Compensatory Adaptation to Media Obstacles:
An Experimental Study of Process Redesign Dyads

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ABSTRACT

Past research on electronic communication media suggests that those media pose obstacles to communication in collaborative tasks when compared with the face-to-face medium. Yet, past research also points at mixed findings in connection with the quality of the outcomes of collaborative tasks, generally suggesting that the use of electronic communication media has no negative effect on those outcomes. A new theoretical framework building on human evolution theory, called compensatory adaptation theory, has been proposed to explain these contradictory findings. This study provides a review and test of compensatory adaptation theory. It investigates the impact of the use of an electronic communication medium on 20 business process redesign dyads involving managers and professionals at a large defense contractor, with a focus on cognitive effort, communication ambiguity, message preparation, fluency, and task outcome quality. The study suggests that even though the use of electronic communication media seemed to increase cognitive effort and communication ambiguity, it had a neutral impact on task outcome quality. These results appear to be an outcome of compensatory adaptation, whereby the members of the dyads interacting through the electronic communication medium modified their behavior in order to compensate for the obstacles posed by the medium, which is suggested by a decrease in fluency and an increase in message preparation. The results generally support predictions based on compensatory adaptation theory.

Keywords: biological influences; communication media; compensatory adaptation; computer-mediated communication; electronic communication; human factors

INTRODUCTION

Research on the effects of technologies on people in business settings has a long history. Within that research tradition, few research topics have received so much sustained attention over such a long period of time as "electronic communication" — that is, the study of communication through electronic media created by artifacts such as the telephone, fax, and computer. This area of inquiry has taken different forms and different names over the years, such as computer-supported cooperative work,

computer-mediated communication, groupware, group support systems, and more recently, a variety of "e" combinations (where "e" stands for "electronic") such as e-collaboration and e-commerce (Grudin, 1994; Davenport, 2000; Dennis, Carte, & Kelly, 2003; Fingar, Aronica, & Maizlish, 2001; Kock, Hilmer, Standing, & Clark, 2000; Kock, Davison, Ocker, & Wazlawick, 2001; Standing & Benson, 2000). While these different varieties present unique characteristics that identify them as distinct "research schools," they all share the same common interest in electronic communication tools and their effects on human behavior. The advent of the Internet, e-business, and the proliferation of low-cost computer networks and electronic communication tools have led to increased interest in research on how electronic communication media affect collaborative work in organizations.

The above interest is shared by the U.S. Department of Defense (DoD), where Internet-based computer networks have removed geographical and time constraints to collaboration among distributed process teams engaged in defense acquisition activities. With the growth of distributed acquisition process teams also comes the challenge of improving defense acquisition processes in a distributed manner, since new technologies, regulatory modifications, and other change drivers constantly push the DoD into rethinking and redesigning the way it procures, purchases, and internally distributes products and services. This can be accomplished through distributed and asynchronous process redesign groups supported by Internet-based electronic communication tools. Yet little is known about the effects of electronic communication media on process redesign groups, particularly in the defense sector. This study tries to fill this gap by conducting a preliminary investigation of the effects of electronic communication media on process redesign dyads (i.e., pairs) targeting defense acquisition processes.

This article is organized as follows. It first reviews different theoretical perspectives that seem contradictory, and that pertain to the adequacy of electronic communication as a full or partial replacement to face-to-face communication in organizational settings. Next, it discusses a new theory that tries to address those contradictions, namely compensatory adaptation theory. The theory is discussed particularly in connection with its two main theoretical principles of *media naturalness* and *compensatory adaptation*. The article then develops a set of hypotheses that are empirically tested through a field study of 20 business process redesign dyads involving managers and professionals at a large defense contractor, with a focus on cognitive effort, communication ambiguity, message preparation, fluency, and task outcome quality. The article concludes with a discussion of the findings and implications for practitioners.

RESEARCH BACKGROUND

It has long been theorized that the face-to-face communication medium possesses inherent characteristics that make it more appropriate for the conduct of a variety of collaborative tasks (Daft & Lengel, 1986; Graetz, Boyle, Kimble, Thompson, & Garloch, 1998; Sallnas, Rassmus-Grohn, & Sjostrom, 2000; Short, Williams, & Christie, 1976; Warkentin, Sayeed, & Hightower, 1997). This has led to the conclusion that the use of electronic communication media, which usually do not incorporate all of the elements present in the face-to-face communication medium (e.g., synchronicity, ability to convey tone

of voice and facial expressions) will lead to decreased *effectiveness* in communication interactions and thus to decreased quality of outcomes in collaborative tasks.

In the human-computer interaction literature, one field study in the early 1990s (Nardi et al., 1993) and two more recent experimental studies (Basdogan, Ho, Srinivasan, & Slater, 2000; Sallnas et al., 2000) provide compelling evidence supporting in part the above conclusions. The field study conducted by Nardi et al. (1993) on the use of video and audio conferencing systems in the operating room of a hospital is particularly interesting because it sheds new light on previous claims that the addition of a video channel (usually in the form of what the authors refer to as "talking heads") to an existing audio channel in an e-communication medium usually does not significantly enhance performance in collaborative tasks (see their paper for a review of previous research on the topic). Nardi et al. (1993) suggest that the results of previous studies might have been biased by technology operation and experimental design problems, and provide unequivocal evidence of the usefulness of video in addition to audio as a "cognitive effort reducer" in a variety of complex and fast-paced interactions between individuals involved in surgical procedures.

The experimental studies conducted by Basdogan et al. (2000) and Sallnas et al. (2000) provide additional support for the notion that the face-to-face communication medium possesses characteristics that make it particularly appropriate for the conduct of a variety of collaborative tasks. They examined the role of touch, or "haptic," feedback in the execution of collaborative tasks in distributed virtual environments. Both studies involved data collection and analysis regarding several pairs of individuals collaborating through a shared virtual environment to perform simple tasks with and without haptic feedback. Sallnas et al.'s (2000) study involved more subjects and higher task variety and complexity than Basdogan et al.'s (2000) study. The similarity of their findings is remarkable. Both studies found that haptic feedback significantly improved task performance, with Sallnas et al.'s (2000) study offering additional evidence linking a reduction in cognitive effort with haptic feedback: "[The analysis of the perceptions by subjects] suggests that it was easier to manipulate and understand the interface when the interaction was supported by haptic force feedback" (p. 474).

Two theories are well aligned with the above conclusions in connection, with the advantages offered by the face-to-face medium over electronic media (particularly media that suppress many of the elements found in face-to-face communication) in connection with variety of collaborative tasks. Those two theories are the social presence theory (Short et al., 1976) and the media richness theory (Daft & Lengel, 1986; Daft, Lengel, & Trevino, 1987).

Social presence theory (Short et al., 1976) conceptualizes different communication media along a one-dimensional continuum of "social presence," where the degree of social presence is equated to the degree of "awareness" of the other person in a communication interaction. According to social presence theory, communication is effective if the communication medium has the appropriate social presence required for the level of interpersonal involvement required for a task. On a continuum of social presence, the face-to-face medium is considered to have the most social presence, whereas written, text-based communication, the least.

Similarly to the social presence theory, media richness theory (Daft & Lengel,

1986; Daft et al., 1987) classifies communication media along a continuum of "richness," where richness is based on the ability of media to carry non-verbal cues, provide rapid feedback, convey personality traits, and support the use of natural language. A reasonable interpretation of the media richness theory's core argument is that decisions regarding matching media to collaborative tasks are based on the need to reduce discussion ambiguity. The face-to-face communication medium is generally considered as among the richest and most effective media for reducing discussion ambiguity (Daft & Lengel, 1986). In contrast, electronic communication media in general are not considered rich because of their inherent limitations in, for example, carrying non-verbal cues (Daft et al., 1987; Lee, 1994).

Many past empirical findings, particularly from the organizational research literature, have supported in part the social presence and media richness theories (Daft et al., 1987; Fulk, Schmitz, & Steinfield, 1990; Rice, 1993; Rice & Shook, 1990). However, among the key problems with the social presence and media richness theories was that they proposed theoretical links between low social presence and low richness, respectively, in communication media, and either: (a) avoidance by users to use those media for collaborative tasks; or (b) low quality of the outcomes of collaborative tasks, if the users decide to use those communication media (Daft et al., 1987; Lengel & Daft, 1988; Short et al., 1976).

Several empirical studies have suggested that these hypothesized theoretical links are wrong, particularly because other factors such as social influences and geographic distribution can both lead users to choose "lean" communication media and modify their behavior in ways that are independent of the degree of social presence or richness of those media and that compensate for problems associated with media "leanness" (Fulk et al., 1990; Lee, 1994; Markus, 1994; Ngwenyama & Lee, 1997). Other empirical studies led to mixed findings. For example, Baker's (2002) study, which compared the performance of 64 virtual teams utilizing four different types of communication media (text-only, audio-only, text-video, and audio-video), found no significant difference in the quality of decisions reached by teams interacting through text-only and audio-only media. However, the same study found that the addition of video to audio-only communication resulted in a significant improvement in the quality of teams' strategic decisions.

Inconsistencies such as the ones mentioned above led, over the years, to several attempts to develop more robust theoretical frameworks combining theoretical elements of the social presence and media richness theories with theoretical elements of theories that take into account other factors, such as social influences (Carlson & Zmud, 1999; Trevino, Webster, & Stein, 2000; Webster & Trevino, 1995). Other attempts tried to review the foundations of the social presence and media richness theories, and create more robust theories that could provide an alternative to the social presence and media richness theories. One such attempt led to the development of compensatory adaptation theory.

Compensatory Adaptation Theory

Compensatory adaptation theory (Kock, 1998, 1999, 2001a, 2001b) has been developed in part to explain the inconsistent findings discussed in the previous section, and in part to provide an alternative

theory that could overcome the limitations of the social presence and media richness theories. Compensatory adaptation theory argues that electronic communication media in general offer certain advantages, such as that of allowing for asynchronous and distributed group interaction, and at the same time, pose obstacles for communication in groups. In this respect, compensatory adaptation theory is similar to the social presence and media richness theories. The key difference is that compensatory adaptation theory attempts to provide a scientific basis for the existence of those obstacles, by arguing that they are primarily due to the fact that our biological communication apparatus, which includes specialized organs and brain functions, has been optimized by Darwinian evolution for face-to-face communication, incorporating five main elements — co-location, synchronicity, the ability to convey body language, facial expressions, and speech.

Evidence about the evolution of our biological communication apparatus suggests that during over 99% of our evolutionary cycle, our ancestors relied on co-located and synchronous forms of communication through facial expressions, body language, and sounds (including speech, which uses a large variety of sound combinations) to exchange information and knowledge among themselves (Boaz & Almquist, 1997; Cartwright, 2000). According to evolutionary principles, a plausible conclusion from this is that our biological communication apparatus was designed primarily to excel in face-to-face communication (Kock, Hassell, & Wazlawick, 2002). That is, since we have communicated only face-to-face during the vast majority of our evolutionary cycle, then our biological communication apparatus (which includes the brain modules involved in the sensing and control of our communication organs) must have been designed for face-to-face communication.

The above conclusion is supported by the presence of obvious face-to-face communication adaptations in our biological communication apparatus. For instance, evolution endowed human beings with a complex Web of facial muscles (22 on each side of the face; more than any other animal) that allow them to generate over 6,000 communicative expressions; very few of these muscles are used for other purposes, such as chewing (Bates & Cleese, 2001; McNeill, 1998). The existence of such a complex Web of muscles would appear to have been a major waste, had we not been designed to use them extensively while communicating with others.

The evolutionary path that led to our species also suggests a noticeable evolutionary direction over millions of years toward the development of a biological communication apparatus that supported even more sophisticated forms of speech, culminating with the development of complex speech approximately 100,000 years ago. The advent of complex speech was enabled by the development of a larynx located relatively low in the neck and an enlarged vocal tract — key morphological traits that differentiate modern humans from their early ancestors and that allow modern humans to generate the large variety of sounds required to speak most modern languages (Laitman, 1984, 1993; Lieberman, 1998). The morphology of the human ear also suggests a specialized design to decode speech (Lieberman, 1998; Pinker, 1994). The adaptive importance of speech for human beings is highlighted by the fact that our enlarged vocal tract also makes us the most likely among all primates to choke on food and ingested liquids.

The Media Naturalness Principle

The evolution of closely matched brain and body functions, which follows from the widely held brain-body co-evolution law of modern evolution theory (Lieberman, 1998; Wills, 1989, 1993), provides a scientific basis for the apparent bias toward face-to-face communication hypothesized by the social presence and media richness theories, and is reflected in compensatory adaptation theory's *media naturalness principle*. The principle states that individuals who choose to use electronic communication tools experience increased cognitive effort and communication ambiguity proportionally to the degree to which the tools suppress elements that are present in face-to-face communication (e.g., synchronicity, ability to convey/perceive non-verbal communication cues). The principle is task independent, that is, it applies to all collaborative tasks, even though it acknowledges that the link is less noticeable in tasks that do not involve intense communication which are seen as tasks that involve little knowledge sharing among collaborators (Kock, 2001b).

The media naturalness principle links the use of electronic communication media with high cognitive effort and communication ambiguity, but not necessarily with specific task-related outcomes. In doing so, it explains empirical findings that supported in part the social presence and media richness theories (Daft et al., 1987; Fulk et al., 1990; Rice, 1993; Rice & Shook, 1990), while at the same time avoiding the problems associated with making predictions about media choice or task-related outcomes based on communication media traits, which led to criticism by social researchers (El-Shinnawy & Markus, 1998; Kinney & Watson, 1992; Kock, 1998; Lee, 1994; Markus, 1994). For example, the media naturalness principle is compatible with the notion that social influences can lead users to modify their behavior (Markus, 1994; Lee, 1994; Ngwenyama & Lee, 1997) in ways that are independent of the apparent degree of naturalness of a medium, even though the cognitive effort required for this to happen will be higher than if a more "natural" communication medium (i.e., the face-to-face medium) were used.

The above discussion is compatible with the notion that electronic communication tools are artifacts developed to solve specific problems, but they also add new problems of their own (Ellis, Gibbs, & Rein, 1991; Nunamaker, Dennis, Valacich, Vogel, & George, 1991; Nunamaker, Briggs, Mittleman, Vogel, & Balthazard, 1997; Walther, 1996). There seems to be a general pattern of gains due to the use of electronic communication tools to relate to group *efficiency*, such as higher number of ideas generated per unit of time (Dennis, Haley, & Vanderberg, 1996; Nagasundaram & Bostrom, 1995) and lower costs associated with running groups (Kock, 2000), even though sometimes losses occur in connection with obstacles to group *effectiveness*, such as less commitment toward group decisions due to lower group cohesiveness and satisfaction (Ellis et al., 1991; Nunamaker et al., 1991; Walther, 1996).

While it is intuitive to think that obstacles to high group effectiveness invariably lead to lower quality of group outcomes, there is a wealth of evidence from fields as diverse as biological anthropology (Dobzhansky, 1971) and analytical psychology (Jung, 1968) suggesting that human beings voluntarily and involuntarily compensate for obstacles posed to them, in some cases overcompensating for those obstacles and achieving even better outcomes than if the obstacles were not present

(Kock, 1998). This compensatory adaptation phenomenon has the potential to contradict deterministic predictions linking negative communication media influences on group effectiveness with low group outcome quality. Kock (1998, 1999) obtained empirical evidence of this compensatory adaptation phenomenon in the context of electronic communication in a study that compared groups performing complex and knowledge-intensive tasks over e-mail and face-to-face. The e-mail medium was consistently seen by group members as less appropriate than the face-to-face medium to accomplish the tasks. Yet, the tasks accomplished through e-mail yielded outcomes that were perceived as being of slightly better quality than those produced by the face-to-face groups.

Compensatory Adaptation Principle

Compensatory adaptation theory argues that users of electronic communication tools present two common patterns of reaction toward those tools. Firstly, users of electronic communication tools in general perceive those tools as creating communication media that pose cognitive obstacles to communication when compared with the face-to-face medium (Kock, 2001a, 2001b), as proposed by the media naturalness principle discussed above. That is, even though electronic communication tools may reduce or eliminate physical obstacles to face-to-face communication — for example, e-mail and instant messaging allow people to communicate instantly over long distances — they also increase the cognitive effort required to communicate information and knowledge. The second common pattern of reaction is one of compensation for the obstacles posed by the media (Kock, 1998, 1999), which is embodied in the theory's *compensatory adaptation principle*. The principle states that individuals who choose to use electronic communication media tend to *compensate* for the cognitive obstacles they perceive as associated with the lack of naturalness of those media, which leads those individuals to generate, when engaged in collaborative tasks, outcomes of the same or better quality than if they had interacted solely face-to-face.

So, in summary, compensatory adaptation theory argues, in an apparently paradoxical way, that obstacles posed by electronic communication media will have no negative effect on the quality of group outcomes as individuals engaged in collaborative tasks attempt to (often involuntarily) and often succeed in compensating for them. Since electronic communication media offer some advantages over the face-to-face medium, such as the possibility of asynchronous and non-collocated interaction, the compensatory adaptation theory argument, based on the two complementary theoretical principles of *media naturalness* and *compensatory adaptation* just discussed, seems to support the paradoxical notion that "less can be more," so to speak.

Hypotheses

As it can be inferred from the review of compensatory adaptation theory presented in the previous section, the theory takes a somewhat general view of collaborative tasks, and does not refer to any collaborative task in particular. This places compensatory adaptation theory in a good position to be tested, and potentially falsified, according to Stinchcombe's (1968) principle of empirical testing variety. That epistemological principle maintains that a theory's validity can be best tested when a variety of predictions regarding related

empirical results can be derived from the theory. In other words, the more independent corroborations are made of the theory's basic propositions under different circumstances, the more likely it is that those propositions are generally correct.

The application of Stinchcombe's (1968) principle of empirical testing variety is illustrated in this study by the choice of two related collaborative tasks as the bases for an empirical test of compensatory adaptation theory, which should be seen as an initial step in testing the theory, and one of many (future) empirical tests of the theory. The related tasks are those of process modeling and redesign, whereby individuals respectively: a) create a model of a particular organizational process; and b) based on the model created, conceptually redesign the process so that improvements in quality and productivity can be achieved. For the sake of simplicity in formulating testable hypotheses, the two related tasks are referred in this section as one main "process redesign" task. This is consistent with current organizational practices, where process modeling is usually seen as part of the larger task of process redesign.

Compensatory adaptation theory's media naturalness principle states that electronic communication media in general, which are assumed to suppress some of the elements of face-to-face communication, cause higher cognitive effort in connection with communication interactions than the face-to-face medium. The reason for this increase in cognitive effort is, according to compensatory adaptation theory, that evolutionary forces shaped our biological communication apparatus so that we excel in face-to-face communication. Because of the suppression of elements that are found in typical face-to-face communication interactions, in electronic communication our brain cannot make use of certain hardwired communication circuits (e.g., those aimed at speech generation and recognition), and thus must rely on other, less efficient learned brain circuits (e.g., those developed through use-induced learning of electronic communication tools). This argument, which is explored in more detail by Kock (2002) and is only summarized here, leads us to hypothesis H1.

H1: The use of an electronic communication medium by process redesign dyads will increase the level of cognitive effort experienced by the members of the dyads.

When individuals are brought up in different cultural environments, they invariably develop different information processing schemas over their lifetimes. Different schemas make individuals interpret information in different ways, especially when information they expect to receive is not actually provided. This phenomenon was originally demonstrated by Bartlett (1932) through a series of experiments he conducted involving the American Indian folk tale "The War of The Ghosts," which is well known among experimental psychologists for its strange gaps and bizarre causal sequences. The experiments yielded evidence that subjects who held different information processing schemas interpreted the tale in substantially different ways and according to their specific cultural schemas. Individuals were expecting certain pieces of information to be provided to them in Bartlett's (1932) experiments. When they were not provided with the information they expected to receive, those individuals "filled in the gaps" based on their existing information processing schemas and the limited information that they were given (see also Gardner, 1985). This conclusion provided a solid foundation on which to explain key

differences in the way different individuals interpreted the tale.

Several generic problems have occurred recurrently during the millions of years that led to the evolution of the human species (e.g., how to identify a fruit that is rich in certain minerals), and the human brain possesses a series of hardwired information processing schemas that are designed to solve those problems (Cosmides & Tooby, 1992; Tooby & Cosmides, 1992). Several of those problems have been addressed by evolutionary adaptations that are associated with the communication process (Pinker & Bloom, 1992). Those adaptations have led to the development of hardwired schemas tied to the communication process that make us search for enough information to effectively interpret the message being communicated, and that information comes to us through several of the stimuli that are present in actual face-to-face communication (Lieberman, 2000), such as contextual cues (available in co-located communication) and immediate feedback (available in synchronous communication) in the form of facial expressions, body language, and voice intonations. When many of those stimuli are absent, which may be caused by their selective suppression through e-communication technologies, one would expect that e-communication technology users will "fill in the gaps" in a manner similar to what the subjects in Bartlett's (1932) experiments did.

However, in the absence of information-giving stimuli, "filling in the gaps" is likely to lead to a higher proportion of misinterpretations, and thus ambiguity, than if the stimuli were not suppressed — as Bartlett's (1932) and other studies show (see, e.g., Gardner, 1985; Pinker, 1997). Given the general similarity of the biological apparatus shared by different individuals, it is likely that they will look for the same types of communicative stimuli. Yet, given their different information processing schemas, their interpretation of the message being communicated in the absence of those stimuli is likely to differ from the interpretations reached at by other individuals. This leads to the conclusion that a decrease in medium naturalness, caused by the selective suppression of media naturalness elements in a communication medium, is likely to lead to an increase in the probability of misinterpretations of communicative cues and thus an increase in *communication ambiguity*. This leads us to hypothesis H2.

H2: The use of an electronic communication medium by process redesign dyads will increase the level of communication ambiguity experienced by the members of the dyads.

The compensatory adaptation principle of compensatory adaptation theory argues that individuals that choose to use electronic communication media for communication try to compensate for the cognitive obstacles they perceive as associated with the lack of naturalness of those media. This behavior is posited by the theory to be a natural and often involuntary reaction to the perception of cognitive obstacles posed by electronic communication tools in general, as stated in the media naturalness principle. Previous exploratory research (Kock, 1998, 1999, 2001c) suggests that this compensatory adaptation behavior is indicated by at least two behavioral patterns — more careful preparation of communication messages and decreased communication fluency (which is defined as the number of words per unit of time conveyed through the medium). This takes us to hypotheses H3 and H4.

H3: The use of an electronic communication medium by process redesign dyads will lead to increased preparation of communication messages by the members of the dyads.

H4: The use of an electronic communication medium by process redesign dyads will decrease the fluency displayed by the members of the dyads.

Finally, compensatory adaptation theory argues that compensatory behavior usually leads individuals to compensate for the obstacles posed by electronic communication media of low naturalness, which often leads to outcomes of the same or better quality than those achieved through more natural media. This provides the basis for hypothesis H5.

H5: The use of an electronic communication medium by process redesign dyads will have no negative effect on the quality of the outcomes produced by the members of the dyads.

In summary, we could say that the set of hypotheses above comprises the essence of compensatory adaptation theory and thus provides the basis for a valid test of the theory. Underlying the theory is the notion that communication media that suppress key face-to-face communication elements pose obstacles to communication, leading to increased cognitive effort (H1) and communication ambiguity (H2). Nevertheless, the theory also argues that these obstacles will trigger compensatory adaptation mechanisms, indicated by increased preparation of communication messages (H3) and decreased fluency (H4). This will, according to the theory, lead to compensation and, in what appears to be a counterintuitive twist, no negative effect on the quality of outcomes in connection with a process redesign task (which arguably requires intense communication) performed electronically (H5).

Research Method

The hypotheses were tested through a field experiment employing a repeated measures design where the communication medium used varied according to two experimental conditions: face-to-face and electronic. The impact of changes in the communication medium factor on a set of dependent variables was assessed by means of multiple ANOVA tests (Green, Salkind, & Akey, 1997; Rosenthal & Rosnow, 1991).

Participants and Treatment Conditions

The research study involved subjects with substantial hands-on experience in process redesign in the defense sector, recruited from management and engineering ranks of a large defense contractor. All of the subjects were college educated, and most held undergraduate degrees in business, computer science, or engineering. The subjects were familiar with each other and with the electronic communication medium used prior to their participation in this field experiment. However, they had no prior experience using the electronic communication medium for the collaborative completion of tasks of the same type as, or even similar complexity to, the experimental task. Their ages ranged from 23 to 60, with a mean age of 35. Fifty-nine percent of the subjects were males.

The subjects were randomly assigned to dyads and to communication media conditions. Each dyad completed two similar process redesign-related tasks using different communication media for each task. Half of the dyads (i.e., 10 dyads) completed

one of the tasks face-to-face, while the other half completed the same task electronically. After this, all dyads moved on to the next task, using different media than they had used in the previous task — that is, the dyads previously interacting face-to-face now interacted electronically and vice versa. This led to the collection of research data in connection with 40 cases of dyads performing the same type of collaborative task.

Electronic Communication Medium

A set of Web-based threaded online discussion boards created the electronic communication media employed in the experiment. The online discussion boards were developed using Microsoft FrontPage 2000 and Active Server Pages. They were used in a quasi-synchronous manner — that is, they were "refreshed" at short time intervals, creating an online chat-like environment where the discussions were threaded. One Web-based online discussion board was created for each dyad. All online discussion boards were identical.

Tasks

Two experimental tasks were used, which can be seen as being of the same general type and also as subtasks of a larger process redesign task. Both tasks were developed based on a "real" process redesign project previously reported by Kock and Murphy (2001) that targeted the process whereby the U.S. Department of Defense procured and purchased complex software development services. Since that real project was a successful process redesign project and experts evaluated its outcomes and found them to be optimal, it was assumed that those outcomes should serve as a basis for comparison with the outcomes produced by the participants in our field experiment. In other words, we employed two hidden-profile tasks in our field experiment (see, e.g., Dennis, Kinney, & Hung, 1999).

In the first task, which involved process modeling, participants were given different pieces of information about a defense acquisition process and were asked to develop a full graphical model of the process using a set of pre-defined symbols (see Appendix A for a more detailed description of the process modeling task). Both pieces of information initially received by each of the members of the dyad were necessary for the generation of the full graphical model of the process (see Appendix C for the expected outcome).

In the second task, which involved process redesign, participants were given different sets of guidelines about how to redesign the process modeled in the previous task and were asked to develop a graphical model of the process after the application of all the redesign guidelines, using the same set of symbols employed in the previous task (see Appendix B for a more detailed description of the process redesign task). Both sets of guidelines initially received by each of the members of the dyad were necessary for the generation of the graphical model of the redesigned process (see Appendix D for the expected outcome).

Procedure

After the participants were randomly assigned to dyads and each dyad was randomly assigned to one of the two communication media conditions, the participants received a general orientation about the tasks and went through a 15-minute "refresh" session on process modeling and redesign.

The dyads were then given 40 minutes to complete the process modeling task, after which each member of the dyads handed in their initial process model (sketch) to an experiment facilitator and completed a questionnaire. After a short break, the dyads (now interacting through different communication media) were given 40 minutes to complete the second process redesign task, after which each member of the dyads handed in their redesigned process model (sketch) to an experiment facilitator and completed a questionnaire (the same questionnaire completed at the end of the process modeling task). No dyad was able to complete its task in less than the time allocated (40 minutes); a few dyads appeared to have completed their work in slightly less than 40 minutes, but nevertheless decided to use the remaining time to perfect their sketches.

Measures

The dependent variables were cognitive effort (H1), communication ambiguity (H2), message preparation (H3), fluency (H4), and task outcome quality (H5). The following variables were measured at the individual level of analysis (thus based on 40 data points) through one-item, perception-related questions (see Appendix F): cognitive effort, communication ambiguity, message preparation, and task outcome quality. The remaining variable, fluency, was measured at the dyadic level of analysis (based on 20 data points).

The question-statement and scale for the cognitive effort variable was based on NASA's task load index (a.k.a., NASA-TLX) developed by Hart and Staveland (1988). The question-statements for communication ambiguity and message preparation were based on a focus group discussion with the participants, conducted prior to the experiment, in which the meaning of the construct's communication ambiguity and message preparation and the proper wording of related questions (to be answered on a seven-point Likert-type scale) were agreed upon. Rosenthal and Rosnow (1991) suggest the test-retest method as an alternative method for reliability assessment, which is a convenient alternative when single-item measures are used since component reliability cannot be computed. Following that suggestion, the instrument comprising the single question-statements for each variable was assessed through the test-retest method with two similar "dummy" process redesign projects conducted two weeks apart. That assessment yielded acceptable results (alpha = .88).

As proposed by Kock (1998), fluency was measured by counting the number of words exchanged by the members of the dyads and dividing it by the number of minutes each dyad took to complete the task (40 minutes for all dyads), yielding a measure of the number of words per minute exchanged by the dyads. These measures were obtained based on four videotaped face-to-face dyad sessions (two for the process modeling and two for the process redesign task) and 10 electronic dyad sessions (five for the process modeling and five for the process redesign task).

Task outcome quality was measured by comparing the process sketches generated by the dyad members with the "correct" models (see Appendix C and Appendix D)—that is, the models generated based on the successful process redesign project team studied by Kock and Murphy (2001). Two different coders generated these "similarity scores" used to assess task outcome quality independently. The scores were generated based on criteria addressing syntactic as well as semantic correctness of

Table 1a. Descriptive statistics and one-way ANOVA results for all variables but fluency

Variable	Mean face-to-face	St. dev. face-to-face	Mean electronic	St. dev. electronic	F	*p*
Cognitive effort	55.01	20.23	77.76	25.12	9.94	< .01
Communication ambiguity	2.47	1.55	4.44	2.00	12.11	< .01
Message preparation	2.99	1.78	4.41	1.79	6.34	< .05
Task outcome quality	4.06	1.69	3.91	1.61	.09	.77

Table 1b. Descriptive statistics and Mann-Whitney U test results in connection with fluency

Variable	Mean face-to-face	St. dev. face-to-face	Mean electronic	St. dev. electronic	Z	*p*
Fluency	71.01	15.75	16.58	5.93	-2.83	< .01

the sketches. Inter-coder reliability was high (alpha = .91).

Analysis Results

Table 1a summarizes one-way ANOVA statistics as well as means and standard deviations in connection with all variables but fluency. Since fluency data did not conform to assumptions underlying ANOVA (e.g., the number of data points was different for each treatment condition), a Mann-Witney U test (a nonparametric technique — see, e.g., Siegel & Castellan, 1998) was employed; its results are summarized in Table 1b.

The analyses of variance yielded statistically significant results in connection with cognitive effort: $F(1, 38) = 9.94$, $p < .01$; communication ambiguity: $F(1, 38) = 12.10$, $p < .01$; and message preparation: $F(1, 38) = 6.34$, $p < .05$. Participants generally perceived cognitive effort, communication ambiguity, and message preparation to be higher in the electronic communication than in the face-to-face condition, which provides general support for H1, H2, and H3.

The Mann-Whitney U test yielded statistically significant results in connection with fluency: $Z = -2.83$, $p < .01$. Fluency was significantly lower in the electronic communication than in the face-to-face condition, falling below what the "typing-versus-speaking effect" would allow us to expect (i.e., typing is inherently slower than speaking; see McQueen, Payner, & Kock, 1999, for a review of studies that addressed this effect). Given that the participants used computers for preparation of written documents on a daily basis, the "typing-versus-speaking effect" would allow us to expect the fluency over the electronic communication medium to be, on average, no less than half the fluency face-to-face (or about 36 words per minute; see McQueen et al., 1999). Thus, the actual fluency in the electronic communication medium (16.58 words per minute) provides general support for H4.

The analyses of variance yielded statistically insignificant results in connection

with task outcome quality: $F(1, 38) = .08$, $p = .77$. That is, there was no significant difference in the quality of the outcomes generated by the members of the dyads across different communication media conditions, which provides general support for H5.

DISCUSSION

This study suggests that the use of a Web-based threaded online discussion board by dyads redesigning a defense acquisition process, when compared with the face-to-face medium, increased perceived cognitive effort by about 41%, perceived communication ambiguity by about 80%, and perceived message preparation by about 47%, while at the same time reducing actual fluency by approximately 77%. The study also suggests that the use of the Web-based threaded online discussion board had no significant impact on the quality of the outcomes generated by the dyads.

Since the hypotheses tested through this study were derived from compensatory adaptation theory, and were generally supported by the evidence, we can conclude that the study overall supports compensatory adaptation theory. In particular, the marked increases in perceived cognitive effort and communication ambiguity provide support for the theory's media naturalness principle. At the same time, the significant increase in perceived message preparation and the drastic reduction in "fluency," coupled with the neutral impact on the quality of the outcomes generated by the dyads, provide strong support for the compensatory adaptation principle.

As previously discussed, many doubts have been raised by researchers (e.g., Fulk et al., 1990; Lee, 1994; Markus, 1994; Ngwenyama & Lee, 1997) in connection with media richness theory. Given those doubts, it seems plausible to explore the possibility that compensatory adaptation theory can replace media richness theory, perhaps with some advantages. This would probably require an expansion of compensatory adaptation theory so that specific predictions could be made in connection with particular types of tasks (Zigurs & Buckland, 1998), and could prove to become a fertile line of theoretical research given the influence that media richness theory has continually exerted on electronic communication research (Allen & Griffeth, 1997; Carlson & Zmud, 1999; Dennis & Kinney, 1998; Dennis & Valacich, 1999; Jackson & Purcell, 1997).

The potential for compensatory adaptation theory to replace media richness theory is highlighted by the fact that it explains findings of this study, which arguably supports one of the notions seen by researchers (Carlson & Zmud, 1999; Jackson & Purcell, 1997; Rice, 1992) as validating in part media richness theory (i.e., that the face-to-face medium is perceived by users as generally "richer" than electronic communication media); at the same time, compensatory adaptation theory can be used as a basis on which one can explain findings that generally contradict one of the key predictions of media richness theory — that groups interacting through a relatively "lean" medium invariably produce outcomes of lower quality than groups interacting through "richer" media.

Some researchers may argue that the findings of this study may be interpreted differently, and be seen as supporting in part media richness theory and pointing at ways in which that theory could be revised to incorporate such notions as that of social influence (Fulk et al., 1990) and common ground (Clark & Brennan, 1991). Fulk et al.'s (1990) social influence model provides the basis from which to predict that social

influences, such as peer pressure, can lead to the use of a "lean" medium, even though media that are perceived as richer (e.g., face-to-face, telephone) may be available. That could lead individuals to develop common ground (Clark & Brennan, 1991) elements (e.g., mutual knowledge, shared beliefs, goals and attitudes, etc.) in connection with the use of a "lean" medium to support a particular collaboration task, or a task of collaborative type. This could, in turn, lead to a "channel expansion" phenomenon (Carlson & Zmud, 1999), where both the perceived and actual richness of the medium would be increased by the development of common ground elements. Such plausible alternative interpretation is analogous to that proposed by Carlson and Zmud (1999) in connection with their channel expansion theory. Therefore, future research should consider the possibility that compensatory adaptation theory is not the best theoretical framework to explain this study's findings, even though there are some indications that this may be the case. Such skepticism and theoretical neutralism is likely to lead to greater progress than the narrower view of compensatory adaptation as a sort of "grand theory" (which it is unlikely to be).

Much of the past research on behavior toward electronic communication tools has focused on individual choice of communication media and, to some extent, the outcomes produced by individuals engaged in collaborative tasks. While that research has led to mixed findings, it nevertheless suggests that behavior toward electronic communication tools is both complex and, notwithstanding much research done in the area, somewhat unpredictable (DeSanctis, Poole, Dickson, & Jackson, 1993; Postmes, Spears, & Lea, 1998; Sallnas et al., 2000). Research findings that appear to be somewhat contradictory have supported predictions based on theories that emphasize characteristics of the communication medium (Short et al., 1976; Daft & Lengel, 1986), as well as theories that emphasize social influences (Fulk et al., 1990; Lee, 1994; Markus, 1994; Ngwenyama & Lee, 1997), which have often been seen as competing types of theories (Trevino et al., 2000; Webster & Trevino, 1995). Underlying this debate between advocates of communication media and social influence theories is a set of puzzling findings, which can be summarized into two main groups of findings: a) that the face-to-face medium is consistently perceived by individuals as a very appropriate communication medium for a variety of collaborative tasks (Daft et al., 1987; Rice, 1992; Markus, 1994; Rice & Shook, 1990; Walther, 1996); and b) that this perception has often been contradicted by the choice of communication media different from face-to-face by individuals conducting collaborative tasks (Lee, 1994; Markus, 1994; Ngwenyama & Lee, 1997) and by those individuals sometimes producing the same or better quality task outcomes than individuals interacting primarily face-to-face (Kock, 1998).

The study described in this article makes an important theoretical contribution that can be used as a basis for reconciling the competing findings above. It does so by providing evidence that generally supports a new theory, compensatory adaptation theory, which builds on the contemporary version of Darwin's (1859) evolution theory. In spite of the caveat presented above regarding the possibility of alternative theoretical explanations that are different from those of compensatory adaptation theory, it is not unreasonable to argue that this article shows beyond much doubt that compensatory adaptation theory has the potential to explain the puzzling and contradictory findings discussed above, and

provide a new basis for future research on electronic communication.

CONCLUSION

Much of the past research on electronic communication media suggests that those media pose obstacles to communication when compared with the face-to-face medium. Yet, past research also points at mixed findings in connection with the quality of the outcomes of tasks, suggesting that the use of electronic communication media has no negative effect on them. A new theoretical framework, called compensatory adaptation theory, has been proposed to explain these contradictory findings. This study provides a test of compensatory adaptation theory by investigating the impact of the use of an electronic communication medium on 20 business process redesign dyads involving managers and professionals at a large defense contractor, with a focus on cognitive effort, communication ambiguity, message preparation, fluency, and task outcome quality.

This study suggests that even though electronic communication media use in process redesign dyads involving managers and professionals seemed to increase cognitive effort and communication ambiguity, that use had a neutral impact on task outcome quality. These results appear to be an outcome of compensatory adaptation, whereby the members of the dyads interacting through the electronic communication medium modified their behavior in order to compensate for the obstacles posed by the medium, which finds confirmatory support from a marked decrease in fluency and an increase in message preparation. The results generally support predictions based on compensatory adaptation theory.

The findings above provide a new basis on which users of electronic communication tools can understand why tools that seem to make communication more difficult can still lead to no impact on the effective use of those tools for communication about complex issues. It is important for electronic communication tool users to understand the phenomenon of compensatory adaptation, particularly because its paradoxical nature may lead those users to believe that outcomes of collaboration tasks are not negatively affected by the use of electronic communication tools because of the tools' effectiveness in supporting communication interactions. This will probably lead to frustration when those users realize that "good [electronic] communication requires hard work" (see Bartlett, 2001, p. 1).

Nevertheless, one implication of this study for practice is that individuals collaborating electronically to accomplish complex and knowledge-intensive tasks such as process redesign can expect to be successful, even when the tasks are conducted entirely electronically. In light of the emergence of the Internet as a key enabler of communication in organizational processes, and the consequent multiplication of organizational forms characterized by their low dependence on physical structures for employee interaction, such as the so-called "virtual organizations" (Barnatt, 1995; Davidow & Malone, 1992), this is not only good news for organizations, but also provides the basis on which to call for increasing use of electronic communication media to support a variety of types of group tasks, ranging from routine group tasks, where the use of electronic communication media is already relatively common, to more ad-hoc (or project-based) ones, where the use of electronic communication media is still rare.

However, the extra "cost" imposed on individuals who wish to communicate electronically, rather than face-to-face,

about complex issues is an important issue that must be addressed in further research. As posited by the media naturalness principle and indicated by this study, compensatory adaptation is associated with "working hard" to compensate for increases in cognitive effort and communication ambiguity. That is, compensatory adaptation has "a price." One possible negative consequence of this finding, not addressed by this study, could be avoidance by group members to participate in future electronic groups after their initial experience, as they would become increasingly aware of the extra cognitive effort required of them. This could have an overall negative impact on the use of electronic media by organizations to support organization-wide initiatives, such as process redesign programs aimed at enabling organizations to obtain quality or productivity certifications. Perhaps the education about users of electronic communication technologies about compensatory adaptation would allow them to understand the extra "cognitive price" that they have to pay, and thus mitigate their negative perceptions about the use of those technologies to accomplish complex and knowledge-intensive collaborative tasks.

Another alternative to address the issue above is to break down complex tasks such as process redesign into subtasks, and use different communication media to support those subtasks. Prior research has shown that the amount of knowledge transfer involved in a communication interaction correlates the perceived difficulty in interacting through non-face-to-face media (Kock, 1998). Therefore, subtasks could be classified according to the amount of knowledge transfer involved, and assigned different communication media, where the degree of similarity of each medium to the face-to-face medium should be matched with the amount of knowledge transfer needed for effective completion of each subtask. That is, for high knowledge transfer subtasks, media that is very face-to-face-like (e.g., videoconferencing) should be used, whereas for low knowledge transfer subtasks, media that incorporate few of the elements found in face-to-face communication (e.g., e-mail) could be used. Following Kock and Davison's (2003) conceptual formulation, high knowledge transfer subtasks are defined here as those that involve process-related explanations and related associative assertions (e.g., explanations of why a certain car assembly process is designed the way it is), rather than only descriptions of process attributes (e.g., the current production capacity of a car assembly process). This matching of subtasks and media is likely to become increasingly common in industry, as new electronic communication tools are developed to support specific types of tasks. In fact, from a long-term perspective, this may become one of the most common approaches to effectively employ electronic communication tools in organizations in general.

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APPENDIX A

Process Modeling Task

The U.S. Department of Defense (DoD) routinely acquires software development services from several companies, including Lockheed Martin and Computer Sciences Corporation. Our task involves the redesign of a hypothetical business process, called the Software Services Acquisition Process (SSAP), through which a branch of the DoD contracts the development of computer-based defense systems. For the sake of illustration, one such computer-based defense system contracted in the past is the Amphibious Tank Radar Manager (ATRM—a fictitious name), which automates the operation of the radar of an amphibious tank.

You and your partner are receiving different pieces of information about the SSAP process (listed in bullet items below), which starts with the DoD issuing a request for proposals (RFP) and ends with the DoD receiving a proposal (or several proposals) from a bidder (or a group of bidders). You will now first discuss these different pieces of information with each other and each develop a sketch of the entire process. **Please bear in mind that each of you will develop a separate sketch based on your discussion. You may discuss the sketch as much as you want, but you must not show your sketch to each other.**

Information Provided to the First Member of the Dyad

- The SSAP process starts with DoD's program manager e-mailing a request for proposals (RFP) document to the bid consultant of a company called Webmasters.

- The DoD program manager then calls Webmasters' bid consultant over the phone to provide him with extra information about the RFP, including the deadline for receipt of proposals and types of organizations eligible to bid.
- Webmasters' bid consultant uploads the RFP from his e-mail inbox onto DoD's RFP's Web site using a system called SecureWorkflow, which automatically notifies potential bidders by e-mail about the RFP.
- The contracts manager of a bidder receives the RFP notification in his e-mail's inbox folder, downloads the RFP from DoD's RFP Web site using SecureWorkflow, and places it in his personal folder.
- As soon as he has some time, the bidder's contracts manager e-mails the RFP to the bidder's technical lead.

Information Provided to the Second Member of the Dyad

- Once a day, the bidder's technical lead checks her e-mail's inbox folder for RFPs. Once an RFP is found, she enters the cover page information about the RFP into a control spreadsheet and saves the RFP document in her RFPs folder.
- As soon as she has some time, the bidder's technical lead e-mails the RFP to the bidder's project manager.
- Once a week, the bidder's project manager checks his e-mail inbox for new RFPs and, once he finds one, prepares a related proposal in consultation with his team.
- The bidder's project manager e-mails the prepared proposal to the bidder's technical lead.
- The bidder's technical lead enters the cover page information about the proposal into the same control spreadsheet in which she previously entered information about the RFP, and uploads the proposal onto DoD's proposals Web site using the SecureWorkflow system, which automatically notifies DoD's program manager of the receipt of a new proposal.

APPENDIX B

Process Redesign Task

You will now apply the process redesign techniques discussed below to the SSAP process, which should lead to a simplification of the process. You and your partner are receiving only half of the redesign techniques each, so you will have to discuss the other techniques with each other in order to be able to apply all of the process redesign techniques. Finally, you will each develop a sketch of the simplified process. **Please bear in mind that each of you will develop a separate sketch based on your discussion**. **You may discuss the sketch as much as you want, but you must not show your sketch to each other.**

Redesign Guidelines Provided to the First Member of the Dyad

- *Foster Asynchronous Communication*. When people exchange information, they can do it synchronously, i.e., interacting at the same time, or asynchronously, i.e., interacting at different times. One example of synchronous communication is a telephone conversation. If the conversation takes place via e-mail, it then becomes an example of asynchronous

communication. It has been observed, especially in formal business interaction, that in the vast majority of cases, asynchronous communication is more efficient than synchronous communication. For example, synchronous communication often leads to wasted time (e.g., waiting for the other person to be found) and communication tends to be less objective. Asynchronous communication can be implemented with simple artifacts such as in-boxes and out-boxes, fax machines, and billboards. Asynchronous communication can also be implemented with more complex artifacts such as computer files. These artifacts work as dynamic information repositories.

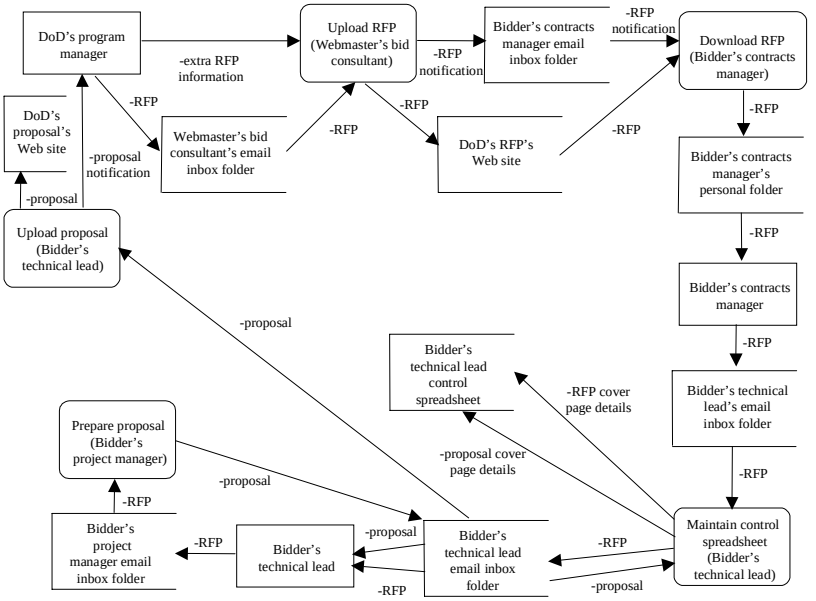
- *Reduce Information Flow*. Excessive information flow is often caused by an over-commitment to efficiency to the detriment of effectiveness. Information is perceived as an important component of processes which drives people to an unhealthy information hunger. This causes information overload and the creation of unnecessary information processing functions within the organization. Information overload leads to stress and, often, the creation of information filtering roles. These roles are normally those of aides or middle managers, who are responsible for filtering in the important bit from the information coming from the bottom of, and from outside, the organization. Conversely, excessive information flowing top-down forces middle managers to become messengers, to the detriment of more important roles. Information flow can be reduced by selecting the information that is important in processes and eliminating the rest, and by effectively using group support and database management systems.

Redesign Guidelines Provided to the Second Member of the Dyad

- *Reduce Control*. Control activities do not normally add value to customers. They are often designed to prevent problems from happening as a result of human mistakes. In several cases, however, control itself fosters neglect, with a negative impact on productivity. For example, a worker may not be careful enough when performing a process activity because he knows that there will be some kind of control to catch his mistakes. Additionally, some types of control, such as those aimed at preventing fraud, may prove to be more costly than no control at all. Some car insurance companies, for example, have found out that the cost of accident inspections, for a large group of customers, was much more expensive than the average cost of frauds that that group committed.
- *Reduce the Number of Contact Points*. Contact points can be defined as points where there is interaction between two or more people, both within the process and outside. This involves contacts between functions, and between functions and customers. Contact points generate delays and inconsistencies and, when in excess, lead to customer perplexity and dissatisfaction. In self-service restaurants and warehouses, for example, the points of contact were successfully reduced to a minimum. Additionally, it is much easier to monitor customer perceptions in situations where there are a small number of contact points. This makes it easier to improve process quality.

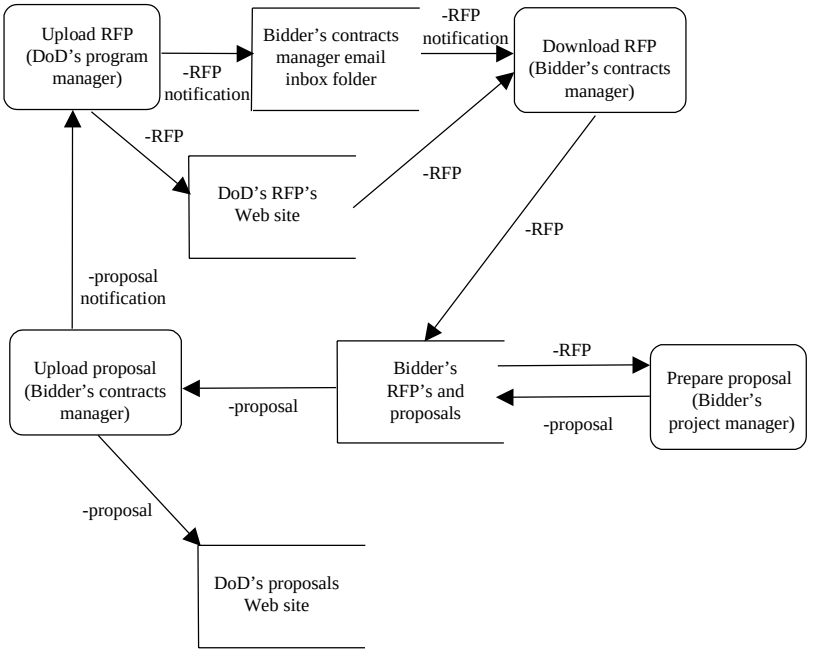
APPENDIX C

Correct Answer for Process Modeling Task



APPENDIX D

Correct Answer for Process Redesign Task



APPENDIX E

Questionnaire Measures

Cognitive effort

Indicate how much effort it took for you to complete the process redesign task by marking anywhere on the continuous scale below with an "X".

```
     0 ----- 25 ----- 50 ----- 75 ----- 100 ----- 125 ----- 150
Absolutely                                                Extreme
no effort                                                  effort
```

Communication ambiguity

Communication between my partner and myself was ambiguous.

```
   1 ------- 2 ------- 3 ------- 4 ------- 5 ------- 6 ------- 7
Strongly                                                 Strongly
Disagree                                                    Agree
```

Message preparation

I had to spend a lot of time preparing my contributions (e.g., group of sentences summarizing facts or conveying ideas) in my discussions with my partner.

```
   1 ------- 2 ------- 3 ------- 4 ------- 5 ------- 6 ------- 7
Strongly                                                 Strongly
Disagree                                                    Agree
```

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