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Team Collaboration in Virtual Worlds: The Role of Task Complexity

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ABSTRACT

Virtual worlds are three-dimensional, computer-generated worlds where team collaboration can be facilitated through the use of shared virtual space and mediated using an avatar. In this study, we examined the effect of task complexity on team collaboration. We used a puzzle game in Second Life as the collaborative task and manipulated task component complexity by varying the number of pieces in the puzzle. We hypothesize that task complexity will influence team trust, team process satisfaction, and one's attraction to the team in virtual team collaboration. The experimental results show that task complexity has significant effects on team trust and team process satisfaction.

Keywords

Virtual worlds, avatars, task complexity, puzzle, team collaboration.

INTRODUCTION

Virtual worlds can be defined as three-dimensional (3D), computer-simulated environments that replicate elements of the real world. Specifically, virtual environments include a space for interaction – they offer users the ability to interact with and manipulate objects within the space, and the user's "presence" is projected into the space using a graphical representation called an avatar. Through the mediation of the avatar, virtual worlds facilitate real-time social interaction and collaboration by enabling users to cognitively immerse themselves in a shared virtual space, interact and communicate using text and voice, and work together on projects regardless of the physical proximity of the users in the real world.

Virtual teams refer to a group of team members who are geographically dispersed and collaborate with one another via information and communication technologies to accomplish tasks (Lipnack and Stamps, 2000; Wainfan and Davis, 2004; Zigurs, 2003). Interestingly, virtual worlds are potentially superior to other communication technologies (e.g., videoconferencing, e-mail, chat etc.) usually employed in virtual teams. Virtual worlds have a wide range of technological capabilities that can enhance verbal, visual, and spatial cues (Davis, Murphy, Owens, Khazanchi and Zigurs, 2009; Kahai, Carroll and Jestice, 2007). Existing communication technologies are unable to provide such technological capabilities. In recent years, virtual worlds have attracted the attention of both businesses and researchers as a new and promising technology for collaborative work (Davis et al., 2009). Virtual team collaboration is fast becoming a key theme in organizational uses of virtual worlds (Kock, 2008). Despite the importance and popularity of collaboration and social interaction in virtual worlds, team collaboration in virtual worlds is an underexplored research area. As is the case with many new technologies, users have the perception that virtual environments have an important and positive influence on outcomes but the mechanisms by which these outcomes are realized have yet to be fully studied and understood. Much of the literature examining computer-mediated teams in the IS domain comes by way of research examining group support systems. Much of this research demonstrates that while technology has a role to play, so too do team characteristics, individual attitudes and behaviors, and the type and nature of the task engaged in by the team. While each of these factors is important, task has consistently been shown to be important in influencing how teams engage in their shared activities, how they perceive their interactions, and how they view the results they generate. While many task characteristics have been examined, task complexity has been shown to be important because it can be measured objectively (Wood, 1986) and it is useful in examining the role of technological support and mediation over a spectrum of more or less challenging task contexts (Mennecke et al., 2000). In this research, we will study the effect of task complexity on team collaboration in the virtual world.

LITERATURE REVIEW

Task Complexity

Task complexity is an important dimension of collaboration and team building (Braarud, 2001; Higgs, Plewnia and Ploch, 2005). Task complexity has been shown to be an important predictor of team processes and outcomes in a variety of team contexts.

Campbell (1988) posited that task complexity is associated with properties of a task that affects a task performer's information processing. Variations in information processing (Schroder, Driver and Streufert, 1967) are attributed to changes in the number of dimensions of required information, the number of alternatives associated with each dimension, or the degree of uncertainty. In Campbell's (1988) proposed framework, four complexity sources, mainly (1) path multiplicity, (2) outcome multiplicity, (3) conflicting interdependence among paths to outcomes, and (4) uncertain or probabilistic links among paths and outcomes, result in an increase in the amount of information required to perform a task.

Wood (1986) identified three components of tasks: (1) products, (2) required acts, and (3) information cues. The first component, products, refer to the abstract quality of the task – for example, the higher the quality of a product, the more complex the task will be. The latter two components constitute task inputs. Required acts are referred to as behavioral patterns of individuals that are required to accomplish the task. It should be noted that a required act is merely a task component rather than a property of a task performer's behavior; that is, each task has certain required actions that are needed to complete the task regardless of who or how the task is actually enacted. Information cues refer to the amount of information processed by a task performer to make judgments while performing a task. Also, Wood (1986) suggested that the relationships between task inputs could be described and moderated by task complexity, which he suggested has three dimensions: component complexity (i.e., the number of task acts and cues), coordinative complexity (i.e., the relationship between task inputs and products), and dynamic complexity (i.e., changes that influence the relationship between task inputs and products). Complexity can be influenced by task behavioral requirements because, for example, an increase in task complexity can be caused by increases in the number of required acts and the amount of information or information cues. Nevertheless, the relationship between these factors is non-additive so that differing combinations of features along each dimension will have unique and non-linear influences on overall task complexity.

Task inputs determine cognitive demands experienced by a task performer in accomplishing the task (Schroder, Driver and Streufert, 1967). Cognitive demands include skills, efforts, and knowledge of the task performer. The different degree of cognitive demands may explain the effect of task complexity on attitudes and task performance of the individuals who complete the task. According to Wood (1986), task complexity will have an important influence on task performance because of the varying influence on the task actor in terms of cognitive demands, which are specified by task inputs. The higher the task complexity, the higher the cognitive demands placed on the task performer (Campbell and Gingrich, 1986). It should be noted that task demands may be perceived differently by task actors based on factors such as the user's experience with the task domain, the user's cognitive resources and capabilities, the user's perceptual skills and resources, and the nature of the technology used to support task completion. These differences in perceptions about task complexity are subjective and unique to users, and should not be confused with the objective components of task complexity defined by Wood (1986); nevertheless, it is these differences in perceptions of task complexity that will interact with the user's use of a technology aid such as a virtual world. A user's perception of whether and how a technology helps or hinders his or her completion of a task will have important influences on the user's acceptance and future use of the technology.

Trust

Mayer, Davis and Schoorman (1995) defined trust as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party."

Team members who are working together depend on each other to achieve and complete their tasks. Mutual trust is, therefore, critical for team members to work effectively (McAllister, 1995). In virtual teams, it may be difficult for team members to acquire sufficient information about others in the group at the beginning of the project to determine whether their team members are trustworthy. Moreover, the nature of virtual teams (e.g., lack of face-to-face interaction) creates a sense of physical and psychological distances among team members, hindering the establishment of trust.

Past studies have found that virtual teams are able to swiftly develop high levels of trust when they do not have enough time to gradually develop trust (Jarvenpaa, Knoll and Leidner, 1998; Jarvenpaa and Leidner, 1999). This type of trust was labeled "swift trust" by Meyerson, Weick and Kramer (1996), who suggested that swift trust was developed when team members presume that others are trustworthy at the outset of the project. Swift trust is important in many organizations today because many project teams (e.g., agile development teams) exist for a short duration or members are involved on the team intermittently.

To understand the impact of task complexity on trust, it is important to examine trust at a "deeper" level by understanding that trust is a multi-dimensional construct. In particular, two dimensions of trust – (1) cognitive-based trust, and (2) affective-based trust – are relevant to examine in the context of task complexity (McAllister, 1995). Cognitive-based trust reflects a person's rational choice to trust based on technical competency and the partner's ability to perform (Sarker, Valacich and Sarker, 2003). The second dimension of trust, affective-based trust, involves the emotional elements and social relationships associated with perceptions of the other actor, their history working together, and similar affective characteristics associated with their interactions.

An important theoretical link between trust and task characteristics lies in the relationship between how task complexity influences cognitive demands (i.e., skills, effort, and knowledge) (Wood, 1986). Specifically, we would expect that the more complex the task, the greater will be the demand on cognitive resources to perform the task. In this context, cognitive trust should be more salient and influential in virtual teams because, as suggested by Meyerson et al. (1996) and Peters and Manz (2007), the formation and maintenance of trust in temporary work teams (i.e., virtual teams) relies more upon cognitive-based trust than affective-based trust. Empirical support for this expectation is offered by Kanawattanachai and Yoo (2002) who examined Meyerson et al.'s (1996) propositions and showed that virtual teams relied more on cognitive-based trust than affective-based trust. When virtual team members carry out a collaborative task, they will need to invest the appropriate amount of cognitive resources needed to match the level of complexity present in the task. In most cases, each team member will use their own perceptions of the task requirements, complexity, and performance requirements to make inferences about whether and how other team members will respond to the task. As a result, when members are faced with a more complex task, they are more likely to rely on cognitive-based trust when engaged in virtual teamwork. Thus, as task complexity increases, overall trust at the team level also increases. Given this, we hypothesize the following for teams that perform tasks in a virtual world environment:

Hypothesis 1: There is a positive relationship between task complexity and team trust.

Team Process Satisfaction and Attraction to Team

Team process satisfaction refers to the affective and positive emotional reaction team members have with the procedures and deliberations accomplished by the team (Lowry, Romano, Jenkins and Guthrie 2009; Reinig, 2003). Complex tasks, by nature, demand more cognitive resources including skills, effort, and knowledge of the task performer (Schroder, Driver and Streufert, 1967) as well as behavioral performance including information processing and the physical process of carrying out the task. As a result, completion of complex tasks, compared to simple ones, produces a greater sense of accomplishment and satisfaction by the teams, leading to a higher level of positive emotional reaction to the team collaboration, i.e., team process satisfaction. Therefore, we hypothesize that:

Hypothesis 2: There is a positive relationship between task complexity and team process satisfaction.

Attraction to the team acknowledges one's personal attachment to the team and other members in the team and is sometimes named cohesion. Researchers found that success in adversity, among other conditions, can increase attraction to the team (Husting 1996). The explanation is that complex tasks require extra amount of work or input such as communication and coordination, which are often viewed as adversity or challenge. Team members have to work interdependently around the assigned task to meet team goals. Thus, going through the process of overcoming the adversity in the complex task, team members feel more emotionally and affectively attached to the team and other members in the team. Therefore, we hypothesize that:

Hypothesis 3: There is a positive relationship between task complexity and attraction to team.

METHOD

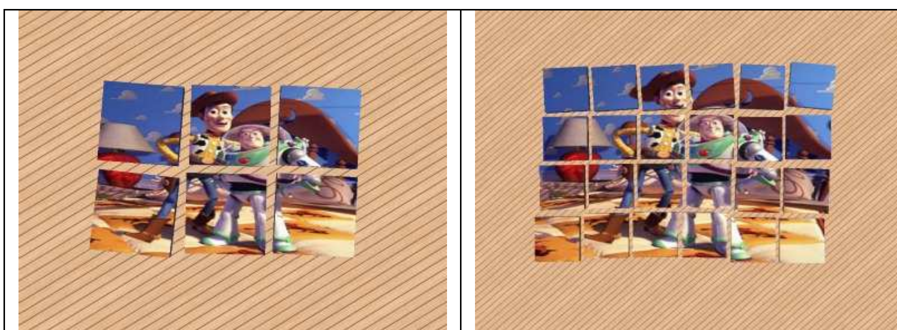
Research Procedures

We conducted a controlled experiment to examine these hypotheses using Second Life, which is one of the most prominent virtual worlds. In total, 216 students from a Midwestern university participated in this research. Subjects were randomly assigned to teams of two (i.e., dyads) and each team was randomly assigned to either the low- or high-complexity condition. Prior to the research, subjects completed a short training task to familiarize them with moving their avatar and moving virtual objects. Following the training, the dyads were asked to complete the task, which involved moving randomly arranged puzzle pieces into a predefined pattern (i.e., a picture). After the subjects completed the task, a post-study questionnaire was administered to assess the team process and to capture data about team member perceptions about the collaboration.

Experimental Manipulation of Task Complexity

In our study, a puzzle was used for the experimental task. Puzzles of various types have been used in a variety of research because they are engaging for subjects, easily understood by the subjects, and the complexity of the task can be easily manipulated by varying the number of puzzle components (i.e., varying the component and coordinative complexity) (Richardson and Vecchi, 2002). Based on Campbell's (1988) framework, puzzles are classified as problem tasks because the puzzle consists of a multiplicity of paths to achieve a desired outcome. Because task complexity is a function of the number of potential paths to the desired outcome, the level of task complexity can be increased by increasing the number of possible paths to arrive at the desired outcome. In other words, by increasing the number of pieces of a puzzle, the level of task complexity is increased.

We varied the levels of task complexity by varying the number of puzzle pieces. Specifically, the low-complexity task consists of six (i.e., 2 x 3) puzzle pieces while the high-complexity task consists of twenty-four (i.e., 4 x 6) puzzle pieces. In both cases, the image created from the puzzle pieces were the same (i.e., a picture from a popular animated movie); however, the size of the puzzle pieces making up the figure was varied. Figure 1 shows examples of assembled low- and high-complexity versions of the puzzle.



Low-Complexity Task/Puzzle | High-Complexity Task/Puzzle

Figure 1: Puzzle Pieces for the Research Task

Measures

We adapted validated scales from prior research examining trust, satisfaction, and attraction to group/team. All question responses were recorded on a 9-point Likert scale. All of the scales were examined using a principal components factor analysis with Varimax rotation. All data were analyzed at the group level. Prior to aggregating team members' assessments, we conducted the r_{wg} index of within-group agreement (James, Demaree and Wolf, 1984) for each measure. If the average r_{wg} score of the scale is greater than .70, an aggregation of individuals' scores into the group level is warranted (Kozlowski and Hattrup, 1992). Based on this analysis, all data were aggregated at the group level. The Cronbach's alpha score and average r_{wg} score for each measure are listed in Table 1.

We included a control variable, propensity to trust, when analyzing team trust. Propensity to trust is a personality trait that varies across individuals where some people are more likely or willing to trust others (Mayer, Davis and Schoorman, 1995). When there is no available information regarding team members, propensity to trust is considered to be an important factor affecting team trust that will subsequently be manifested among team members (Jarvenpaa, Knoll and Leidner, 1998; Mayer, Davis and Schoorman, 1995). We adapted the measure for propensity to trust from Jarvenpaa, Knoll and Leidner (1998).

Measure	Sources	Cronbach's Alpha	r_{wg}
Team trust	Pearce, Branyiczki and Bakacsi (1994)	.86	.86
Team process satisfaction	Green and Taber (1980)	.90	.86
Attraction to team	Evans and Jarvis (1986)	.94	.83

Table 1. Measurement of Dependent Variables

RESULTS

Manipulation check

A one-way ANOVA was used to test the effectiveness of the task complexity manipulation. A 5-item scale of subjective task complexity (Cronbach's alpha = .93) was adopted from Maynard and Hakel (1997). The manipulation check yields a significant effect for levels of task complexity, F(1, 81) = 20.73 , p < .001. Subjects in the high-complexity condition (*M* = 4.90, *SD* = 1.44) perceived their task to be more complex than did the subjects in the low-complexity condition (*M* = 3.54, *SD* = 1.09). We therefore deem the task complexity manipulation to have been implemented successfully.

Hypotheses testing

Team trust was examined by conducting an ANCOVA analysis with propensity to trust as a covariate. The ANCOVA result shows that there is a significant difference in team trust after controlling for propensity to trust, F(1, 104) = 4.96, *p* < .05. Specifically, teams in the high-complexity condition reported higher team trust than teams in the low-complexity condition (see Table 2).

The results show that there is a significant difference in team process satisfaction, F(1, 106) = 5.49, *p* < .05. Teams in the high-complexity conditions reported higher team process satisfaction than teams in the low-complexity condition (see Table 2).

For attraction to team, there is no significant difference between different levels of task complexity, F(1, 106) = .18, *p* = .67 (see Table 2).

Dependent Variable	Low Task Complexity (*n* = 56)		High Task Complexity (*n* = 52)		Total (*n* = 108)		ANOVA	
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*Sig.*
Team trust	**6.10**	1.28	**6.63**	1.25	6.35	1.28	4.96	.02
Team process satisfaction	**6.08**	1.11	**6.60**	1.18	6.33	1.67	5.49	.02
Attraction to team	6.13	1.34	6.25	1.32	6.19	1.32	.18	.67

Table 2. Experimental Results

DISCUSSIONS AND CONTRIBUTIONS

This study empirically examines the effect of task complexity in virtual team collaboration. The findings suggest that an increase in task complexity positively influences team trust and team process satisfaction. These findings are interesting and contribute to the team building literature. For example, this is the first study we are aware of that examined team trust in combination with task complexity. Additionally, these results were observed in the context of virtual world use, which also builds on prior research examining team interactions in these venues. These results offer useful implications for team facilitators and team leaders. Specifically, to foster teamwork and team development, our findings suggest that more complex tasks will improve team member perceptions about other team members. The reasons for this finding probably relate to the interdependence that is needed when team members engage in more complex endeavors. For example, for a simple task, less interaction and cooperation is needed to complete the exercise. In this case, the small number of pieces involved in the low complexity task would have been easily completed by the team members in a short amount of time and with less of a requirement for coordination and cooperation between team members. This lower level of reliance and involvement with each other would lessen the requirement to trust that the other team member would engage in the required acts to complete the task. A practical implication of this is that a task needs to be complex enough to provide the opportunity to require interaction and coordination of acts during task completion.

As one of the first research studies to examine team collaboration in virtual worlds, this study contributes to the literature on collaboration and virtual world use. The findings are in line with those of past studies (e.g., Jarvenpaa, Knoll and Leidner, 1998; Jarvenpaa and Leidner, 1999), which suggest that virtual teams are able to develop high levels of trust quickly when a task is known to be of a short duration. Our results build on this prior research by showing that the complexity of the task will moderate the development of trust and process satisfaction. In this case, the teams were randomly formed prior to the start of the experiment. Nevertheless, the team trust indicators have a mean of 6.10 (out of 7) for low complexity task and 6.63 (out of 7) for high complexity task. This shows that team members who are unknown to each other can develop swift trust in a virtual world environment relatively rapidly. This rapid trust formation is likely due to the embodied representation of the users, which fosters higher levels of involvement in the task and interactions with the other social actors (Mennecke et al., 2010).

These results also have practical implications for team building. The study shows that virtual worlds can be used for team building exercises. This is relevant for a variety of teams but it is particularly important for geographically dispersed teams. An increasing number of organizations are globalizing and have organizational members situated in non-proximate locations. With virtual worlds, team building can be conducted virtually, and it appears that even simple team building exercises such as a puzzle assembly exercise can be effective when completed in a virtual world. Additionally, it appears that team trust and team process satisfaction are enhanced with more complex tasks; therefore, an important implication of this study is that facilitators and team leaders should consider the relative complexity of team building exercises when using such tools to build trust within their teams.

CONCLUSIONS AND FUTURE RESEARCH

Team collaboration in virtual worlds is an important topic that deserves more attention and research. This research examined task complexity and empirically tested three hypotheses related to team collaboration in virtual worlds. The results show that team trust and team process satisfaction increase with the complexity of the task. High task complexity results in higher team trust and team process satisfaction. Attraction to the team, on the other hand, was shown to not be significantly affected by task complexity.

In this research, we manipulated task complexity such that the complexity level was within a manageable level. We believe the results might be different if task complexity were to be above a certain ‘manageable’ threshold where cooperation, engagement in the task, and other behaviors supporting teamwork might break down or falter. To keep the tasks manageable for subjects and to examine trust in a comparable range of task contexts, we limited the complexity of the task in this research to a manageable cognitive level to study the relative effects of complexity on team collaboration. Future research should examine the effects of complexity of different types of tasks including cognitive, affective, and psychomotor tasks. We also intend to collect qualitative data to supplement the quantitative data which will offer more in-depth explanations about the team building and collaboration process. Finally, this study represents a snapshot view of a short-duration team; therefore, longitudinal studies would also help us understand more about the evolution of team trust and team process satisfaction as teams form and develop.

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