The Impact of Virtual Teamwork on Real-world Collaboration

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ABSTRACT

With the rapid advance of online gaming and virtual reality technology, virtual teamwork has become increasingly popular. People spend more and more time working with others in 3D virtual environments to accomplish common goals. In this study, we investigate the impact of virtual teamwork on collaboration in the real world. We conducted a study with a sample of 60 participants. These participants were asked to work in groups of three and play a Nintendo Wii music game. Half of the groups were assigned to the control condition where members played the game individually. The other half of the groups were assigned to the experimental condition where members play the game altogether as in a band. After the game play, all groups performed a collaborative problem-solving task and a creativity task. Results show that groups in the experimental condition performed significantly better than the groups in the control condition. This suggests that virtual teamwork has a positive effect on collaborative problem-solving and group creativity in the real world.

Categories and Subject Descriptors

J. 4 [**Social and Behavioral Sciences**].

General Terms

Experimentation, Human Factors.

Keywords

Virtual teams, collaboration, problem-solving, group creativity, teamwork, video games, social interaction, human-computer interaction.

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1. INTRODUCTION

With the rapid advances in computer and Internet technology, online virtual activities have become increasingly popular. People no longer only use text-based communication tools such as emails or instant messengers. They often engage in teamwork with others in highly immersive virtual worlds. For example, many 3D online games allow multiple players to work in teams. *Second Life*, a virtual world where users can collaboratively build 3D objects and communities, has reached 15 million users in 2008. According to Gartner, Inc. (a leading information technology research company), 80% of active Internet users will have a "second life" in virtual worlds by the end of 2011. We have entered into an era where virtual teamwork has become common.

Meanwhile, collaborative activities are common and critical in the real world. As individuals bring different set of knowledge and skills, group collaboration allows a team to tackle problems more complex than what individuals can do alone. Studies have found that groups perform better in problem-solving and idea generation than individuals in terms of time taken, the number of problems solved, and the number of solutions generated [7, 28]. Collaboration has been considered as an important factor in most organizations. Many businesses try to enhance their employees' collaboration through workshops and training. A recent survey shows that Fortune 500 companies intensively use group collaboration in their projects as it gives them an edge in the global market [23, 35].

In this research, we aim to understand how virtual teamwork affects collaboration in the real world. More specifically, we want to investigate if simple virtual teamwork in game play can improve the effectiveness of collaboration. As research has found that groups with better

collaboration perform better in problem-solving (e.g., [3]) and group creativity (e.g., [42,45]), we used the results of a collaborative problem-solving task and a group creativity task as the indicator of collaboration effectiveness. We conducted an experimental study using a Nintendo Wii music game with 60 participants. After the game play, participants completed a problem-solving task and a creativity task. Results show that groups with members playing the game altogether as in a band performed significantly better than the groups with members playing the game individually. This suggests that virtual teamwork has a positive effect on group collaboration.

In the following, we first describe background research related to our study. Then, we present our experiment design and findings. In the end, we discuss the implications and limitations of our study.

2. RELATED WORK

Previous research on virtual teamwork has focused on virtual teams with members from different locations and coordinating their work through groupware and communication technologies such as email, teleconferencing, and videoconferencing [29, 36, 38, 50]. While these teams share common characteristics such as trust and openness as conventional groups [51], their collaboration has found to be different from face-to-face collaboration. Hedlund, Ilgen, and Hollenbeck [24] found that computer-mediated teams made riskier decision than face-to-face groups and exchange less information during collaboration. Jonassen and Kwon [30] found that in computer-mediated group problem-solving, members reflected more on ideas and perspectives in reaching their decisions. Team communication was more task- oriented compared to face-to-face communications which was more cohesive and personal. Several models have been developed to describe the dynamics in virtual teamwork (e.g., [13, 15, 36]). Duarte and Snyder [13] divided virtual team development into four stages: inception, problem-solving, conflict resolution, and execution. They further described the social dynamics that parallel the above four stages as interaction and inclusion, position status and role definition, allocation of resources and power, and interaction and participation. Vartiainen and Andriessen [50] proposed a general model of virtual team building. It includes three stages: forming by agreeing, maintaining by communicating, and completing by learning. These models provide general guidelines on how to build and improve virtual teamwork. In contrast, our study focuses on simple teamwork that does not involve the use of communication technology and complex task coordination. We aim to understand the impact of virtual teamwork such as playing music in a band, playing sports in a team, or team-based combat. These activities are common in virtual worlds and easy to participate. Each team member performs a set of moves with minimum coordination and communication. However, each individual's performance impacts the overall performance of the group. Furthermore, different from the above studies where team members often know each other through working in the same organization, our study focuses on team members that do not know each other before they engage in virtual teamwork. As it is extremely common to work with strangers in online games and virtual worlds, we believe that understanding the impact of such teamwork is critical.

A number of studies have investigated the impact of real-life collaboration on virtual collaboration. Hossain and Wigand [27] and Fisher and Fisher [15] found that groups with initial face-to-face communication have a high level of trust and achieve better virtual collaboration. Groups that do not have face-to-face interactions tend to have low social control and increased feeling of isolation [32]. Given the above findings, initial face-to-face meetings are recommended for developing positive ingroup relationships and teamwork norms [15]. In contrast, our work investigates the impact of virtual teamwork on face-to-face collaboration. Similarly, we hypothesize that initial virtual teamwork will help the development of trust and rapport between team members and improve face-to-face collaboration afterwards.

Numerous studies have been conducted on to assess the transfer of knowledge from virtual environments to the real world. These studies provided mixed results. For example, Kozak, Hancock, Arthur, and Chrysler [13] shows that there is no difference between groups that received training in virtual reality context than the groups received no training. Hamblin [22] found that virtual reality can be effective training simulators although they are less efficient than real-world training. Pleban, Mathews, Salter, and Eakin [43] found that desktop virtual environments can successfully improve decision making, but the training of motor skills requires fully immersive environments with headsets [44]. While above research focuses on virtual environments that are designed for training, our work focuses on casual settings such as online games or virtual environments like Second Life. We aim to understand the impact of virtual teamwork that people can easily engage in without special setup or training. In addition, people engage in such teamwork not for the purpose of learning specific skills or knowledge, but for entertainment or relaxation.

A significant amount of research has been conducted to understand the impact of playing video games. For example, cognitive psychologists focus on cognitive abilities such as attention, concentration, reaction time, visual tracking, and memory. They have shown that playing

either violent or non-violent games can improve cognitive performance and visuomotor coordination (e.g., [4, 20, 34]). Researchers have also investigated possible negative effects of violence in games [21, 46], a topic that the general public is most interested in. While studies have found that playing violent games can cause an increased level of aggression when players encounter confrontation shortly after the game play (e.g., [8, 18]), the correlation between violent games and aggression was found to be smaller than the one between television and violence [46]. Recent work on online games has started to explore cultural and social interactions in the virtual world (e.g., [10, 14]). However, these studies focus on social interactions inside the virtual worlds. In contrast, our work aims to understand the impact of video games in the real world. In addition, while the above research focuses on individual game play and its impact on individuals, our work focuses on virtual teamwork and its impact on group performance.

3. STUDY

In the following, we describe our study on the effect of virtual teamwork on real-world collaboration.

3.1 Design

We used a between-subjects experimental design. Participants in our study were randomly assigned to the control group and experimental group. Participants in the experimental group participated in a virtual teamwork while participants in the control group performed the same task individually. We then asked the participants to perform a collaborative problem-solving task and a group creativity task. As research has shown that more effective collaboration results in better performance in group problem-solving (e.g., [3]) and group creativity (e.g., [42, 45]), we used these results as indicators of the effectiveness of collaboration. We compared the results to test if there is a significant difference in the performance between the control group and the experimental group.

3.2 Participants

Sixty undergraduate students participated in the study in exchange for course credits for their psychology courses. There were 36 females and 24 males, between age 19 to 23 (M = 20.42, SD = 2.08). These participants were randomly assigned to three-person groups. Therefore, there were 20 groups in total, 10 groups for the control condition and 10 for the experimental condition. Both the control condition and the experimental condition had six mixed-gender groups and four same-gender groups. To prevent participants from collaborating with acquaintances and therefore having better collaboration, we did not allow participants to participate if they had acquaintances in the group.

3.3 Procedure

Figure 1. The music game from the Nintendo Wii "Rayman Raving Rabbids 2" game disc.

In each study, the three-person group was first asked to play the Nintendo Wii music game from the "Rayman Raving Rabbids 2" game disc (see Figure 1). In the game, a player was represented by an animated avatar on the screen. The player used a remote wireless controller to simulate playing a virtual musical instrument (i.e., drums, trumpet, or vocalist) in a band. During a song, "music notes" represented by icons scrolled down the television screen. When they reached a bar at the bottom of the screen, the player needed to shake the wireless controller according to the moves indicated by the icons. If the player correctly followed the icons, the bottom bar would flash green, and melodious music would be produced. If the player missed the icons, the bottom bar would flash red, and a discordant sound would be produced. In this way, players were able to get both audio and visual feedback about their action.

To play the game, the three-person group were led to sit in a row in front of a TV. We used wooden barriers to separate participants so that they would not communicate with each other. This ensured that the teamwork during game play was entirely virtual. Participants were told that their task was to use their assigned virtual instrument to play a song. Each participant was randomly assigned to play a different virtual instrument, and was given one minute to familiarize with the game in the practice mode. After that, participants in the experimental condition played a song altogether as in a band for five minutes, whereas

participants in the control condition played the song one-by-one (each person played five minutes). In the control condition, to minimize practice effects, when one person was playing, other group members were asked to face away from the television screen until it was their turn to play. This ensured that every participant in both the experimental and control group played the game for the same duration of time.

The reason that we used music band play as the teamwork activity is because band play is a typical form of teamwork. While each player in the band plays different notes, the combination of these notes creates the cord. To perform a nice song, each player needs to play his or her notes correctly. Anyone's mistake will affect the music produced by the band. The shared responsibility among players makes the players work together towards the same goal as a team. This form of teamwork is common in online games and virtual worlds.

We used the Nintendo Wii music game because of four reasons. First, it is very simple for novices to learn how to play. Different from many games and online virtual environments where first-time players need to learn a series of commands and keystrokes, Wii games allow players to use wireless controllers to control their virtual characters. This is very intuitive and most of new players can learn how to play within a few minutes. Second, the teamwork in the music game is very simple and straightforward. It does not require special form of communication or coordination. Each player plays his or her own notes and everyone's performance contributes to the performance of the team. If one player misses a note, the whole team will hear and see. The overall quality of the song depends on the performance of each player. Third, the game has both single and 3-player modes. In both modes, players have the same song and screen view. The only difference is that in the single-player mode, only one column of icons scrolls down the screen. In the 3-player mode, three columns of icons scroll down the screen simultaneously, and each player follows one column of icons to play. Fourth, the Wii game console was introduced in Singapore less than a year ago. It was unlikely for participants to have prior experience with the Wii music game. In fact, none of our participants reported to have had experience with the game before. This eliminates the potential confounding variables associated with participants' prior Wii gaming experience.

Figure 2. The 3D jigsaw puzzle.

After the game play, participants were asked to sit around a table and complete a problem-solving and a creativity task. We randomized the order of the problem-solving task and creativity task to counterbalance the order effect. Half the experimental groups and half the control groups did the problem-solving task first. The other half of the experimental and control groups did the creativity task first. We video-taped the groups during the two tasks.

We used a 3D jigsaw puzzle for the problem-solving task. The puzzle is made up of 60 pieces and each piece has four inter-locking sides. On each side, there is an arrow indicating how the adjacent piece should be connected to the piece. If two pieces are not connected according to the arrow direction, sooner or later, a problem will occur. We did not tell the participants about the function of the arrows. Participants were only given a pile of puzzle pieces and a picture of the completed puzzle for reference (see Figure 2). They had to assemble as many pieces as possible within six minutes.

We used the jigsaw puzzle for our collaborative problem-solving task because jigsaw puzzles have been used in numerous studies for problem-solving (e.g., [31]). A jigsaw puzzle game engages a group in an analytical task that requires all team members' contributions [39]. To quickly assemble as many pieces as possible, team members need to collaborate effectively. One person needs to be in charge of connecting the pieces and the other two need to find the pieces needed from the pile. If each person works on his/her own, not only time would be wasted on looking for puzzle pieces in the pile, but each individual's work may not be able to connect in the end. Furthermore, we did not tell the group about the meaning of the arrows on the side. These arrows are the key to solve the puzzle. It is critical that all members understand the meaning of the arrows as soon as possible. Otherwise, they would waste time connecting the pieces in the wrong way. Participants can either discuss it and find out the meaning together, or if one

member realizes the meaning, he or she needs to quickly share the information with other team members so that the other members can connect the puzzle pieces correctly. Therefore, to perform well in the puzzle-solving task, the group needs to communicate with each other and work collaboratively.

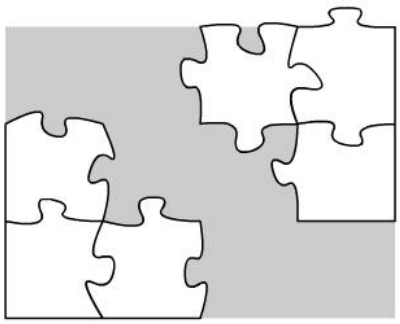

Figure 3. Jigsaw puzzle.

When the puzzle task was completed, we counted the number of edges shared by connected pieces, rather than the number of how many pieces were connected. For example, for pieces in Figure 3, we would count four because there are four shared edges among the pieces. In this way, our counting method produces a higher score for a 15-piece assembly than for three 5-piece assemblies (because a 15-piece assembly has more shared edges). In other words, the group that works together to assemble a 15-piece assembly will have a higher score than the group that has each member assembles a 5-piece assembly without connecting them together. Our counting method gives groups that coordinated their tasks a higher score than the groups that did not collaborate. Therefore, we use it as an indicator of the effectiveness of group collaboration in problem-solving.

For the group creativity task, we used the task described in Goncalo and Staw [19]. We gave the group a scenario where a bookstore has closed down on campus. The group needed to think of creative business ideas for the empty store space. The group was given six minutes to generate ideas and choose the most creative one as their final decision. We randomly assigned one group member to be the recorder and gave him/her a single sheet of lined paper. While the group brainstormed potential business ideas, the recorder wrote down the group's ideas. The recorder was instructed to write down each and every solution that was proposed, and indicate the final decision chosen by the group. The recorder was also allowed to participate in the discussion. After the task was completed, we collected the ideas generated by the group.

Research has shown that group creativity depends on the ability to generate ideas. The total number of ideas generated is a good indicator of group creativity (e.g., [9, 47]). Therefore, we counted the total number of ideas generated by the group, and use it as one indicator of group creativity.

As creativity is defined as the ability to generate unique or original ideas [1], we further followed the method in Goncalo and Staw [19] to assess the uniqueness of the most creative idea chosen by the group. Two independent raters rated the ideas using a 5-point scale (5 = Extremely creative, 4 = Somewhat creative, 3 = Average creativity, 2 = Somewhat uncreative, 1 = Extremely uncreative). The raters were instructed to focus on the "novelty" of each idea while making their ratings. As the two raters demonstrated significant agreement in their ratings of the ideas ($r = .94$, $p < .01$), their ratings were averaged together to give a single score for the creativity of the selected idea. This score represents the quality of the group creativity. We used it as another indicator of group creativity.

Upon completion of the tasks, each participant was separately thanked, debriefed, and excused. No participant correctly guessed the true purpose of the study.

4. RESULT

Table 1. Problem-Solving Score, Number of Creative Ideas, Creativity Score of Selected Idea Means for Control and Experimental Conditions (N = 20).

	Condition			
	Control	Experimental	*t*	*df*
Problem-solving score	61.60 (27.09)	108.30 (24.48)	-4.05**	18
Number of Creative ideas	8.40 (3.84)	12.10 (3.48)	-2.26*	18
Creativity score of selected idea	2.25 (1.32)	3.60 (1.13)	-2.46*	18

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

We performed three independent t-tests to test if there is a significant difference between the control group and experimental group. As shown in Table 1, the experimental group ($M = 108.30$, $SD = 24.48$) had significantly more shared edges in the puzzle pieces that they connected than the control group ($M = 61.60$, $SD = 27.09$) [$t(18) = -4.05$, $p = .001$]. Since the total number of shared edges represents the problem-solving performance, this suggests that the experimental group performed significantly better than the control group in the problem-solving task.

Table 1 also shows that experimental group (M = 12.10, SD = 3.48) generated significantly more creative ideas than the control group (M = 8.40, SD = 3.84) in the creativity task [$t(18) = -2.26$, $p = .04$]. Furthermore, the selected ideas from the experimental group (M = 3.60, SD = 1.13) were rated as significantly more creative than the ones from the control group (M = 2.25, SD = 1.32) [t (18) = -2.46, p = .02]. These results show that both the quantity and quality of the creative ideas generated by the experimental group were significantly better than the ones generated by the control group. The experimental group outperformed the control group in the creativity task.

As the only difference between the control group and the experimental group is playing the music game individually or in a team, the above results suggest that the virtual teamwork has an positive effect on collaborative problem-solving and group creativity.

5. DISCUSSION and FUTURE WORK

We plan to further investigate what actually differed between the control group and experimental group and caused the difference in their performance. Research has shown that social identity is an important factor in affecting group performance. Despite shared interests and cooperative interdependence, team members tend to categorize themselves into different social categories [48, 49]. This causes positive affect such as trust and liking among members within the same category but also negative intergroup attitudes and discriminatory behaviors between members with different categorical identities [6, 40]. We speculate that the virtual teamwork facilitates members to develop a common ingroup identity [16, 17] and therefore improves their collaboration. We will test this hypothesis by assessing members' group identity after playing the video game. Furthermore, research has shown that group interaction styles impact group performance [11, 25, 26, 52]. These styles can be categorized as constructive, passive/defensive, and aggressive/defensive [12]. They facilitate or hinder the exchange of information among group members. Watson and Michaelsen [52] identified three groups of positive behaviors and one group of negative behaviors as components of group interaction style. Based on our observation, we found that during the jigsaw puzzle-solving task, groups in the experimental condition often started with discussion on how to solve the puzzle together. They discussed the meaning of the arrows on the puzzle pieces and collaboratively figured out its use. This allowed the team members to quickly start off on the right track. Furthermore, members in the experimental group often have one member connect the pieces and the other two help him or her finding the pieces needed. This coordination greatly saved time and effort. In contrast, members in the control group often went on their own ways to figure out the meaning of the arrows and connect the puzzle pieces by themselves. In the group creativity task, we have the impression that the experimental group exchanged ideas more often than in the control group. We plan to verify these observations by coding and analyzing the videos that we took during our study. We will use the group interaction style theory as guidance to identify positive and negative behaviors in group collaboration and investigate if there is a significant difference in interaction style between the experimental group and control group.

One limitation of our study is that our sample size is relatively small and all of our participants are from Singapore. While they include Malay, Indian, and Caucasian, the majority of them are Chinese. It would be interesting to test subjects from the western culture. Meanwhile, our study only experimented with one game. In the future, we plan to use other games and collaborative tasks to verify our findings. In our study, we used the Nintendo Wii game with wireless controllers. While we speculate that very soon people would be using similar devices in online virtual environments, most of the current online games and virtual environments still use mice and keyboards. Furthermore, while we tried to use the Wii game to simulate online teamwork by separating participants using barriers, the game was not truly played online. Therefore, to generalize our findings to online virtual environments, we plan to have participants perform teamwork in *Second Life* online and test their group performance afterwards. In addition, during our study, participants collaborated with the same people that they played with in the game. However, in real life, it is uncommon to work with people met in online games or virtual environments such as Second Life. Therefore, we plan to further investigate if virtual teamwork will make people more collaborative even when they work with the ones that they did not meet in virtual teamwork. Also, the music game that we chose is a non-violent game. Many multi-player games such as Counter Strike have players work as a team to fight enemies. Players need to coordinate their actions and cover each other during the game play. In our future studies, we will investigate how teamwork in violent games affects collaboration in the real world.

Our study shows that even without verbal and visual communication, teamwork in virtual environments can result in better collaborative problem-solving and creativity in the physical world. This result provides new evidence of how virtual activities impact people's real-world behaviors, and has important applied implications. For example, a number of corporations such as the US Federal Aviation Administration allow employees to play video games before they engage in cognitive tasks. This is because

evidence shows that playing video games can improve people's cognitive capabilities (e.g., [4, 5, 20, 34]). With the evidence provided by our study, corporations can have employees engage in virtual teamwork before they start collaborative tasks. As online virtual worlds are more and more accessible nowadays, such approaches can be very feasible and promising.

6. CONCLUSION

In this paper, we described a study that investigates the impact of virtual teamwork on face-to-face collaboration. Results show that playing a music game in a team has a positive effect on the performance of collaborative problem-solving and creativity. This suggests that simple teamwork in virtual environments can facilitate face-to-face collaboration shortly after the game play. Our work can lead to practical implications such as having employees participate in virtual teamwork game play before they start their collaborative tasks.

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