The Art of Tug of War: Investigating the Influence of Remote Touch on Social Presence in a Distributed Rope Pulling Game

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Abstract. In this paper we investigate whether remote touch in the form of force feedback from another player's actions can enhance feelings of social presence and enjoyment of a collaborative, spatially distributed rope pulling game. Dyads of players situated in different rooms were either given an 'elastic band' type force feedback, or were given force feedback of the other player's actions (i.e. remote touch). Results showed that feedback from another player's actions enhanced feelings of social presence but not enjoyment of the game.

Keywords: Remote touch; Social presence; Distributed play; Haptic feedback

1 Introduction

The well-known game of tug of war, where two teams, each holding one end of a rope, attempt to pull the other team over a predesignated point, is a prime example of a game where players are physically engaged with their whole body. What is more, force feedback plays a crucial role. Here, the rope serves as a medium that delivers the force feedback generated by each of the teams over a short distance. In essence, we can speak of a spatially distributed game, where players are in physical contact with each other through the shared medium of the rope. Though the spatial distribution of a classic rope pulling game is limited by the length of the rope, efforts have been made to enlarge the spatial distribution of the rope pulling game through the use of Internet communication [1][2]. Harfield et al. [1] describe a distributed rope pulling system that was designed to enable children in distant locations to play a game of tug of war over the Internet. Similarly Christian et al. [2] present a tug of war game in which the player plays against a virtual character. The strength of the virtual character's pull is determined by the player's own strength.

In distributed rope pulling systems, remote touch [3], in the form of active force feedback about the actions of the other player, could play an important role in providing a sense of presence of the other player. Indeed, in presence research remote touch has been found to enhance task performance [4][5], and enhance feelings of presence [4][5][6][7]. However, empirical investigations into such effects of remote touch in entertainment systems are more scarce. In this paper, we investigate whether remote touch, rather than general haptic feedback, can enhance feelings of social presence and enjoyment in a collaborative game. To this end we developed a desktop-sized rope pulling installation that allows two players to play a collaborative game over the Internet. To investigate the effect of remote touch in this distributed rope pulling setup, we designed a study where dyads of players played a collaborative game in which they either received general elastic band type force feedback, or force feedback from the other player's actions (i.e. remote touch).

2 Related Work

2.1 Distributed Exertion Interfaces

In distributed entertainment, players play with each other at a distance with the use of interactive technologies, giving the feeling as if the players are co-located. These entertainment technologies can vary in their goal, style of play, and the used technology [8]. Work by Mueller et al. [9] [10][11] provides a number of examples of systems that enable players to engage in physically demanding exertion games with other players at a distance. Mueller et al. [9] created a competitive break-out-style game where players had to kick or throw a ball against a wall with a video projection of another player. Compared to an alternative played with a standard computer keyboard, the physical game showed an increase in social bonding and a perceived increase in quality of the sound and video. An example of a similar game is Mueller et al.'s [10] "Airhockey over a distance". Here, players play on an augmented airhockey table that incorporates a projection screen of a player in another location, and "puck-launchers" that can launch physical pucks, creating the illusion that the physical object crossed the space between the players. An informal evaluation indicated the potential for enhancing players' feelings of connectedness. In Mueller et al.'s [11] shadow boxing, two physically separated players each stand in front of a screen showing a projection of the other player's silhouette. Players can punch, kick or use their whole body to hit the projection of the other player and score points. The aim of the system was to demonstrate the possibilities of creating sports-like social games that can be played at a distance. In a similar fashion, Harfield et al. [1] developed a tug-of-war exertion game that can be played by physically separated players. The system is capable of measuring forces of up to 250 kg. Two teams of physically separated players are tasked with generating as much force as possible. The position of the rope is visualized on a screen and adjusted in accordance with the amount of force generated by each team. Though no formal evaluation was conducted the authors conjectured that the system helped young students collaborate with students from another continent. Finally, Yao et al. [12] describe a number of rope-based exertion games. For example, Multi-jump is a distributed rope jumping system where one player twirls a real rope. The motion of the rope is measured, and is displayed on a projection screen in front of another player in a distant location, who has to time his/her jumps in accordance with the visualization. Other games include a collaborative kite flying game, a competitive horse riding game, and a wood cutting game. In informal evaluations, the authors found that the rope-based games show the potential to stimulate social experiences, by providing users with the feeling of being engaged in a co-located activity.

Each of the systems described above incorporate some tangible element which allows players to physically interact with each other at a distance. However, none of these systems incorporate any haptic feedback technology. Research into haptics and telepresence shows benefits of using haptic feedback in interactions between users at a distance. The next section provides a brief overview of literature on haptics and remote touch.

2.2 Haptics and remote touch

Researchers have constructed numerous devices that allow users to touch each other at a distance. Such remote touch, or mediated social touch [3] devices are generally built with the idea that haptic feedback can be used for affective communication, and to enhance feelings of presence. Devices are for example used to communicate different types of touch through vibration patterns [13], or to provide intimate contact at a distance [14]. Another approach is to have users interact through a shared object [15]. This approach bears close resemblance to a distributed rope pulling system where active force feedback would provide users with the feeling that they are manipulating separate ends of the same rope.

Though effects of remote touch have been understudied compared to the number of devices that have been created [3], remote touch has been found to be experienced similar to real touch [16], to have effects on compliance to requests that are comparable to real touch [17], and to enable people to haptically communicate emotions at a distance [18][19].

In telepresence research the addition of remote touch in collaborative virtual environments has been found to have a number of beneficial effects on task performance and feelings of presence. For example Chellali et al. [4] demonstrated that in a collaborative biopsy simulator for medical students, a combination of visual and force feedback improved collaborative performance between students, and increased feelings of copresence. Sallnäs et al. [5] present a study in which two participants collaborated, using two force feedback joysticks, to manipulate an object in a virtual environment. Results showed that, compared to the condition where no haptic feedback about the other participant's actions was provided, force feedback improved task performance, perceived task performance, and perceived virtual presence in the collaborative virtual environment. Giannopoulos et al. [6] had two participants in different locations collaborate to complete a jigsaw puzzle. In one condition, turn-taking between participants occurred by 'nudging' the other participant using a force feedback joystick. In the other condition participants only had visual feedback of the other participant. Force feedback was found to increase feelings of social presence in the virtual environment. Finally, Sallnäs [7] conducted a study in which participants passed objects to each other in a virtual environment, using two force feedback joysticks. Compared to the condition where no force feedback was provided, force feedback improved perceived virtual presence, perceived social presence and perceived performance.

It is worthwhile to note here that in the studies described above, all of the tasks are collaborative. Research into social touch between co-located individuals suggests that this may be a very important contextual factor. Camps et al. [20] found that touch in competitive settings reduces helping behavior, whereas touch in collaborative settings enhances helping behavior. Therefore, beneficial effects of remote touch in a rope pulling game are most likely to occur in collaborative settings. This was considered in the design of our distributed rope pulling system described in the next section.

3 Rope pulling system design

3.1 First Prototype

The first prototype consists of two small rope pulling devices, with which users can manipulate a single paddle in a brick-breaker game. By pulling their respective ropes, one player can pull the paddle to the left and the other player can pull the paddle to the right. When one player pulls the rope, the other player will feel a resistance in their rope, equal to the amount of force exerted by the first player.

In this setup, a video call is running in the background of the brick-breaker game. The physical setup of the device contains a servo motor (Modelcraft rs-2), a load cell and an Arduino micro-controller. A rope, in this version a thin plastic wire, is connected to a wheel on the servo motor. The load cells measure the pulling force of each player and the servos move the ropes according to the force difference. The units are connected to different computers and communicate via the Internet in a server-client manner.

This test setup was used to compare the user experience of playing the brick-breaker game with the rope pulling system, to the user experience of playing the same game with a regular computer keyboard. In an informal evaluation with eight student participants playing with both versions, all indicated their preference for the rope pulling system. Although this prototype showed it is possible to play such a game over the Internet, the implemented server-client connection caused noticeable lag that lead to somewhat unstable gameplay. As the boxes were not yet attached to anything the user had to hold the box with one hand while pulling with the other, which did not represent a natural rope-pulling experience. Furthermore, the feeling of the plastic wire did not represent the actual tactile sense of a real rope. These issues were addressed in the design of the final prototype.

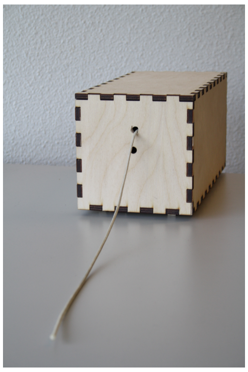

Fig. 1. The final prototype.

Fig. 2. The test condition in use.

3.2 Final Prototype

Hardware Based on the results of the informal evaluation, the final prototype contains two boxes that are fastened to a table. The plastic wire used in the first prototype was replaced with an actual rope. To rule out any potential lag issues, the Internet connection was removed, and instead, a direct serial connection on a single computer was used in the final prototype. To further enhance the experience, the servos were replaced with faster models (Blue Bird BMS-661DMG+HS) that also allowed for a higher maximum pull-force. Figure 1 depicts the final prototype.

Game We designed a game in which players have to catch eggs falling from the top of the screen with a basket. The game was intentionally designed to be very minimalistic and only shows the basket, falling eggs and score. The basket also slants slightly when it is pulled to one side as to provide players with additional visual feedback about the movement of the basket.

4 User Studies

The final prototype was used in two studies. First, a pilot study that served to assess the level of enjoyment of the egg-catching game played with the rope pulling system. Second, the main study was conducted to investigate the effect of remote touch on feelings of social presence and enjoyment within the collaborative egg-catching game.

4.1 Pilot Study

During development of the final prototype, the rope pulling system was tested with a group of 16 children in the age range 7-11. We pilot tested the setup with children because we considered them to be a viable target group for a potential large scale distributed rope pulling installation (see also [1]). All children played the game once. Two rope pulling devices were placed next to each other on a table, and a computer monitor displayed the game.

After playing the game we ask each individual child three questions: 1) *"What did you like about the installation?"*, 2) *"What did you not like about the installation?"* and based on the again-again table method [21]: 3) *"If there was more time, would you like to play this game again?"* with three possible answers: *yes*, *maybe* or *no*. The children were also asked whether they had any comments on the game and system in general.

From this informal evaluation we gathered that the children generally liked the rope pulling system and egg-catching game. Eleven children had no negative comments, and all except one child liked at least one aspect of the game. The most frequent positive comment was the aspect of working together (mentioned 5 times). The social aspect of trust in the other player and arguing with the other player were also mentioned as positive. The act of physically pulling the rope was mentioned as a positive aspect of the system (4 times). Finally, the majority of children stated that they would have liked to play the game again (14 yes, 1 maybe, 1 not). Other observations included that some children tried to take the rope from the other player and play the game by themselves. Others tested the limits of the system and most were very curious about how the system worked.

The pilot study indicated that the system definitely has the potential to be a fun and interesting way for children to interact with each other in a physical game environment. After observing the children playing with the rope pulling system and hearing their comments we were confident that the system would be suitable for use in the main study.

4.2 Main Study

The main study was conducted in order to study the effect of remote touch, in the form of active force feedback about another player's actions, on feelings of social presence and enjoyment of a collaborative game. To this end we formulated two hypotheses, namely:

> H1: Remote touch in the form of active force feedback about another player's actions will increase feelings of social presence in a collaborative game;
>
> H2: Remote touch in the form of active force feedback about another player's actions will increase enjoyment of a collaborative game.

These hypotheses were tested in a study where dyads of players, situated in different rooms, played a variant of the collaborative egg-catching game using the rope pulling system. Players either received general force feedback or remote touch force feedback.

Participants The participants were all voluntarily participating students or employees of a Dutch university. A total of 40 participants (20 dyads, 10 dyads in each condition) participated in the study. In total, 25 participants were male and 15 were female. The participants' age ranged from 18-62 years old (M = 22.9, SD = 8.54). We used adults for the main study because it was easier to get a larger sample size this way, and use more robust measures. As part of the demographics, we asked participants to indicate how well they knew each other on a 5-point Likert scale (1 = not at all, 5 = very well). Results showed that the majority of participants did not know each other (M = 1.13, SD = .52).

Materials Each participant used a rope pulling device as depicted in Figure 1. Depending on the experimental condition, participants played a slightly different version of the egg-catching game, and received either general force feedback or remote touch force feedback. Both versions of the game were collaborative in nature. The control group played a version of the game in which the feedback was similar to an elastic band, pulling the basket to one side of the screen. We chose this type of feedback because it fit the game, providing natural feedback from the rope itself (i.e. stretching), and would provide force feedback similar to the remote touch condition. The side to which the basket was pulled was different for both players (i.e. one player's basket was automatically pulled to the left, and the other player's basket was automatically pulled to the right). Both players had a separate basket of a different color. To underline the collaborative nature of the game, the score in the top left corner of the screen was a cumulative score representing the total number of eggs caught by both players. The test group played a version of the game in which they received remote touch force feedback depending on the way the other player manipulated their rope. A single basket was visible on the screen. When one player would pull their rope, the basket would move to the left and when the other player pulled their rope the basket would move to the right. This created the illusion that both players manipulated one end of a continuous rope to which the basket would appear to be attached. The score represented the total amount of eggs caught in the basket. Figure 3 shows two screenshots comparing each version of the game. Participants could communicate with each other using a headset and through a video call displayed on a separate screen. Figure 2 depicts the setup used in the main study. As a measure of social presence we used the validated social presence questionnaire by Harms and Biocca [22]. We asked participants seven additional questions (Table 2).

Procedures The study was conducted with dyads of participants. Participants were guided to two adjacent rooms. The first participant arrived a few minutes before the second so that participants could not meet prior to the study. Each room was equipped with an identical rope pulling setup (Figure 2). Participants signed an informed consent form, and were given a written explanation of the experimental procedures, an explanation of the rope pulling system, and an explanation of the egg-catching game. It was explained that the goal of the game was to collaborate with the other player in a distant location and catch

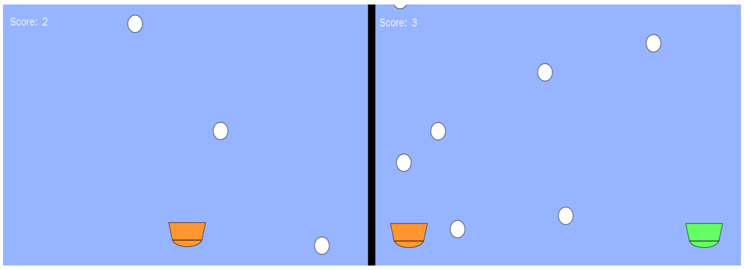

Fig. 3. Screenshot of the two different conditions of the game. The test condition is shown on the left, the control condition is shown on the right.

as many eggs as possible, as indicated by the score (Figure 3). Players were free to communicate as they liked using the headset and video call. Next, participants were asked to play the game for two minutes. After the play session, participants completed the social presence questionnaire, additional questions, and demographic questions on the computer that previously displayed the video call. Finally, participants were debriefed about the goals of the study.

Results After correcting for the reversed questions, the items on the social presence scale showed acceptable to good internal-consistency (Cronbach's α), as can be seen in Table 1. Note, that two items were removed from the Perceived Emotional Interdependence scale.

To test the hypotheses, we used a one-tailed independent samples t-test. Scores on the six social presence items and the scores on the additional questions were compared between the control group and the test group. The results for the social presence items are shown in Table 1. As can be observed from Table 1 four of the six items of the social presence questionnaire showed a significant difference ($p < .05$) between the control group and the test group, and two items showed a marginally significant difference. The test group showed significantly higher scores than the control group for co-presence, perceived affective understanding, perceived emotional interdependence and perceived behavioral interdependence (all at $p < .05$). In addition, the test group showed higher scores for perceived message understanding and attention allocation, although the difference was only marginally significant (at $.05 < p < .1$). These findings support H1.

Table 1. Social presence questionnaire items. 5-point Likert scale, 1 = strongly disagree, 5 = strongly agree

Item dimension	α	$\mathbf{M}_{control}$	$\mathbf{M}_{test}$	t(38)
Co-Presence	.68	3.88	4.18	-1.80^{1}
Attentional Allocation	.78	3.10	3.46	-1.56^{2}
Perceived Message Understanding	.79	3.73	4.00	-1.43^{2}
Perceived Affective Understanding	.93	2.95	3.39	-1.76^{1}
Perceived Emotional Interdependence	.84	2.70	3.23	-1.83^{1}
Perceived Behavioral Interdependence	.79	3.34	3.75	-2.00^{1}

^{1} $p < .05$; ^{2} $.05 < p < .1$

Table 2. Results of additional questions (5-point Likert scale, 1 = strongly disagree, 5 = strongly agree)

Questions	$\mathbf{M}_{control}$	$\mathbf{M}_{test}$	t(38)
1) I enjoyed playing this game	4.25	4.55	-1.64[3]
2) I thought playing this game was boring	1.85	1.55	1.21[3]
3) While playing this game with this specific installation I felt more connected to the other player than when I'm playing with a traditional setup (keyboard, controller)	3.35	4.50	-4.83[1]
4) I enjoyed playing this game with this specific installation more than when I'm playing with a traditional setup (keyboard, controller)	2.95	3.39	-1.76[2]
5) While playing the game it felt like the feedback the system gave came from my opponent	3.95	4.60	-2.41[1]
6) Playing the game felt similar to playing rope pulling in real life	1.95	2.70	-2.18[2]
7) If there would be more time available, I would play this game again	3.60	3.75	-.48[3]

[1] $p < .001$; [2] $p < .05$; [3] *not significant*

Table 2 shows the seven additional questions about game experience. Four of the questions show a significant difference between the groups. For questions 3, 5 and 6 the test group showed significantly higher scores than the control group. Again, these findings support H1. Question 4, which was about enjoyment, showed a significant difference between the groups. Participants in the test group indicated more strongly than participants in the control group, that they enjoyed playing the game with the rope pulling interface more than they would have enjoyed playing the game with a more traditional controller. For the other three questions (questions 1, 2, and 7) about enjoyment, scores in the test group were higher than in the control group, but the difference was not significant. With this H2 is not supported.

5 Discussion and future work

The findings from the main study support H1. Indeed, results from the social presence questionnaire showed that the test group who received remote touch force feedback, had stronger feelings of social presence towards their game partner than participants in the control group who received the elastic band force feedback. This shows that the social aspect of the remote touch force feedback added to the feelings of social presence, more than did the general type of haptic feedback. This statement is supported by the additional questions in which participants in the test group indicated feeling a stronger connection to their game partner than did participants in the control group. In addition, participants in the test group indicated strongly that they had the feeling that the force feedback was generated by their partner. This indicates that the remote touch force feedback was indeed perceived as a form of physical contact between the two players. Furthermore, participants in the test group found the game to be more like real life rope pulling than participants in the control group. However, it is possible that the slight difference between both versions of the egg-catching game (i.e. participants in the test group actually pulled 'against' each other), explains this difference. This can be considered a limitation of the approach of our study. In our current approach we can not infer a difference between the role and effect of the remote touch force feedback and the effect of sharing control over a single entity in the game (i.e. the basket) versus only sharing an overall goal but with each player controlling an individual entity in the game (i.e. separate baskets, but a cumulative score). However, research into telepresence [4][5][6][7] shows clear effects of remote touch force feedback on feelings of social presence in different contexts with and without manipulation of a common object. Therefore it seems most likely that the effects found in this study are due to the differences in haptic feedback.

Overall the rope pulling system was considered to be very enjoyable by players in both groups. However, no significant differences were found for any of the additional questions dealing with player enjoyment. These findings do not support H2. Though for all the enjoyment questions (see Table 2 questions 1, 2, 4, and 7) the test group did have higher mean scores. A potential explanation is that, although the remote touch did make the game more enjoyable, the base level of enjoyability was already high for both variations of the game, reducing potential differences on the 5-point Likert scale. It also has to be noted here that this is only a first time use measure. It would be interesting for future research to look at long term effects and different types of games.

The findings from our study have a number of implications for research, as well as the entertainment industry. Our findings support the notion that adding remote touch haptic feedback, in our case force feedback, can add to a player's feelings of social presence of another player more so than general haptic feedback. The inclusion of remote touch haptic feedback into games and game controllers might be a fruitful direction for providing entertaining, social experiences. Exertion type games, played at a distance, might benefit from remote touch in that it could provide additional realism (i.e. the physical aspect of playing sports together). Moreover, a full-scale installation, that would ideally feature high torque motors that could handle multiple children pulling at a larger rope, would seem a viable approach to connecting children with their peers across cities, countries and continents.

6 Conclusions

In this paper we investigated whether remote touch in the form of force feedback from another player's actions could enhance feelings of social presence and enjoyment of a collaborative distributed rope pulling game. To this end, in an iterative fashion, we designed, created and tested a desktop-sized distributed rope pulling game. We created two variations of a collaborative egg-catching game where players had to catch eggs falling from the top of the screen to increase their cumulative score. In one version of the game players each had an individual basket to catch eggs and received elastic band force feedback, while in the other version players controlled a shared basket and received remote touch force feedback of the other player's actions. The main study with 40 participants playing the game in dyads showed that players in the remote touch condition, had significantly stronger feelings of social presence towards the other player, than did players in the control condition. Players in both groups found the game to be very entertaining, but this was slightly more so the case for players in the remote touch group. However, ratings for enjoyment did not differ significantly between the remote touch and control groups.

Overall, our results point to the importance of remote touch haptic feedback for enhancing feelings of social presence in collaborative games.

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