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New Product Development Decision-Making Effectiveness: Comparing Individuals, Face-To-Face Teams, and Virtual Teams*

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ABSTRACT

A total of 411 subjects participated in two decision-making experiments in order to examine the effectiveness of new product development project continuation decisions. In Study 1, individual versus face-to-face team decision-making effectiveness was compared. Study 2, an extension of Study 1, compared the new product development decision-making effectiveness of individuals, face-to-face teams, and virtual teams. A virtual team is a geographically and temporally dispersed and electronically communicating work group. In Study 2, the virtual teams communicated asynchronously via groupware technology. Our findings suggest that teams make more effective decisions than individuals, and virtual teams make the most effective decisions.

Subject Areas: Computer-mediated Communication Systems, Multivariate Statistics, Product Development, Product Planning, Project Management, and Strategic Decision Making.

INTRODUCTION

In an effort to gain effectiveness in new product development (NPD), firms increasingly use formalized and structured processes (cf. Page, 1993; Griffin,

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1997). Though they vary in their levels of complexity, virtually all NPD processes have two core features—activities and decisions. Figure 1 illustrates a generic NPD process. Specifically, activities include various marketing, technical, and business/financial analysis tasks required to generate information and take an idea from a concept to a tangible market offering. Interspersed throughout these activities are project review points, frequently called gates or go/stop points, where the various project information is reviewed and decisions are made to either continue the project onto the next stage or stop it (permanently or temporarily). Typically, individuals from various functional areas conduct the NPD activities while a different set of individuals act as decision makers by conducting project reviews, making continuation decisions, prioritizing NPD projects, and making critical resource commitments (Cooper, 1993).

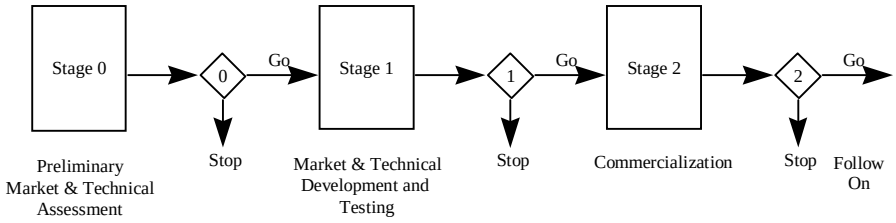
Project review decisions are the focal point of this study. The types and number of NPD activities, participants conducting the activities, and communication patterns and levels during the NPD activities have been studied extensively (see Montoya-Weiss & Calantone, 1994; and Brown & Eisenhardt, 1995, for reviews). However, we know far less about project review points and the resulting continuation/termination decisions (for exceptions, see Boulding, Morgan, & Staelin, 1997; Schmidt & Calantone, 1998). Since costs normally grow at an increasing rate as a project moves closer to commercialization, review points and the concomitant decisions are crucial for maintaining project control.

In this paper, we investigate the effects of (1) the structure of the decision-making unit (DMU) and (2) the mode of communication on NPD decision-making effectiveness at project review points. We define structure as the number of decision makers participating in the project review decision. First, we compare the effectiveness of individual versus team-based decision making at NPD review points. To our knowledge, no empirical research has determined whether individual managers or a team of managers make better NPD project continuation decisions.

Second, we consider the effects of communication mode on team-based NPD decision making. Specifically, we compare the decision-making effectiveness of face-to-face decision-making teams to dispersed (virtual) decision-making teams. Increasingly common in global organizations, virtual teams can be described as dispersed across space and time, with members brought together through communication technologies to complete a task (Warkentin, Sayeed, & Hightower, 1997; McDonough, Kahn, & Griffin, 1999). Past research has not considered whether conventional face-to-face teams or virtual teams are more effective in making NPD project continuation decisions. It is important to understand if communication technology affects NPD decision making at project review points.

This paper is organized as follows. First, we review the key elements of various NPD, decision making, and information systems research literatures and develop our research hypotheses. Next, we describe the research methods used to test the hypotheses and present the results of two studies. In the final section, the research results are discussed, and implications for research and practice are offered.

Figure 1: A stage-gate new product developoment process.



THEORETICAL DEVELOPMENT

Due to the competitive pressures, limited resources, and accelerating costs that characterize most NPD projects (Cooper & Kleinschmidt, 1986), it is imperative that NPD project continuation decisions be made effectively. We define effective NPD decisions as those that lead to desired results (e.g., project continuation when merited and eventual product success).

NPD project continuation decisions, like other strategic investment decisions, are prone to managerial decisional errors. Cooper (1996) found that stringent go/stop decisions are strongly associated with successful NPD, though managers rated NPD decisions as the weakest aspect of the NPD process. Recent studies by Boulding et al. (1997) and Schmidt and Calantone (1998) show that individuals may continue to fund failing NPD projects. Research on escalation of commitment in the managerial and organizational decision-making literatures shows that individuals may continue pursuing or allocating funds to a losing course of action even in the face of negative feedback about the chosen path (Staw, 1976, 1981; Staw & Ross, 1987). Escalation of commitment is the antithesis of effective decision making. We use this phenomenon as the basis for studying NPD decision-making effectiveness at project review points.

Individuals Versus Teams

Though there has been little research on NPD decision points, the expanding research on NPD activities provides guidance for optimally structuring the DMU for effective NPD project review decisions. Studies have shown that between 64 and 76% of firms use cross-functional teams to conduct NPD activities (Page, 1993; Griffin, 1997). Past research suggests that four important benefits are realized when teams are used to conduct NPD project activities compared to individuals acting alone:

1. Teams reduce development costs (Brown & Eisenhardt, 1995; Kessler & Chakrabarti, 1996).
2. Teams shorten the time from idea to commercialization, especially if the project activities are conducted simultaneously (Brown & Eisenhardt). As an example, Cooper and Kleinschmidt (1994) concluded that a cross-functional, dedicated, and supported NPD team was the most important factor associated with project timeliness.

3. Cross-functional NPD teams produce higher quality products (Kessler & Chakrabarti, 1996; Patti, Gilbert, & Hartman, 1997).

4. Research shows that products developed using teams perform better financially (Montoya-Weiss & Calantone, 1994; Brown & Eisenhardt).

In sum, teams provide benefits compared to individuals when conducting NPD activities, but do teams make more effective NPD decisions?

In the escalation of commitment literature it has been shown that individuals who are personally responsible for initiating projects tend to remain committed to them (or fund them at higher levels) even when they are failing (compared to individuals who did not initiate the projects) (cf. Staw, 1976; Bazerman, Giulano, & Appelman, 1984; Brockner et al., 1986; Whyte, 1991; Boulding et al., 1997). Decision makers continue to commit resources to turn the situation around and thereby prove to themselves and others that their earlier decisions were correct.

Though Brockner and Rubin (1985) suggested that the tendency to persist in a losing course of action might differ depending on whether individuals or groups make the decision, the limited past research has been equivocal. In a replication of Staw's (1976) research where escalation was examined for both individuals and groups, Bazerman et al. (1984) found that escalation of commitment occurs in individual and group decision-making situations and at about the same level. Whyte (1991, 1993) performed two studies that investigated escalation of commitment in individuals and groups. In the first study, he concluded that groups were more adept than individuals in making decisions (i.e., they were less likely to continue funding a losing course of action). Self-justification was found to be less relevant when groups make decisions compared to when individuals make decisions. In the second study, Whyte (1993) found that groups escalate their commitment more than individuals.

In the NPD project review context, we expect decision-making teams to make more effective NPD continuation decisions than individuals. Specifically, we expect that teams will have less of a tendency to escalate their commitment to a failing project compared to individuals when evaluating the same project and information for two reasons. First, compared to individuals, we expect that team members will feel less personally responsible for beginning the now-failing course of action since the decision-making power and responsibility is diluted and shared among the team (cf. Myers & Lamm, 1976; McGrath, 1984, p. 80; Whyte, 1991). Therefore, there is less need for the team members to justify their decision by trying to "turn the situation around" through continued investment. Second, compared to individuals, teams will have more information, knowledge, experiences, and varied viewpoints from which to draw. Individuals are limited in their ability to search for alternatives, recall information from memory, and to compare alternatives on multiple criteria (Staw, 1981). In a team setting, members can prompt others and use information in a synergistic way that is different from other members because each possesses different knowledge and skills (Steiner, 1972; McGrath). These higher levels of collective knowledge result in teams performing critical evaluation tasks better than individuals (Steiner; McGrath). For example, Laughlin, Bonner, Miner, and Carnevale (1999) found that when groups were given quantity estimation tasks, they were more accurate than individuals performing

the same tasks. Finally, groups are better at catching errors in proposed ideas than are the individuals who proposed them (Nunamaker, Dennis, Valacich, Vogel, & George, 1991). This discussion is stated formally in our first set of hypotheses:

H1: Compared to individuals, teams make more effective project continuation decisions.

H2: Compared to individuals, teams more accurately assess the likelihood of success at NPD project review points.

H3: Compared to individuals, teams do not become as committed to failing projects when making NPD project continuation decisions.

Impediments to Effective Team Communication

Assuming teams are more effective than individuals at making NPD continuation decisions, how should team members communicate? Past NPD research on face-to-face teams has focused on teamwork and communication with respect to NPD activities, that is, the conduct of the marketing, technical, and financial/business tasks. Interestingly, little research has considered the effect of the mode of communication on NPD decision-making effectiveness.

The NPD literature suggests that team members should meet face-to-face (see Cooper, 1993). The pioneering work of Allen (1977) showed that communication among team members decreases dramatically as spatial separation between the members increases. Allen argued that the iterative, creative nature of NPD involves multiple functional units and requires the rapid and rich feedback that face-to-face communication affords. More recent findings have been similar and suggest that physical proximity increases the frequency of communication, which in turn leads to increased performance of the development team and the final product (Pinto, Pinto, & Prescott, 1993; Patti et al., 1997).

While face-to-face communication might be quite effective for conducting NPD activities, face-to-face communication may not be the most effective mode for making NPD project review decisions. First, individuals have cognitive limitations that prevent them from performing optimally in face-to-face decision situations. Second, face-to-face teams are subject to group dynamics or social influences that may contribute to decisional error. Both of these factors are discussed next.

In order for a team to reach a decision, team members engage in three cognitive processes: (1) information recall, (2) information exchange (sending and receiving), and (3) information processing (using the information, assessing its implications, and storing it) (Dennis, Hilmer, & Taylor, 1997-1998). Individuals have limited cognitive resources to spread across the three processes. In face-to-face settings, most individuals can engage effectively in only one cognitive process at a time. For example, if an individual is trying to recall information related to an ongoing discussion, she or he is less likely to be actively listening or processing newly received information. Similarly, an individual can only hold a limited amount of information in his or her short-term memory. This suggests that the value of face-to-face communication as a "rich" mode of communication is limited

by the capacity of an individual to simultaneously recall, exchange, and process information. Thus, information that is critical to effective NPD project evaluation may not be fully utilized in face-to-face project review settings.

The effectiveness of NPD decision making by face-to-face teams may also be hindered by social influences. In small groups, one of the most significant psychological tendencies is a "strain toward uniformity," or the tendency for group participants to agree on issues and conform to some behavioral pattern (Steiner, 1972; Nemeth & Staw, 1989). This may be partly due to the fact that in verbal discussions only one team member can speak at a time, so other members are blocked from contributing. "Production blocking" significantly reduces information recall and exchange as members who are prevented from speaking often forget or suppress their thoughts that seem less relevant or important (Diehl & Stroebe, 1987). Individuals also may withhold information or opinions out of apprehension about the group's reaction to them (Diehl & Stroebe) or because they feel pressured to conform to the views of the majority (Steiner; Nemeth & Staw, 1989). Withheld information could be important, ultimately leading to less effective decisions.

Normative and informational influences contribute to conformity in teams (Deutsch & Gerard, 1955). Normative influence refers to dependence on others' opinions for social validation or the motivation to conform to the opinions of others to preserve a favorable self-perception and self-presentation (Myers & Lamm, 1976). Here, preferences are shaped by peripheral cues such as the number of people arguing for a position rather than the quality of information or argument. Conversely, informational influence involves members actively assessing information and integrating it into an overall understanding of the situation (also called persuasive arguments). Informational influence is characterized by a tendency to accept the viewpoints of others as information about reality. Informational influence theory argues that new information offered by one member will likely be more persuasive than information previously considered and/or commonly known among members (Vinokur, Trope, & Burnstein, 1975). However, past research on face-to-face teams has found that new information often is ignored (Stasser & Titus, 1987). These researchers suggest that, in verbal discussions, new information is only superficially considered since members must pay close attention to the ongoing discussion. As a result, the contribution is missed due to limited cognitive resources. Also, new information is often discounted if it challenges pre-discussion choices or initial group decisions (Lord, Ross, & Lepper, 1979).

According to Nemeth and Staw (1989), social influences (normative and informational) tend to increase group conformity in the following conditions: in face-to-face settings, with greater task difficulty, with greater ambiguity in the stimulus situation, with increasing relative size of the majority (homogeneous group composition), and with increased (real or perceived) expertise on the part of the majority. Any or all of the conditions may describe a team charged with making NPD project review decisions.

All of this suggests that the effectiveness of teams making NPD project review decisions may be enhanced with a different communication environment. With this in mind, we turn our attention to the potential impact of communication technology on the effectiveness of team-based decision making for NPD project continuation decisions.

Communication Technology and Team Decision Making

Computer-mediated communication systems are sociotechnical systems that support and enhance discussion-related activities of groups engaged in collaborative and cooperative work. Firms increasingly are using spatially and temporally dispersed NPD development teams and management review groups connected via communication technology. Past research suggests that communication technology has potential effects on the outcomes of teamwork, as well as on the nature of team interaction processes (cf. Fjermestad & Hiltz, 1998-1999). Various synchronous (same time) and asynchronous (different time) technologies are available to face-to-face and dispersed decision-making teams, including videoconferencing, teleconferencing, email, and groupware.

Research in the information systems area has extensively examined the effects of computer-mediated systems on same-time/same-place group work (see Fjermestad & Hiltz, 1998-1999, for a review). In terms of decision-making outcomes, past research has often found different and conflicting results when comparing face-to-face and computer-mediated teams. In some studies, face-to-face groups make better decisions, while in others no differences were found. Generally, computer-mediated teams exhibit a lower frequency of communication than face-to-face teams, although they tend to exchange more task-oriented messages as a proportion of total communication (Chidambaram, 1996; Hedlund, Ilgen, & Hollenbeck, 1998). Empirical research suggests that computer mediation equalizes participation since members tend to be less inhibited in their interactions, and the effects of status differences are mitigated (Weisband, 1992; McGrath & Hollingshead, 1994).

While much research has been conducted on group decision making under same-time/same-place conditions, there has been a paucity of research on different-time/different-place teams supported by asynchronous technology. (See Warkentin et al., 1997, and Furst, Blackburn, & Rosen, 1999, for reviews). This is despite the fact that asynchronous technology is commonly used in the workplace and that a larger portion of future teamwork will be fully dispersed (Kinney & Panko, 1996). In the limited number of studies that have examined decision making by dispersed teams, computer-mediated systems were found to be fairly effective. Dispersed, asynchronous teams generated more diverse perspectives, conducted more in-depth analyses, and produced higher quality decisions than face-to-face groups (Ocker, Hiltz, Turoff, & Fjermestad, 1996). However, due to coordination challenges, asynchronous teams may need more time to reach a decision and have more difficulty in achieving consensus (Hollingshead, McGrath, & O'Connor, 1993). In the following, we focus our discussion on the characteristics of asynchronous technology, specifically groupware, and how these characteristics potentially impact the effectiveness of virtual teams engaged in NPD decision making. The question is, how do virtual teams compare to face-to-face teams in terms of the effectiveness of their NPD project review decisions?

Past research shows that different types of tasks differ in terms of the degree of richness and interactivity in communication required for effective task completion (Daft & Lengel, 1986; McGrath & Hollingshead, 1994). Daft and Lengel defined richness as the capacity of communication media to convey cues and

facilitate shared understanding in a timely manner. Rich media allow the conveyance of multiple cues (verbal, paraverbal, and nonverbal) and support rapid bidirectional communication (interactivity and feedback). Conversely, in lean communication environments, team members are unable to convey nonverbal and paraverbal cues, and there are often delays between the time a message is sent and a response is received. Related to richness is the concept of social presence, which describes the degree to which the technology enables team members to feel psychologically close or present. High social presence enables the conveyance of social influence and other symbolic content and social context cues whereas media low in social presence filter out those cues.

While generally considered to be lean and low in social presence, asynchronous groupware enables geographically and temporally dispersed virtual teams to share databases, documents, and messages, and to engage in ongoing (yet asynchronous) threaded discussions. So, why would communication environments characterized by leanness and low social presence positively impact the effectiveness of NPD project continuation decisions? We contend that asynchronous groupware possesses characteristics that can attenuate some of the process losses (described earlier) that may impede the effectiveness of face-to-face decision-making teams.

First, we expect lean communication environments to decrease the likelihood that team members are swayed by normative influences. Leaner media reduce the costs and risks associated with taking a minority position because the team's perceived power to exert influence on dissenters is significantly decreased (Tan, Wei, Watson, Clapper, & McClein, 1998). Because influence is strongest when directed at a known individual, leaner media make normative influences considerably more difficult to convey. Technology, as mediator of communication between an individual and the team, allows an individual to more comfortably contribute comments that contradict opinions of others (Connolly, Jessup, & Valacich, 1990).

Second, leanness and low social presence should increase the likelihood that participants are swayed by informational influences because positions or ideas, rather than people, must be influenced. As mentioned, past empirical research indicates that virtual teams tend to be more task oriented and exchange less socioemotional information. Issues are more likely to be evaluated based on their merit rather than on whether they represent the team's majority position.

Third, asynchronous groupware possesses three characteristics that greatly reduce the cognitive and communication limitations present in synchronous contexts: rehearsability, parallelism, and reprocessability (Dennis & Valacich, 1999). Rehearsability is the extent to which a team member can fine-tune or edit a message before sending it. Asynchronous communication allows team members more time to compose messages and, therefore, it is easier to establish the reasoning behind it and attribute an idea to its originator. Other team members can similarly consider an idea before responding. Parallelism allows for the simultaneous input of information that mitigates production blocking, which may be the cause of poor information sharing in face-to-face decision-making teams (Dennis & Valacich). Because members do not have to take turns talking under time pressure, the opportunity to participate is equalized and more information may be revealed.

This suggests that more information related to the NPD project likely would be disclosed. Finally, reprocessability is the extent to which a message can be reexamined and processed again. Here, technology enables the creation of an electronic team memory and should facilitate information processing and use. It allows team members to repeatedly process a message to ensure understanding and, in the context of an NPD project review decision, this may facilitate more complete deliberation. Reprocessability is particularly important as the complexity or volume of information increases (Dennis & Valacich).

In concert, the broad characteristics of leanness and low social presence, and the more specific characteristics of rehearsability, parallelism, and reprocessability should lead to more precise information exchange, revelation of more information, and more objective NPD project evaluations. All of this suggests that virtual NPD decision-making teams supported by asynchronous communication technology should be less likely to exhibit escalation of commitment behavior relative to face-to-face teams. We expect virtual teams to make more effective NPD continuation decisions at project review points. The above discussion is summarized in the following three hypotheses:

H1a: Compared to face-to-face teams, virtual teams make more effective NPD project continuation decisions.

H2a: Compared to face-to-face teams, virtual teams more accurately assess the likelihood of success at NPD project review points.

H3a: Compared to face-to-face teams, virtual teams do not become as committed to a failing new product development project when making NPD project continuation decisions.

Methodology

To test the research hypotheses, a total of 411 subjects participated in two experiments. In Study 1, we examined the effect of the DMU structure (individuals versus face-to-face teams) on NPD decision-making effectiveness at project review points. In Study 2, we replicated and extended the first study by examining the effect of communication mode on team decision-making effectiveness. Specifically, we compared the effectiveness of NPD project continuation decisions for individuals, face-to-face teams, and virtual teams. The virtual teams communicated solely through Lotus Notes® discussion databases, an asynchronous groupware technology.

Task

Subjects acted either as an individual manager or as a member of a management team and made NPD project review decisions. The participants in both Study 1 and Study 2 made go/stop decisions at Gates 1 and 2 of the NPD process shown in Figure 1. At the start of the exercise, participants were instructed that corporate policy at the hypothetical company mandated that all products must achieve a 30% market share and must be profitable. The hypothetical products in this exercise were industrial sensor devices. Participants were told that approximately $500,000 already had been spent on conducting preliminary market and technical assessments (see

Appendix). They also were told that it would cost the same amount of money to commercialize each product, but that the company was unable to develop both products. In reality, there was no difference between the two products, and identical information was given for each one.

The exercise began by having participants (individually or as a team) choose between the two products because the escalation of commitment literature suggests that responsibility for initiating a project is related to continued commitment to a project (even when it is failing). This decision was based on personal/team preferences and assumptions. Following the decision to develop one product, the exercise commenced in Stage 1 of the NPD process and finished after Stage 2. For these stages, regardless of the chosen product (but unbeknownst to the participants), identical performance information was presented from which individuals and teams were instructed to make project continuation and related decisions (See Appendix).

Until a product is commercialized, investment decisions must be based on forecasted information. In addition, early decisions in the NPD process must be made without reliable information. As a product moves closer to commercialization, information becomes more accurate as market and technical uncertainties diminish. However, only after a product is commercialized is actual performance information available. Consequently, in stage 1 of the exercise, participants were told that information they received was projected. After commercialization (in stage 3), they were told that the information they received was actual rather than forecasted. All individuals and teams received negative performance feedback at stages 1 and 2 since, by definition, escalation of commitment occurs only when the outcome is negative. As shown in Table 1, performance increasingly fell short of hurdles. After commercialization, market share was substantially below the corporate mandate, and the product clearly was losing money. The performance information for each stage was not interpreted; rather, it was simply presented with no reference to the hurdles.

Subjects

In Study 1, 202 subjects participated in the decision-making experiment: 101 working individually and 101 working in 29 face-to-face teams. The Study 1 sample was 66% male. In Study 2, 209 subjects participated: 70 working individually, 70 working in 19 face-to-face teams, and 69 individuals working in 17 virtual teams. The Study 2 sample was 69% male. Across both studies, participants had an average of six years of professional work experience, and the participants were Master's level students participating from three geographically dispersed public universities.

Procedures

Both studies required the subjects to read an NPD scenario, process information (quantitative and qualitative), and make NPD project review decisions. By necessity, the experimental procedures differed between virtual teams and the other conditions. The individuals and face-to-face teams completed the decision-making experiment in a classroom setting. In order to prevent any artificial time pressure,

Table 1: Measures.[a]

	Stage 1			Stage 2		
	Mean	*SD*	α	Mean	*SD*	α
Likelihood of Funding[b,c] How likely is it that you (your team) would launch the new product?	4.1	3.1	n/a	3.2	3.4	n/a
Commitment[d] I (my team) am (is) committed to this new product.	2.9	1.6	.77	2.3	1.2	.79
I would feel guilty if I stopped funding this new product project.[e]						
I (my team) feel(s) a sense of loyalty to this new product.[e]						
Likelihood of Success[d] I believe that this new product will fail to meet the hurdle rates set by management.[f]	3.7	1.6	.74	3.2	1.5	.74
I believe that this new product will be a success.						
Ultimately, I believe that this new product will contribute negatively to my annual performance rating.[f]						

[a]The measures used in Study 1 and 2 are identical. For brevity, we report the descriptive statistics and reliabilities for Study 2 only since the results from Study 1 are virtually identical.
[b]Item measured on an 11-point scale (0 to 100% chance) anchored by *definitely would not* and *definitely would*, with *even chance* at 50%.
[c]Adapted from Garland et al.'s (1990) study.
[d]Items measured on 1-to-7 scales anchored by *strongly agree* and *strongly disagree*.
[e]Adapted from Binder's (1985) study.
[f]Indicates a reversed-scaled item.

we allowed twice as much time to complete the task as pretests indicated was necessary (approximately two hours). The members of the virtual teams in Study 2 were instructed to communicate solely through the Lotus Notes® databases (described below), allowing them to conduct asynchronous discussions. Because pretests indicated the task could be completed in three days, we allowed seven days to complete the exercise to prevent artificial time pressure. In both types of team settings the decision required reconciliation of different views and consensus on a final group position. After each decision, participants answered questions designed to test the hypotheses.

Communication Technology

The virtual teams used custom-designed Lotus Notes® discussion databases that enable asynchronous collaboration by passively facilitating discussion. Notes® can support a discussion by classifying entries into main topics and responses, where a response is a document attached to the entry to which it refers (Vandenbosch &

Ginzberg, 1996-1997). Every message has a time stamp and reveals the author's identity. In essence, Notes® allows for the creation of threaded, yet asynchronous, discussions. Because the participants from one of the universities all worked full-time, their participation generally was limited to non-work hours. Thus, the virtual teams were both geographically and (to varying degrees) temporally dispersed.

The Notes® discussion databases were designed with ease of use in mind. Participants accessed their own team database via a username and password, with no access rights to other teams' databases. The discussion databases were hosted on a server at one of the author-affiliated universities. All participants accessed their respective team database via a Web browser (e.g., Netscape Navigator). The Notes® databases were electronically opened and closed by the research team according to a predefined schedule. An example of a team database is shown in Figure 2.

Dependent Variables

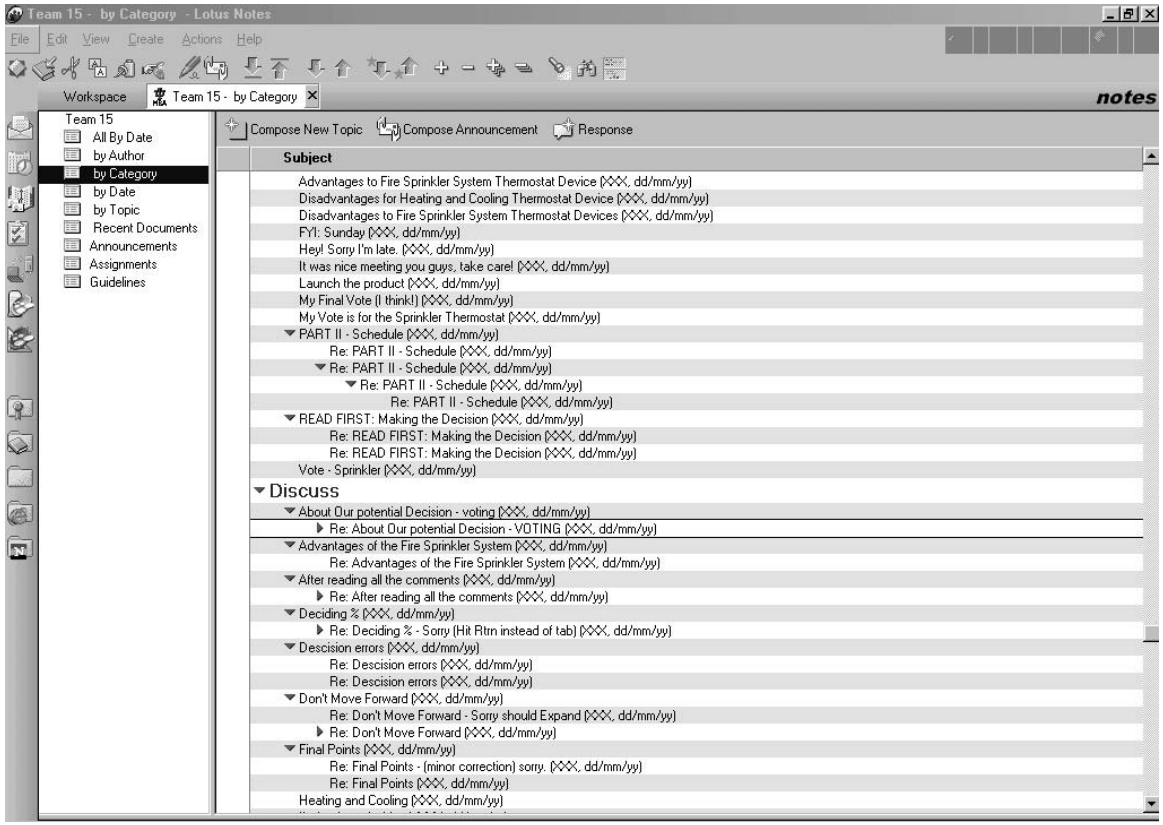
The dependent variables in both studies were: (1) likelihood of continuing to fund the NPD project; (2) assessment of the likelihood of the new product success in the market; and (3) self-reported commitment to the NPD project. The detailed measures are reported in Table 1.

It is important to note again that all of the project-related information presented to subjects at the project review points and in both studies was identical and indicated that the project was failing to perform at the mandated levels. Relative to our dependent variables, this means better decisions are indicated by lower inclinations to provide continued funding for the project, perceptions of lower expected success due to negative feedback, and lower levels of commitment to the failing project.

ANALYSIS AND RESULTS

To increase confidence in our measures and results, we conducted confirmatory factor analysis (maximum likelihood estimation procedures in EQS software, version 5.7b) to test the convergent and discriminant validity of the dependent variables at Stages 1 and 2. The results of the CFA indicate that the dependent variables are indeed separate constructs. We used repeated measures analysis of variance (ANOVA) to test our hypotheses. For the repeated measures ANOVAs, the stage of the NPD process (Gates 1 and 2 in Figure 1) was the within-subjects factor. The between-subjects factors were the DMU structures (individual versus team) in Study 1 and communication mode used by the NPD teams (face-to-face versus virtual teams) in Study 2. In the following sections, we discuss our ANOVA findings for Study 1 and Study 2. For completeness, we reanalyzed the data using repeated-measures MANOVA because we were concerned about the potential for increase in Type I error that results from using multiple univariate ANOVA analyses. The results of the MANOVA and ANOVA were identical with respect to the support for the research hypotheses. We report and discuss the results of the separate univariate repeated ANOVAs because we believe this is the more appropriate method. Huberty and Morris (1989) discussed situations when univariate analyses are more appropriate than multivariate analyses.

Figure 2: Example of a virtual team discussion database.



Study 1 Results

The results of Study 1 are presented in Figures 3 through 5. The between-subjects results were all highly significant ($p < .01$) in the hypothesized direction. These results show that, across the two stages of the NPD process, compared to individuals, decision-making teams are significantly: (1) less likely to recommend funding the NPD project (H1), (2) less likely to believe that the failing project will be successful (H2), and (3) less committed to the failing NPD project (H3). In sum, support was found for H1 through H3. These results suggest that teams are less likely to demonstrate escalation of commitment behavior at NPD project review points compared to individuals. Having found that teams make more effective NPD continuation decisions, we turn to Study 2 to examine how the mode of communication affects decision-making effectiveness for face-to-face versus virtual teams.

Study 2 Results

The results of Study 2 are presented in Figures 6 through 8. For Study 2, all of the between-subjects' results are highly significant ($p < .001$). Study 2 validates the major finding of Study 1 by showing that decision-making teams (both face-to-face and virtual) make significantly more effective NPD project review decisions compared to individuals. Duncan multiple range tests reveal a significant ordering effect ($p < .05$) for H1a, H2a, and H3a (See Figures 6, 7, and 8). These results indicate that virtual teams communicating via Lotus Notes® are least likely to recommend funding the failing NPD project. Teams that communicate face-to-face are the next least likely, and individuals acting alone are most likely to continue funding the failing NPD project (Figure 6). The same pattern of results was found for assessments of NPD success (Figure 7) and commitment to the failing project (Figure 8). Virtual teams performed most effectively, face-to-face teams were next most effective, and individuals were least effective.

Table 2 summarizes the results of both studies. All of the overall ANOVA models were significant and each of the six research hypotheses was supported.

Potential Covariates

To account for potential confounding variables that may have interacted with our main effects, we collected data from respondents regarding their gender, number of years of work and NPD experience, largest dollar amount they were responsible for allocating to a project, education level (e.g., undergraduate, masters, PhD), and types of college degrees earned (e.g., engineering/technical, marketing, finance/accounting). Also, since the virtual teams were on average larger in size than the face-to-face teams ($\bar{x}_{\text{virtual}} = 4.2$ versus $\bar{x}_{\text{ftf}} = 3.6$; $p < .05$), we statistically controlled for this.

All control and dependent variables exhibited low and statistically insignificant correlations with all other dependent variables ($p < .05$, two-tail). A covariate can improve the precision of data analysis only if it correlates with the dependent variables; the stronger the correlation, the more variance it explains. Despite the low correlations with the potential control variables, we reanalyzed the data using repeated-measures ANCOVA. Because the covariates did little to increase the amount of variance explained and were statistically insignificant, we do not report these results.

Figure 3: Study 1, H1 results.

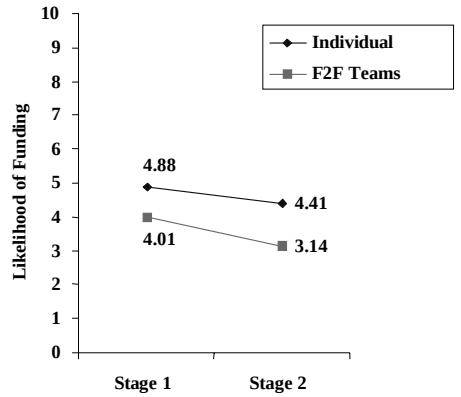


Figure 4: Study 1, H2 results.

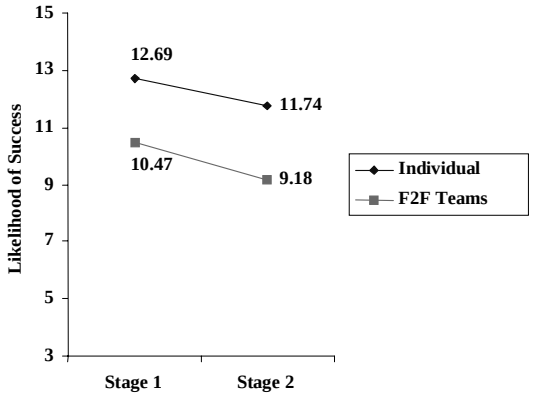


Figure 5: Study 1, H3 results.

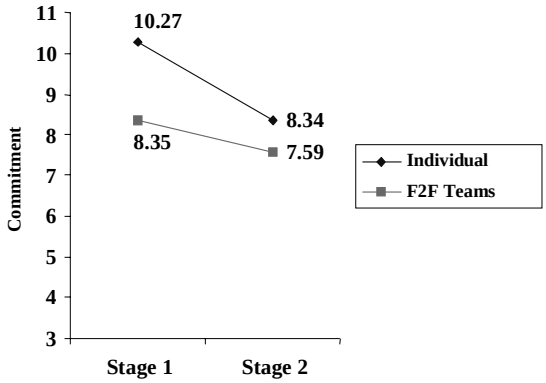


Figure 6: Study 2, H1a results.

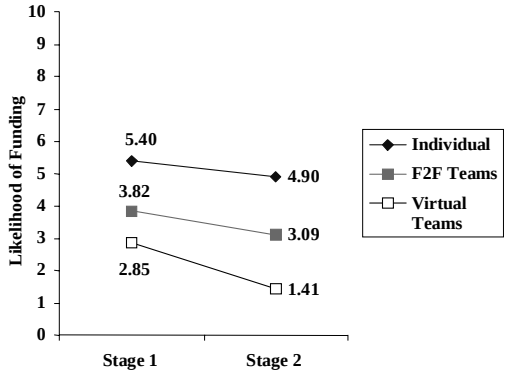


Figure 7: Study 2, H2a results.

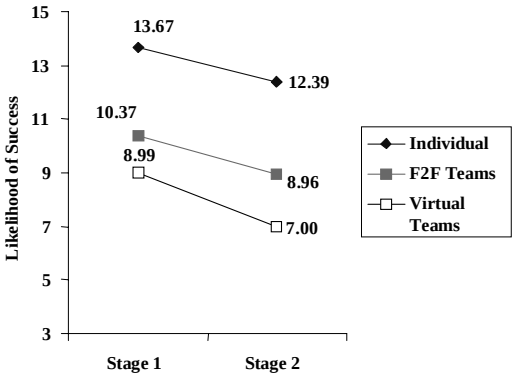


Figure 8: Study 2, H3a results.

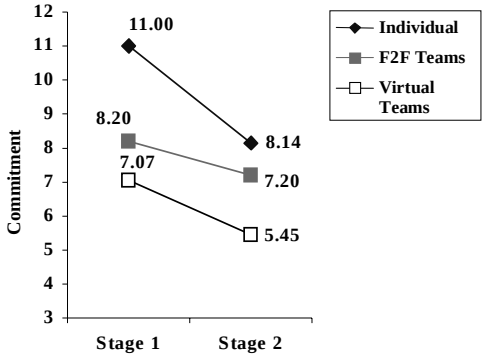


Table 2: Summary of results.

Hypothesis	Dependent Variable	Overall Model: *F* Statistic, *df*	Overall Model: Significance Level	Post Hoc Analysis*	Conclusion
Study 1 - Individuals Versus Face-to-Face Teams					
H1	Likelihood of Funding	(7.31, 1)	.007	n/a	Supported
H2	Likelihood of Success	(20.05, 1)	.000	n/a	Supported
H3	Commitment	(7.43, 1)	.007	n/a	Supported
Study 2 - Individuals Versus Face-to-Face Teams Versus Virtual Teams					
H1a	Likelihood of Funding	(23.27, 2)	.000	A > B > C	Supported
H2a	Likelihood of Success	(33.95, 2)	.000	A > B > C	Supported
H3a	Commitment	(14.80, 2)	.000	A > B > C	Supported

*****Duncan multiple range tests ($p \leq .05$). A = individuals; B = face-to-face teams; C = virtual teams.

DISCUSSION

In this research, we explored two related questions: (1) How does the structure of the DMU impact the effectiveness of NPD project review decisions? (2) What is the impact of the decision-making team's communication mode on the effectiveness of NPD project review decisions? The escalation of commitment literature has shown that individuals can continue to fund failing NPD projects under certain conditions. A primary purpose of this research was to determine whether NPD project review teams would be similarly inclined, and if technology alters NPD review team communication in such a way as to affect escalation tendencies. The way in which Lotus Notes® and other forms of groupware affect group dynamics and the outcomes of collaborative work remain largely unanswered questions (Warkentin et al., 1997). While exploratory in nature, the findings of our two studies provide several insights into how the structure of the DMU and communication technology can affect NPD project review decisions.

The main finding of this research suggests that decision-making teams, face-to-face and virtual, make NPD project review decisions more effectively than individuals acting alone. It appears that teams are less likely than individuals to continue projects whose outcomes appear dubious. The reason for this may be partly due to the fact that the teams in our study did a better job than individuals in estimating the chances for success and, therefore, became less committed to risky NPD projects. This finding complements research on NPD processes that has shown development teams to be more effective than individuals in performing NPD activities. We suggest that teams make more effective project review decisions due to the differing experiences, knowledge, and perspectives that each team member brings to the task at hand.

The second key finding is that virtual teams appear to make more effective NPD decisions compared to face-to-face teams. Two key factors help explain this finding. First, past research has considered various underlying social processes

that determine decision-making effectiveness and tendencies to remain committed to a losing course of action. However, most of this past research has considered face-to-face (same-time/same-place) teams. We posit that in virtual teams, the traditional social cues and mechanisms that facilitate human interaction and decision making are altered by the communication technology. The leanness and low social presence of the asynchronous communication environment posed by Lotus Notes® may have contributed to more focused and objective decision making in our study. Since decisional errors can be partially attributed to a breakdown in rationality as a result of social power or group dynamics (Staw, 1981), this may explain why the communication environment served to reduce the incidence of escalation of commitment behavior in our study.

Second, the three additional characteristics (rehearsability, parallelism, and reprocessability) of the asynchronous meeting environment of Notes® may have contributed to the increased effectiveness of decision making in the virtual teams in our study. In concert, these capabilities may have supported the virtual teams while performing the NPD decision tasks by enabling more effective information recall, exchange, and processing.

We believe that our study offers important insights that can contribute to the development of useful normative guidelines regarding how to structure the decision-making unit for NPD project review points and how to facilitate effective communication among team members. Our research findings suggest that teams make more effective NPD project continuation decisions, and for tasks such as ours, the effectiveness of teams can be heightened if the members communicate via technology rather than face-to-face.

Limitations and Future Research

As with virtually all research, the findings should be interpreted with caution due to certain limitations. One inherent limitation of this research and all escalation of commitment research that uses decision-making experiments is that the stakes are low in hypothetical situations (Garland, Sandefur, & Rogers, 1990). In the "real world," the outcomes are potentially more damaging to one's career, and the pressures to escalate commitment are greater (Brockner et al., 1986). However, our research design provided a unique opportunity to examine NPD decisions at project review points free from the influences of many other factors. Clearly, the use of graduate students as subjects limits the extent to which we can generalize our findings. While most of the participants had significant work experience or were presently working full-time, they are not completely representative of decision makers or management groups on actual NPD projects. The hypothetical task and the use of a groupware system was a unique experience for most participants. As research in this area continues, field research with organizational work groups will greatly expand our understanding of the effects of the DMU structure and communication mode on NPD decisions at project reviews.

As organizations increasingly resort to global NPD development teams and management review teams, many questions remain as to the impact of differences among participants (e.g., language, culture, functional background, conflicting values, commitment to the project) on communication and decision-making processes (McDonough et al., 1999; McDonough, Kahn, & Barczak,

2001). The student participants in this research were relatively homogeneous in their makeup. Clearly, future research should assess the external validity of this research and extend our findings to additional contexts. The propensity to escalate in NPD situations may not be the same in other contexts. Studying individual decision makers and management decision-making teams in organizational settings will enhance our understanding and generalizability.

Our findings generate many questions relative to virtual decision-making teams and the communication technologies that support them. While our findings suggest that virtual teams were more effective than face-to-face teams for NPD project review decisions, much research remains to be done. We do not know with certainty why teams make better decisions than individuals and why virtual teams make even better decisions. Within the traditional input-process-output framework of group work, this study may be characterized as one looking at relationships among select inputs (DMU structure and communication mode) and outputs (decision-making effectiveness). As an initial exploration, this study sheds light on project continuation (termination) decisions and the mechanism of escalation in NPD project review decision making. We drew on extant theory and research from the small group, escalation behavior and information systems areas to speculate about why we found differences and how the inputs may affect intervening group processes. Future empirical research is needed to focus on the mediating process factors in order to deepen our understanding of decisional and communication processes within NPD project review teams.

Virtual teams are not a panacea. Asynchronous communication does not duplicate the normal "give and take" of face-to-face discussion. Considerable delays may occur between the time a message is sent and the time a reply is received. While positive from a deliberation perspective, this may make it difficult to coordinate and maintain a discussion theme. Disjointed discussion and the use of more information may unnecessarily increase the time to reach a decision (Dennis et al., 1997-1998). In this study, the focus was on decision-making effectiveness in project continuation decisions, as opposed to the efficiency (or speed) of those decisions. In practice, it is the quality of the decisions at review points (that is, the tendency to escalate and continue failing projects) that tends to be the problem, as opposed to the timeliness of these decisions. Timeliness is often a problem in the development activities. In our research design, we eliminated any time pressure on the study participants because past research suggests that time pressure will change team behaviors and potentially affect outcomes (Jarvenpaa, Knoll, & Leidner, 1998; Moreland & Levine, 1992; McGrath, 1984). Future research should explore the effects of communication technology on the timing of decisions and how time pressures in general may affect the effectiveness of decision making at NPD project review points.

Past research has found that interaction in computer-mediated communication environments is more impersonal, more task oriented, more businesslike, and less friendly than in face-to-face settings. In our context, this may have lessened the potentially negative effects of normative influence by supporting the production function of the virtual decision-making team (McGrath, 1984). However, there is evidence that this creates a less satisfying experience for team members and slows the development of relational links among members (Chidambaram,

1996). Researchers have associated relational links with many positive outcomes including motivation, increased morale, better decisions, and fewer process losses (Walther & Burgoon, 1992). Developing relational links involves activities related to member support and team well-being (McGrath & Hollingshead, 1994; Warkentin et al., 1997). The importance of relational links to NPD project review teams is an important avenue for future research.

Finally, given that the virtual teams in our study did not have an opportunity to meet in person or communicate via synchronous media (e.g., teleconferencing, videoconferencing), we acknowledge that this limits generalizability. We partially took this approach because the use of asynchronous technology is increasingly commonplace when team members are geographically and temporally dispersed and travel budgets are cut. In addition, by limiting communication strictly to Lotus Notes®, we were able to investigate our hypotheses free from the influences of other media. However, information may appear to be less influential when contributed via such technology (Hollingshead, 1996), and in organizational settings, the credibility of the source of information can be important to the acceptance and processing of information. An important avenue for future research is to explore the effects of alternative media and mixed media use on NPD project review decisions.

CONCLUSION

NPD theories have emerged from same-place/same-time environments to provide a deeper understanding of effective NPD processes (Brown & Eisenhardt, 1995). While it is almost taken for granted today that cross-functional teams outperform individuals in development activities, little is known about the relative effectiveness of teams versus individuals in the context of NPD project review decisions. Our results suggest that teams make more effective NPD project continuation decisions than individuals. We believe that our research is an important step in understanding factors that impact the effectiveness of NPD project review decisions.

As organizations face increasing global competition, reduced product life cycles, mass customization, and the increased need to quickly respond to customers, more and more firms are managing the NPD process across temporal and geographic boundaries (McDonough et al., 1999). Yet, there is a paucity of research on dispersed virtual teams and the technologies that support them (cf. Fjermestad & Hiltz, 1998-1999), especially in the NPD context. Our results indicate that the effectiveness of decision-making teams at project review points is magnified when teams are dispersed and communicate through asynchronous media. We believe our research provides insights regarding how communication technology can be used to effectively support an important business process—new product development. [Received: May 9, 2000. Accepted: August 22, 2001.]

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APPENDIX

STAGE 1 SCENARIO

Due to long lead times, several pieces of machinery and other tooling necessary for the production of the new sensor have been ordered, and a few have already been received and installed in the factory. In addition, training of the production workers is nearly complete.

Stage 1 of the new product development process has just been completed. So far, $3.5 million has been spent on developing the new sensor. The *projected* performance information is presented below.

Projected annual sales:.....$24.5 million

Projected annual profits:.....$5 million

Projected market share: 25%

GATE 1 DECISION

You are (or Your Product Development Team is) responsible for determining if the product should be commercialized (launched) at a total cost of $12.0 million (for production, distribution, and marketing).

STAGE 2 SCENARIO

Stage 2 of the new product development process was completed 18 months ago at a total cost of $15.5 million. The *actual* performance information to date is presented below.

Actual annual sales: .....$17.1 million

Actual annual profits: .....($1.5 million) (loss)

Actual market share: 22%

GATE 2 DECISION

You are (or Your Product Development Team is) responsible for determining if the product should remain on the market at an annual cost of $500,000.

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