interactions such as the discussion of errors. This insight is particularly relevant to creative project teams because they typically perform in time scarce environments that suppress such behaviors to the detriment of the team's performance on the creative task. By ignoring the role of social interactions in this process, creative project teams may be limited in the knowledge that they can extract from these iterative processes.

A practical implication from this research is that it highlights the importance of allocating appropriate amounts of time for teams for learning and reflection amidst time scarce environments. Prior research suggests that teams performing creative tasks will benefit from iterating as frequently and as quick as possible (Dow et al., 2009; Eisenhardt & Tabrizi, 1995). The findings in this study adds to this work by providing evidence-based guidance on how time should be allocated between action and transition activities while these teams iterate. Teams in time scarce environments are more likely to shorten or compress the amount of time – a tendency that was very evident in the teams that were assigned to the control condition in this experiment. The duration of discussions in these teams averaged 1.95 mins which was slightly less than the amount of time that teams in the Short Transition condition were given. A number of teams in the control condition also had to be reminded by the experimenter that they had to stop building their prototype so that they would have some time left for discussion.

In highly dynamic and unpredictable situations such as those that creative project teams are exposed to, teams view time as a scarce resource (Stalk, 1990) and its availability can subsequently exert powerful effects on behavior. As argued in this research, allocating sufficient time to transition phases in iterative prototyping fosters the interactions associated with learning in teams. When temporal resources are perceived to be scarce, people are compelled to make

judgments on the fly which might be adaptive under some circumstances, but will generally have an adverse effect on the performance of creative project teams by restricting learning behaviors.

Although it is still important for teams to engage in rapid iterations, it is just as important that transition phase activities are insulated from this rapid pace of activity. Even though the rapid pace of action phase activities may negatively affect prototype performance in the short-term, the findings from this study suggests that the long-term performance will not be adversely affected because it is the accelerated improvements in prototype performance over time that affects final performance through a more positive group atmosphere and improved coordination within the team.

CHAPTER 4: GENERAL DISCUSSION

Summary of Results

The broad objective of this dissertation is to deepen our understanding of how creative project teams can perform more effectively. To meet this objective, I examined the innovation processes in creative project teams in two studies. In Study 1 (Chapter 2), the underlying patterns of planning, enacting, and reviewing activities that teams engage in to produce innovative outcomes were examined in a case study of two project teams in an IMD studio. My analysis revealed two distinct activity cycles consisting of unique configurations of planning, enacting, and reviewing activities. The first, experimentation cycles, were utilized by the teams to discover project requirements, scope, and constraints through trial and error. The second type of cycle identified, validation cycles, enabled the teams to align their final outputs with project requirements through incremental modifications. The manner in which the planning, enacting, and reviewing activities manifested in each type of cycle were also elaborated upon. To illustrate how these findings can deepen theoretical models of team innovation, I then developed a number of testable theoretical propositions about the effects that different durations of planning, enacting, and reviewing activity phases in each type of cycle will have on team performance.

In Study 2 (Chapter 3), a model for how structuring the duration of transition phases affects the rate of improvement in prototype performance and the quality of team outputs was proposed and tested. Intermediating processes such as the number of error statements discussed while prototyping, group atmosphere, and coordination quality were also included in the model.

To investigate these relationships, a lab experiment was conducted where groups of participants performed a creative, open-ended task in which they were to build a floating vessel from Lego pieces according to certain specifications. Results from this experiment provided

preliminary support for the proposed model. Specifically, it was found that structuring longer durations of transition phases led to more discussion of errors. Discussing more errors provides more opportunities for team members to surface and correct mistaken assumptions, brainstorm, and share unique knowledge with one another resulting in steeper rates of improvement in prototype performance. Steeper rates of improvement in prototype performance were found to be positively associated with group atmosphere. A positive group atmosphere subsequently improved the quality of coordination amongst team members, which led to higher quality outputs that better met desired ends.

Implications of Dissertation Findings

In addition to extending theory about dynamic processes in creative project teams, the broader implications of this dissertation for research on creative project teams and team innovation are discussed in the ensuing sections. These implications touch on the psychosocial effects of prototype performance during the iterative process and an organizing framework of dynamic group processes.

Psychosocial effects of prototyping performance

One of the highlights from Study 2 is the emphasis on the iterative, prototyping process as a way of developing positive team states such as trust, respect, and commitment. Prior work by management scholars on the iterative process has focused primarily on the information or cognitive benefits through learning (e.g., Eisenhardt & Tabrizi, 1995; Thomke, 2003), although researchers in engineering design have recently taken note of the social benefits (Dow et al., 2011; Gerber & Carroll, 2012). In this dissertation, I draw on the notion that intermediate feedback affects team emergent states (Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Marks et al., 2001) to further examine the idea that prototyping performance can also affect these states. To

the extent that these states influence their willingness and ability to work together, performance will also be affected. This research therefore demonstrates the effect that prototyping performance over time can have on the team's final outcomes, holding the number of iterations constant.

In spite of these results, caution should be taken in interpreting these findings because the extent to which the positive relationship between improvements in prototyping performance over time and coordination is affected by how these improvements are attained is unclear. In these experiments, the results showed that improvements in prototype quality were attributed to the more liberal discussion of errors. How might this relationship between the improvement in prototype performance and group atmosphere be affected if the improvements were caused by other factors rather instead of team members discussing more errors? For instance, what if these improvements were due to chance discoveries? Would the resultant improvements in prototype performance still increase team members' positive attitudes about one another? These issues can be disentangled in future research.

The practical implication of these findings for teams performing creative tasks is that they need to also pay attention to learning processes amidst iterating frequently. It is also important that teams be mindful about what they learn from these iterations by allocating sufficient time to review the flaws of prior versions and to find ways to improve on these flaws. Indeed, the findings from Study 2 are highly consistent with the mantra for creative project teams to "fail often and fail early", with the additional reminder to not fail to learn.

Ironically, this focus on errors may have detrimental side effects on the group's atmosphere. Being too fixated on errors may distort the team's perception of their effectiveness even if there is learning taking place, which can reduce collective efficacy and lead to more

negative attitude towards one another. It is therefore also important that the focus on errors does not spillover into the team's psychosocial well-being. How the balance between these conflicting priorities can be accomplished remains a question that future research can address.

Framework of dynamic group processes

This dissertation has highlighted additional approaches to characterize dynamic group processes. Multiple approaches to characterize dynamic group processes can enhance the vocabulary that scholars have to converse about these phenomena, which increases the chances of focusing, or at the very least, incorporating the dynamic aspects of these phenomena into their research. But in addition to increasing the ways that scholars can discuss dynamic phenomena, it is also helpful to organize these ideas into a coherent framework which I attempt in the final chapter of this dissertation. While a theory of change have been posited by Van de Ven and Poole (1995), this theory explains the motors driving change, whereas the framework discussed here refers to different ways for describing how things change.

One approach to characterize dynamic processes is in terms of the dynamic profile of constructs (Cronin, Weingart, & Todorova, 2011). Additionally, this dissertation illustrated two other approaches to characterize dynamic processes: as configural pattern, and as temporal characteristics.

The dynamic profile of a construct can refer to changes in the levels of a construct over time, its relationship with other constructs over time, and the compilation of the construct over time. An example of this dynamic profile approach in this dissertation can be found in Study 2, where the performance trajectory of prototypes was examined as both a dependent variable and a predictor. Although, this study only focused on upward trending trajectories, dynamic processes can also be represented as downward trending, curvilinear or as more complex forms such as a

sine wave. While the dynamic profile approach is construct-focused, the configural patterns and temporal characteristics approaches are phenomena-focused.

The configural patterns approach characterizes dynamic process in terms of their underlying elements and the configuration of these elements over time. Study 1 is an example of this approach where I elaborated on the different ways by which cycles of planning, enacting, and reviewing activities unfold over time in creative project teams. In addition to activity patterns, these elements can also be patterns of interactions (e.g., Brett, Weingart, & Olekalns, 2004; Stachowski, Kaplan, & Waller, 2009) and events (e.g., Staudenmayer, Tyre, & Perlow, 2002). In essence, characterizing dynamic process with the configural approach describes how these elements relate to one another over time in terms of their sequential ordering. Various orderings are described by Ancona and colleagues (2001) in terms of the possibilities that multiple activities can map to one another.

The temporal characteristics approach characterizes dynamic process in terms of how its underlying elements relate *to time*. For example, in Study 2 of this dissertation, dynamic iterative processes were differentiated in terms of the duration of transition phases. Other dimensions of time described in the literature include the predictability, regularity and frequency of the underlying events, activities, and interactions that comprise this process (Ancona et al., 2001; Bluedorn & Denhardt, 1988; McGrath & Rotchford, 1983).

Although these ideas about groups and time have been discussed extensively by scholars, these ideas have not, to my knowledge, been applied to the context of team innovation despite the chaotic and unpredictable nature of innovation processes (Cheng & Van de Ven, 1996). This framework for characterizing dynamic processes thus expands boundaries for investigating dynamic processes in creative project teams and those tasked with innovation. For example, a

dynamic profile approach could involve examining how changes in external communication affect performance. A steep downward sloping curve might indicate that communication channels have deteriorated, while a horizontal line may be an indicator of external parties who micro-manage or external stakeholders' lack of trust in the team. A configural patterns approach might involve investigating the effect of different patterns of interactions and events on the performance of creative teams. For instance, the lengths of error-brainstorming statement chains could be used as an indicator of dynamic interactions associated with learning. A temporal characteristics approach would involve examining the predictability, regularity or frequency of events such as transition phases, project milestones, crises, and conflicts in relation to team performance. Using the temporal characteristic of rhythm as an example, I shall illustrate how adopting these approaches in research can trigger novel questions and uncover new phenomena.

The general idea that temporal rhythms can affect performance has been explored at the firm level (Huy, 2001; Klarner & Raisch, 2013) but there is little research to date that explores and tests this idea at the group level³. Although prior research in dyads and groups have examined sequences of interaction and activities (e.g., Brett et al., 2004; Stachowski et al., 2009; Tschan, 1995, 2002; Waller, 1999; Waller, Gupta, & Giambatista, 2004), an investigation of rhythm requires duration to be superimposed on these sequences. It is not just the sequential relationship between activity A and activity B that is of interest, but the temporal space between A and B. Recent work by Klarner & Raisch (2013), who found that different rhythms of change affect firm level outcomes, suggests that examining these effects at the group level can be

³ Notable exceptions are work by Gersick (1988, 1989), and by Ancona and Waller (2007)

promising in furthering our understanding of enhancing the performance of creative project teams.

In addition to the notion raised in this dissertation about whether an ideal rhythm for different types of activity cycles exists, a focus on rhythm also brings attention to the multiple rhythms that teams are buffeted by (Ancona & Waller, 2007). The ensuing “dance of entrainment” performed by teams to balance these multiple rhythms raises questions about the strategies and capabilities for coordinating different rhythms. One strategy could be to synchronize different rhythms into a coherent whole by speeding up or slowing down the pace of rhythms. What then are the mechanisms for doing so and what determines which rhythms are adjusted? Another strategy could be to insulate rhythms from one another. If so, what then are the strategies and mechanism for these? Perhaps some teams are simply more versatile than others in staying in sync amidst different rhythms. If so, what are the properties and capabilities of these teams that contribute to their versatility?

On top of these multiple rhythms, team leaders also have to ensure that members are in sync with one another. To some extent, their roles are similar to an orchestral conductor who dictates the rhythm of the performance while simultaneously coaxing and coercing team members to stay in rhythm. However, an important point of differentiation between leaders in creative project teams and orchestral conductors is the higher need for improvisation faced by the former. Leadership phenomena in creative project teams can therefore be likened to leading an orchestra through an improvised piece. The unique features of this phenomenon raise questions about the leadership behaviors and leader-member interactions that are beneficial to team performance on creative tasks.

The above is merely an indicative list of potential research questions and phenomena to be discovered and is by no means exhaustive. The main point here is that characterizing the ways that processes are dynamic can yield new directions for research which are obscured when processes are conceptualized as static phenomena. More importantly though, given the chaotic and unpredictable nature of innovation processes it is all the more critical for research to account for dynamic processes. In doing so, management scholars will be better able to offer evidence-based guidance for how managers might influence the unfolding team process to improve the performance outcomes of creative project teams. Recent technological development make the pursuit of these research questions more of a reality. While the cost of collecting fine-grained real-time data on a large scale would have been prohibitive before, technologies which improve the ease of sharing documents, calendars, and less intrusive methods of movement tracking, render such approaches of data collection more feasible. I am therefore optimistic that these questions can be more widely addressed by scholars in the near future.

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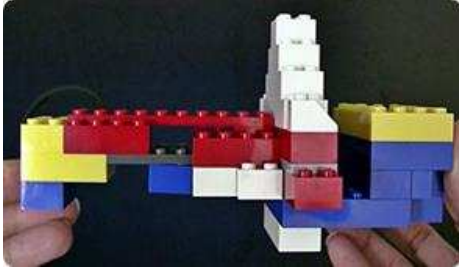
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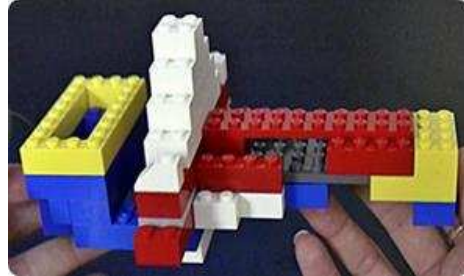
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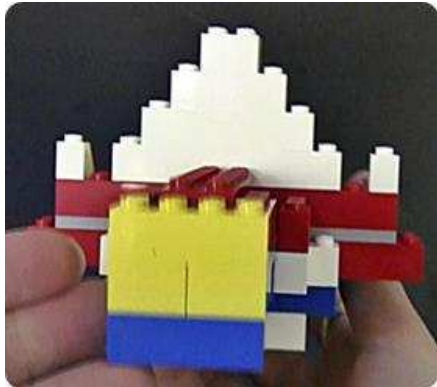
APPENDIX A: SAMPLE TEAM OUTPUT



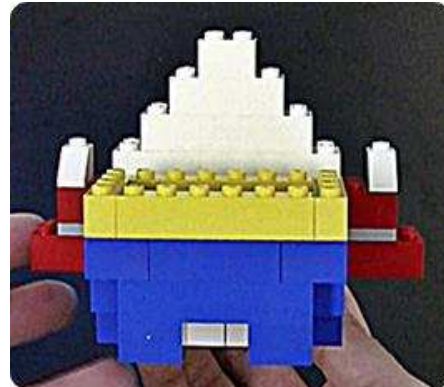
Left view



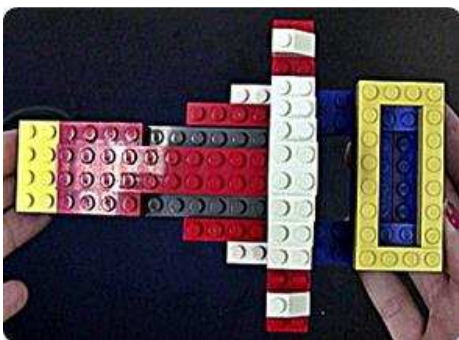
Right view



Front view



Back view



Top view

APPENDIX B: SCORING CRITERIA

Function

- 1) Buoyancy: 5 points deducted if vessel sinks. +10 points for each steel ball carried.
- 2) Durability: 5 points deducted if vessel breaks from a 1-foot drop. +10 points for each additional 1ft it is able to remain intact when dropped.
- 3) Weight: 10 points deducted if vessel is under 100g. +1 point for every gram over 100g, up to 140g.
- 4) Height: +4 points for every .5 inches, up to 5 inches.

Aesthetics: Structure

- 1) Narrow front relative to the rear: “Wide front relative to the back” (1 point) to “Narrow front relative to the back” (5 points). 5-point scale in increments of 1 point.
- 2) Height of the front relative to the rear: “Front is a little lower” (1 point) to “Front is much lower” (5 points). 5-point scale in increments of 1 point.
- 3) Boxiness: “Very boxy” (20 points deducted) to “Not boxy” (0 points deducted). 5-point scale in increments of 5 points.

Aesthetics: Color

- 1) Randomness of color scheme: “Very random” (10 points deducted) to “Well-planned” (0 points deducted). 5-point scale in increments of 2.5 points.
- 2) Color symmetry: “Low symmetry” (1 point) to “High symmetry” (5 points). 5-point scale in increments of 1 point.
- 3) Patterned designs in use of colors: “Unpatterned” (1 point) to “Highly patterned” (5 points). 5-point scale in increments of 1 point.
- 4) Use of accent pieces to emphasize features: “Few features” (1 point) to “Many features” (5 points). 5-point scale in increments of 1 point.
- 5) Novelty: “Low novelty” (2 points) to “High novelty” (10 points). 5-point scale in increments of 2 points.

APPENDIX C: SURVEY ITEMS

Group Atmosphere (Jehn et al., 2010).

7-point scale. Response categories are: Strongly Disagree, Disagree, Slightly disagree, Neither Agree nor Disagree, Slightly Agree, Agree, Strongly Agree.

1. Even when we disagree, I respect my team members during this exercise.
2. I have a high regard for the other individuals in this team during this exercise.
3. In general, I respect my team members.
4. I feel very committed to this group during the exercise.
5. I like the other members of this group.
6. I will talk up this team to my friends as a great group to work in.
7. To what extent do you trust your team members during this exercise?
8. To what extent do you feel comfortable delegating important functions to your team members?
9. To what extent do you feel that your team members can be counted on to help you?
10. To what extent are your team members perfectly truthful and honest with you?

Coordination quality (Lewis, 2003).

5-point scale. Response categories are: Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree

1. Our team worked together in a well-coordinated fashion.
2. Our team had very few misunderstandings about what to do.
3. Our team needed to backtrack and start over a lot.
4. We accomplished the task smoothly and efficiently.
5. There was much confusion about how we would accomplish the task.

APPENDIX D: RUBRICS FOR EVALUATING FINAL DESIGNS

Rater instructions: Boxiness

Your task is to evaluate the “**boxiness**” of each design.

Please follow the procedure below:

- 1) For each design, examine the “Top” view, and evaluate how much each design resembles a box.
- 2) The more a design deviates from a boxy-look, the more points it will receive.
- 3) Review your ratings after every 20 designs, and after completing all the ratings to verify that the criteria you used to form your ratings has been consistently applied.

Rating scale

1 - Very boxy

Design is squarish, chunky and resembles a box.

No features have been added to break up the boxiness.

2 - Boxy

This design maintains the squarish, chunky look of a box.

Although there is some attempt to break up this look with little protrusions on the side, these seem minor compared to the squarish base.

3 - Moderately boxy

Narrow front and slight protrusions help this design break away from the squarish, chunky look. Narrow front does not seem well-integrated with the squarish body, which results in the overall design still looking somewhat boxy.

4 - A little boxy

The front of this design tapers to the front and to the back, which helps to break up the boxy look.

However, this tapering is quite abrupt (compared to the next category) and the design still looks boxy, although less than those in the previous categories.

5 - Not boxy

Squarish-look is broken up by major protrusions on the side.

These protrusions also vary in shape and design, which helps to break apart the boxy look even more.

The front of the boat also narrows gradually.

Rater instructions: Color symmetry

Your task is to evaluate the “**color symmetry**” of each design.

Please follow the procedure below:

- 1) For each design
 - a. Examine the color scheme symmetry for the Top, Front and Back views by imagining a line drawn down or across the center of the picture.
 - b. Compare the symmetry of the Left vs. Right views.
- 2) The more symmetrical the color scheme for a design is, the more points it will receive.
- 3) Review your ratings after every 20 designs, and after completing all the ratings to verify that the criteria you used to form your ratings has been consistently applied.

Rating scale**1 - Non-symmetrical**

Little evidence of symmetrical color scheme from all views.

2 - Slightly symmetrical

Some attempt at color symmetry is evident, although this is minor.

The symmetry only makes up a minor portion of the design, and is only evident from some views.

3 - Moderately symmetrical

Moderate evidence of symmetry from multiple views.

Asymmetrical colors make up a dominant part of the design and stand out.

4 - Highly symmetrical

Color scheme is mostly symmetrical from all views.

Asymmetrical colors are small and only make up a minor portion of the design.

5 - Perfectly symmetrical (5 points)

Color scheme is perfectly symmetrical from all views.

Rater instructions: Randomness of color scheme

Your task is to evaluate the “**randomness of color scheme**” of each design.

Please follow the procedure below:

- 1) For each design, examine the color scheme for each view.
- 2) The more planned the color scheme for a design appears to be, the more points it will receive.
- 3) Review your ratings after every 20 designs, and after completing all the ratings to verify that the criteria you used to form your ratings has been consistently applied.

The extent of “color scheme planning” can be determined as follows:

First, do the designers appear to be randomly adding blocks without regard to the color scheme, or do they seem to be following a plan? (One can usually tell by seeing how integrated the color scheme is with the design)

Second, if there seems to be a plan, how well was it executed?

Rating scale

1 - Highly disorganized color scheme

Color scheme looks disorganized from multiple viewpoints. Evidence of planning in the use of colors is not discernible.

2 - Somewhat disorganized, minimal planning

Overall color scheme looks disorganized and messy. But some attempt at a planned color scheme is discernible from certain viewpoints.

3 - Less disorganized, moderate levels of planning

Evidence of planned color scheme is clearly discernible from most, but not all, views. From certain viewpoints, the design looks more organized and less messy. However, flaws in implementation are very apparent.

4 - Moderately high levels of planning

Evidence of planned color scheme is discernible from all views. Looks neat and organized overall. Color scheme looks well implemented, but with obvious flaws although these are minor.

5 - Very high levels of planning

Evidence of planned color scheme is discernible from all views. Color scheme looks well implemented with no obvious flaws. Any flaws are minor, almost to the point of being negligible.

Rater instructions: Relative height

Your task is to evaluate the extent of “**relative height between the front and rear**” of each design.

Please follow the procedure below:

- 1) For each design, examine the Left and Right views of the designs.
- 2) Evaluate how high the rear is relative to the front of the design.
- 3) The greater this difference in height, the more points the design receives.
- 4) Review your ratings after every 20 designs, and after completing all the ratings to verify that the criteria you used to form your ratings has been consistently applied.

Rating scale**1 - Flat**

Front to rear is flat with no variation in height.

2 - Slight difference in height

Difference in height between front and rear is approx. 1 block.

3 - Moderate difference in in height

Difference in height between front and rear is 2-3 blocks

4 - Moderately large difference in height

Difference in height between front and rear is at 4-5 blocks

5 - Large difference in height

Difference in height between front and rear is at 6 or more blocks

Rater instructions: Patterned designs in use of colors

Your task is to evaluate the extent of “**patterned designs in use of colors**” of each design.

Patterning, in this context, refers to the spatial organization of colors. A color scheme is considered to exhibit a high degree of patterning if a) colors are grouped together in some coherent manner, or b) they spaced out in a consistent manner. This applies both to singular colors as well as groups of colors (e.g., motifs).

It is also necessary to determine how well patterns are implemented. Due to time pressure and other constraints, designers may not be able to flawlessly execute their ideas resulting in mismatched pieces. Raters will need to make a judgment call on whether these are “flaws in a patterned color scheme”, or one without patterns.

Note that the ratings do not ask how attractive or intricate patterns are, merely whether one exists or not.

Please follow the procedure below:

- 1) For each design, examine the color scheme for each view.
- 2) The more patterned the color scheme for a design appears to be, the more points it will receive.
- 3) Review your ratings after every 20 designs, and after completing all the ratings to verify that the criteria you used to form your ratings has been consistently applied.

Rating scale

1 - Unpatterned

Color scheme shows little evidence of a decorative design or motif from all views.

2 - Slight degree of patterning

Patterns in the color scheme are slightly noticeable from multiple views, or moderately noticeable from one view.

3 - Moderate degree of patterning (3 points)

Patterns in the color scheme are moderately noticeable from multiple views. Flaws in patterning are evident in multiple views.

4 - Moderately high degree of patterning (4 points)

Patterns in the color scheme are very noticeable from multiple views. Minor flaws are evident in a few views.

5 - Very high degree of patterning

Patterns in the color scheme are clearly noticeable from every view. Flaws, if any, are minor and almost negligible.

Rater instructions: Relative width

Your task is to evaluate the extent of “**relative width**” of each design.

Please follow the procedure below:

- 1) Examine the structure of these designs from the pictures.
 - a. Evaluate how narrow the front of the vessel is relative to the rear of the vessel.
 - b. The larger the difference, the more points the design will receive.
- 2) Review your ratings after every 20 designs, and after completing all the ratings to verify that the criteria you used to form your ratings has been consistently applied.

Rating scale**1 - Uniform width**

No difference between the width of front and rear of vessel.

2 - Slight difference in width

Difference of 1-2 dots between the width of front and rear of vessel

3 - Moderate difference in width

Difference of 3-4 dots between the width of front and rear of vessel

4 - Large difference in width

Difference of 5 dots between the width of front and rear of vessel

5 - Very large difference in width

Difference of more than 6 dots between the width of front and rear of vessel

Rater instructions: Accent pieces

Your task is to evaluate the use of “**accent pieces**” of each design.

Accents are the little Lego pieces, such as 1x1 blocks, flat 2x2 plates, or sloping piece. These designs will be evaluated on the following basis:

- 1) Quantity: How many accent pieces were used?
- 2) Quality: Do these pieces serve a structural function, or add aesthetically to the design?

Please follow the procedure below:

- 1) Examine the structure of these designs from the pictures.
 - a. Evaluate the use of accent pieces of each design.
- 2) Review your ratings after every 20 designs, and after completing all the ratings to verify that the criteria you used to form your ratings has been consistently applied.

Ratings scale

1 - None used

No accent pieces used.

2 - Minimally used, no aesthetic contribution

Up to approx. 2 pieces used. These pieces neither contribute to the aesthetics of the design nor emphasize structural features.

3 - More frequently used, no aesthetic contribution

Slightly more accent pieces used (e.g., more than 2). These pieces may contribute a little to the aesthetics of the design and may emphasize structural features, but this is minor.

4 - More frequently used, some aesthetic contribution

Up to approx. 4 accent pieces used. These contribute somewhat to the aesthetics of the design and emphasize structural features.

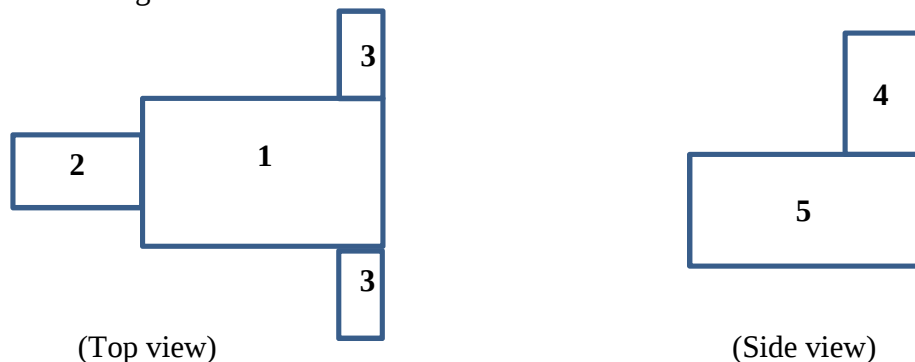
5 - Frequent use with strong aesthetic contribution

A fair number of accent pieces used (e.g., approx. more than 4). These enhance the aesthetic appeal of the design and also emphasize structural features.

Rater instructions: Novelty

Your task is to evaluate the degree of “**novelty**” of each design.

Designs can be broken down into 5 areas:



First consider the structure and color in each of the 5 areas:

- a) How typical or unique is that area of the vessel?
- b) How simple or complex is that area of the vessel?

Next, consider the design as a whole to determine how distinctive the overall design is.

Please follow the procedure below:

- 1) Examine the structure of these designs from the pictures.
- 2) Review your ratings after every 20 designs, and after completing all the ratings to verify that the criteria you used to form your ratings has been consistently applied.

Rating scale**1 - Typical**

Very minor, almost negligible degree of variation and uniqueness, in most areas.

2 - Low novelty

Minor degree of variation and uniqueness in 1 area.

3 - Moderate novelty

Minor degree of variation and uniqueness in more than 1 area, or moderate degree of variation and uniqueness in one area. Overall design is not necessarily distinctive.

4 - Moderately high novelty

Significant degree of variation and uniqueness in at least 1 area. Design is distinctive and stands out.

5 - Very high novelty

Significant degree of variation and uniqueness in multiple areas. Design is very distinctive and stands out.