Distributed Embodied Team Play, a Distributed Interactive Pong Playground

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Abstract. This paper presents work in the field of distributed exertion games, which are controlled by moving the body. People play these games together while being located at different places in the world. The novel contribution of this paper is the introduction of *distributed team play* in which both collocated and distributed players participate. In our Distributed Interactive Pong Playground (DIPP) players bounce a ball towards a goal by moving, walking, and running around in a 5.3 by 5.3 m interactive playground. We investigate whether we can increase coordination in movement between players by changing the game to enforce teamwork. This was done by letting the players in a team control one end each of a shared paddle, as opposed to both players having separate paddles. Although the results should be taken with care, the comparisons do indicate that we could steer the amount of coordination between players in this way. Furthermore, we investigated the effect of distributed team play on the level of coordination. The results indicate that coordination goes down if the teammate is at another location. In this distributed team setting, enforced team work through a connected paddle still leads to a higher level of measured coordination. In contrast, our current analysis of self-reported social presence did not show a clear difference, not favoring enforced team work nor a particular team distribution. With the DIPP and this study we provide a new direction for distributed exertion games with a focus on aspects of team play.

Keywords: Play · Interactive playground · Embodied interaction · Exertion games · Pong · Coordination · Social presence · Collocated · Distributed · Team play

1 Introduction

Computer entertainment can help people fulfilling a happy, pleasant and perhaps even a meaningful life [3,23]. Physical exertion and playing together with other people are a large part in this. *Distributed games* build upon the rise of broadband internet gaming technology. They allow computer entertainment to better include

This paper builds on Steven Gerritsen's Master's thesis work [5].

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the social-relatedness factor, even when the people whom we want to play with are physically far away. *Exertion games* (or exergames) target intense physical effort to play the game [16], which can result in enjoyment but also has other benificial effects. For instance, the high prevalence of obesity in western countries could be targeted with these exergames, as these games have been proven to increase energy expenditure [21]. The combination of the two leads to *distributed exertion games* [16], which allow one to play intense physical games, together with other people, over a geographical distance. Mueller et al. created several games and sport experiences that can be enjoyed with people on the other side of the world, including *table tennis for three*, *jogging over a distance*, kicking a ball against a wall (*break out for two*) and *airhockey over a distance* [18].

Although these games target interaction with distributed players, they do not allow for concurrent interaction with collocated players. In our research we thus investigate an extension on these distributed exertion games in which players are distributed as well as collocated, using our Distributed Interactive Pong Playground (DIPP). This allows us to investigate social connectedness and team interactions in a distributed exertion game. The game is played in teams of 2 vs. 2. Players control their paddle in order to bounce the ball into their opponents' goal by stepping, walking and running around an interactive space. To play this game we use an interactive camera-projection system based on the Interactive Tag Playground [9]. Our current system shows the same game visuals at two different locations. The interactive space of 5.3 by 5.3 m tracks players based on the depth streams of four Kinects and a real-time tracking algorithm. Subsequently our game incorporates these positions and uses two projectors to provide appealing visualizations on the floor. Two of these interactive spaces were linked to each other in combination with a microphone array and Skype connection to create the DIPP.

Our current study explores how people play together in the DIPP. An important part of people's interaction is how they coordinate their movements and how present they feel the other is [1,19]. We try to change and measure this coordination between players. We propose and try-out five different configurations of the game. We vary whether the two players in one team control one paddle together or if each player in the team has his/her own paddle. We also vary whether each team is collocated at one location (with the opponents being at the other location) or whether the members of the teams are distributed over the two locations (physically sharing that location with one person from the opponent team). In order to compare this to non-distributed play we use also observed play in a totally collocated game of interactive pong.

2 Related Work

Several distributed exertion games have been introduced in the last decade [18]. Almost all of them build upon an existing game, activity or sport. *Breakout for two*, is an interactive wall on which targets have to be hit with a ball, while an opponent player is simultaneously shown on the same wall but is playing from another location. The game is a combination 'of soccer, tennis and the popular computer game Breakout' [10, p. 4]. The targets are shared between the players and have to be hit several times before they break out, and only when the last hit is delivered a point is awarded to that player. *Table tennis for three*, is similar to *break out for two* but is based on table tennis instead of soccer and tennis. The players see their two opponents and hit similar targets on an upstanding part at the end of a table tennis table [17]. Here two players can decide to play 'together' against one. *Airhockey over a distance*, is a distributed game that builds on the table game of air hockey [15]. Players again can view their opponents projected at the half of the table. Players have to slide a puck into the goal of the opponent, by hitting the puck with a small round bat. Half-way (under the 'wall') a system detects the position and velocity of the hit puck where it disappears in a small slot. A 'canon' at the other location then shoots a puck with similar velocity and from approximately this position towards the goal of the opponent. This opponent defends its goal and attempts to score by hitting the puck back again. *Shadow Boxing*, is an installation where players can kick, punch and use their bodies to hit the opponents' shadow, which is projected on a 'touch sensitive' mattress-like wall [14]. *Tug of war*, is a system where the well known game of rope pulling is used as a starting point for a distributed game [2]. The game provides distributed haptic feedback, it is played by pulling a small rope that is connected to a servo motor which provides a pulling force based on the opponent pulling force. The game unlike the previous games is played in a cooperative way, by pulling or releasing the rope the players control a shared basket on the screen that can be used to collect falling objects.

Several of these systems have also been used to show that (distributed) embodied gaming can have positive effects on play experience and relation between players. Playing with *Tug of war*, when compared to a variation where there was no physical feedback of the other user, resulted in an increase of several dimensions from social presence of the distributed player [2]. Playing with *break out for two* when compared to a keyboard alternative, made the players feel they knew one another better and became better friends, increased fun, and unexpectedly resulted in increased perceived quality of the audio and video [11]. Participants playing with the *table tennis for three* reported that they could imagine it would help to increase rapport, and forgot the world around them [18]. Exertion games, also when not distributed but still compared to non-embodied interaction styles, can indeed have an effect on social interaction, trust, emotional experience, role-taking, competition, and connectedness [12]. Exertion games as well as similar movement-based social immersive media including camera-projection systems, can be designed in various ways to encourage emotional responses, deal with appropriate game-play time, competition etc. [20], can be designed to steer or change player interactions [8,22], and a wide set of guidelines have been created to aid in development of such games [7].

Many benefits of the developed distributed exertion games and distributed games have been linked to how players play together with another player. Although two players playing a game together was seen in tug-of-war and it was

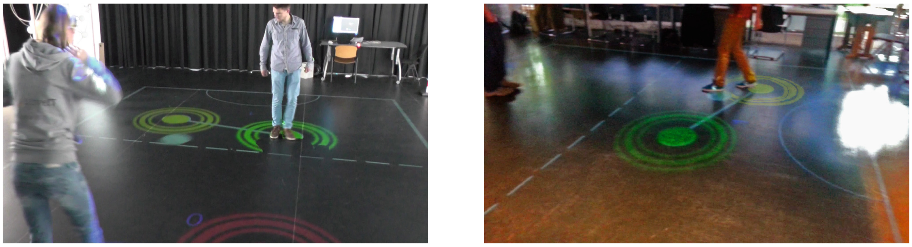

Fig. 1. The Distributed Interactive Pong Playground (DIPP). In this configuration, two opposing players are collocated and have distributed teammates, the paddle can be seen between the distributed team of green (L) and yellow (R). (Color figure online)

also welcomed for local players to team up during the *Breakout for two* games to increase throughput, to our knowledge there are not yet team distributed exertion games [10,18].

3 Design of DIPP

We propose our team distributed exertion game DIPP that includes two players on each team, two players on two location, a virtual ball and two virtual goals, see Fig. 1. Each player is represented with a unique colored circle projected at their position. The players control a paddle by moving around the play-field, the paddle can be used to bounce the ball in their opponents goal. The game is played for 7.5 min after which it will automatically stop.

3.1 The System

The system consists of duplicate setups at two locations communicating over the (university's) network using the UDP protocol. Both setups have four top-down oriented depth sensors (Kinect), a tracker PC (transforming depth information to tracks of players), a visualization PC and two projectors, see Fig. 2. One 'game' PC, the master, gathers the track information and transforms these to game coordinates. These game coordinates are used to run the game, the master sends the game information to another 'game' PC at the second location. This second PC simply visualizes the game objects at the second location. This setup forces the game to be deterministic. This is unlike the setup of what seems to be the first distributed embodied game, arm wrestling over a phone-line, in which both players could win at their end of the game [13][1]. Mueller et al. pointed out that the audio channel is the premium communication channel (in a distributed game) [18]. In order to let players communicate verbally we set-up a Skype call between the two locations using two additional Kinects, allowing communication in the entire playing field without letting the players wear microphones.

[1] Introduced in 1986, idea by Doug Black and Norman White, http://v2.nl/archive/works/telephonic-arm-wrestling, last visited 27-2-2016.

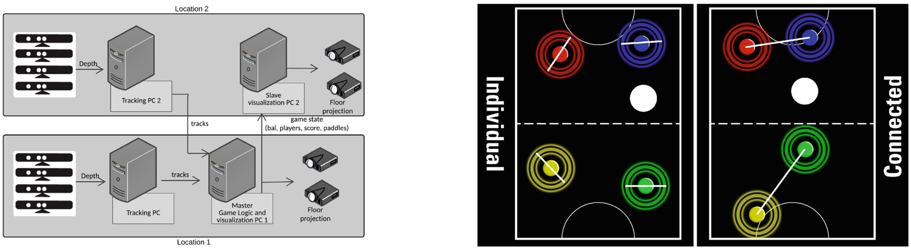

Fig. 2. The setup of the DIPP. On the left the system layout, at 2 locations we installed 4 Kinects and 2 projectors, and we use two tracker PCs sending tracks of players (ID and position), and by processing this info a master PC sends game info (ball, players, score and paddles) to a slave PC. On the right the two game variations are shown.

3.2 The Variations in Game and Distribution

Our contribution focuses on cooperative team play and the mix between collocated and distributed players. We are interested to see how players will play in different distributions and if we can increase coordination between players by changing the game play. Ideally, such an increase in coordination could also lead to an increased social presence of the other players.

We made two game variations, see Fig. 2. In the *individual* mode players are assigned an individual paddle. They still play in a team but each paddle is controlled by one player. The paddle rotates towards the ball until the distance is below a certain threshold (approximately 1.5 m). In this way players can bounce the ball in different directions by approaching the ball in different angles. In the *connected* mode players in a team each control one end of a connected paddle. Players can also rotate this paddle by moving around the other player. When the players are too far apart (approximately 1.5 m, twice the size of an individual paddle) the paddle breaks (disappears). While both forms require teamwork, we try to encourage closer coordination between players with the connected version. Especially once the game is distributed we still want the players to still pay attention to the (other) distributed players.

We also vary the way players are distributed. Players can either have their teammate at the same location, or have their teammate distributed and have an opponent at the same location. This leads us to 5 conditions to investigate: (#1) collocated$_{individual}$, (#2) collocated$_{connected}$, (#3) distributed-opponent$_{connected}$, (#4) distributed-team$_{individual}$, and (#5) distributed-team$_{connected}$. A possible sixth condition, distributed-opponent$_{individual}$, was played only once, deemed least interesting and was omitted from analyses due to a lack of participants.

We expect (1) that the coordination will be higher if we steer towards a more *connected* game than with an *individual* game (*coordination in #1 > #2*), (2) distributing a connected team still has a detrimental effect on their coordination in movement, thus in distributed play the coordination will be higher for collocated teams than for a distributed teams (*coordination in #3 > #5*),

(3) that if we have distributed teams the connected version will still have a higher coordination (*coordination in* $\#5 > \#4$).

4 User Study

4.1 Procedure

The experiment consists of groups of four participants that know each other, playing only one of the five conditions in order to reduce the threshold (time) to participate. The two setups are both located at our university, in different buildings 400 m apart. Participants were recruited in groups of four players that knew each other at the university. Participants were told that they would play a game of Interactive Pong, were informed about the game and had to give written consent. Participants were then asked to fill in a digital pre-experiment questionnaire, including questions regarding familiarity with each other and a baseline for the 'including Other In the Self' (OIS) scale by Aaron et al. [1]. We let the participants choose the teams, so there was no influence from us in this creation. Based on which distribution type the group had to play in, we took the participants to the associated locations.

Once the players arrived at the other location we tested the communication channel. We had to omit the Skype connection in one game from #4 due to technical difficulties. In another game from #5 we switched to a speaker phone. We first let the participants play the game as long as they needed to get used to the game (about 1 min). This was done in order to remove any difference in pre-knowledge people may have in playing interactive games and/or previous versions of the pong game. We then started a 7.5 min session where we let them play uninterrupted. At the end of the session, participants answered a questionnaire including the OIS-scale, and questions regarding the social presence of the other players including six different constructs [6]. This particular questionnaire was chosen as it fitted the intended measure, had proven internal consistency, its development based on existing theory seemed appropriate and it was applied successfully in the context of the *Tug of war* game. After finishing the questionnaire we asked the participants to share their thoughts on the game. We also saved the real-world positions of the players during the games, this data of the tracker allowed us to investigate the physical coordination between the players.

4.2 Participants

In total we had 80 participants, equally divided over the four conditions, 62 were male and 19 were female. All participants were between 19 and 34 years of age (23 on average), most were studying at our university. Two participants had an autism spectrum disorder (in #2 and #5). Seven participants had physical discomforts/limitations (back-ache, motor disorder, low energy levels etc.) most were unnoticeable in play-behavior with our direct observations, and spread over all conditions, although 3x in #5 and 2x in #3.

4.3 Results

Observations and Interviews. Some players in the distributed opponent configurations thought they were part of a Turing test. We were explicitly asked this question a couple of times (seemingly more often in #3). Players immediately had several ideas how to improve the game, like restricting the time one stands close to the goal. Nonetheless, most players indicated to us they liked the game very much, and we heard utterances such as *'This is so strange, this is so cool!'* (in #4). During the games several players were cheering and booing, giving high fives if they scored, and some made exaggerated movements like jumping in the air when (almost) scoring. These behaviors all seem to be qualitative indications of players being immersed in the game.

Questionnaire. Similar to Beelen et al. we performed comparisons on the social presence constructs between players in the different conditions [2]. However, as we are performing more exploratory investigations in this new type of setup, in our study this resulted in two-tailed tests on 13 different hypotheses regarding the effect of distributions and game variations on the social presence. A detailed description of each test or even hypothesis is outside the focus for this current paper as it would require too much space for explanation, instead we only discuss some interesting (condensed) 'results'.

The analyses of these 13 hypothesis on 6 constructs plus the difference in pre- and post-test in the OIS-scale, resulted in 91 comparisons, thus requiring a Bonferroni correction (0.05/91 = 0.00054). Reliability for the six constructs is known [6] and internal consistency for this study was good to excellent, Cronbach's α in the range of 0.74–0.92 for all player comparisons for each of the constructs. Due to non-normal distributions we used the two-tailed version of the Mann-Whitney U test and all with $n_1 = n_2 = 16$. With the uncorrected significance level **only 21 of the 91 comparisons would have been significant** ($p < 0.05$).

None of the social presence constructs or the IOS scale indicated a difference for teammates in the distributed teams conditions comparing *connected* (#4) and *individual* paddles (#5), (7x n = 16, $p > 0.05$). Furthermore, **no effect is seen for teammates if we compare the collocated version (#1 and #2)**, (7x n = 16, $p > 0.05$). Although not significant, there were even indications that **aspects of social presence (PAU/PMU) of the remote opponent might even increase with individual paddles (#4) instead of connected paddles (#5)**. PMU did not differ significantly (#4, Mdn = 3.33 vs #5, Mdn = 2.67), $U = 61.5$, $z = -2.52$, $\frac{0.05}{91} < p < 0.05$. Nor did PAU differ significantly (#4, Mdn = 2.92 vs #5, Mdn = 2.00), $U = 53.5$, $z = -2.82$, $\frac{0.05}{91} < p < 0.01$).

We did find a significant difference for teammate-OIS during enforced distributed play, between having a teammate distributed (#5, Mdn = 0.0) or collocated (#3, Mdn = 2.0), $U = 35$, $z = -3.56$, $p < \frac{0.05}{91}$). PMU was not significantly different (#5, Mdn = 3.25, #3, Mdn = 4.17), $U = 44$, $z = -3.18$, $\frac{0.05}{91} < p < 0.001$), nor was PAU (#5, Mdn = 2.33, #3, Mdn = 3.42), $U = 67$,

$z = -2.31$, $\frac{0.05}{91} < p < 0.05$. All (trends) were in the direction of **decrease of OIS/PMU/PAU for the connected distributed teammate (#5) compared to a connected collocated teammate(#3)**.

Coordination Between Players. One measure for coordination between people is their correlation in movement[2] [19]. For our exploratory study we see speed as an appropriate measure for movement. If players are coordinating their play-behavior more, we should be able to see an increase in correlation between player speeds. If over the game both players have high speeds and low speeds at the same moments in time, we see this as form of coordination.

Implementation of Coordination Measurement with Players' Speed. To investigate this form of coordination we filtered and transformed the position data. Using Matlab 2012a we did this as follows. Our tracker provided 'lines' of raw position data with a time stamp ($t(i)$), id, and x,y positions. The interval with which the tracker provides information is not constant (varying around 12.5 to 28 fps). For every first time stamp ($t(0) = ts_0$) we encountered, we looked for position data within a time slot of 50 ms ($\pm\ ^1/_{fps}$) or less ($(t(i) \leq (ts_0 + 50))$, and saved all available position data for all players. When more than one positions is given for a player id within this time slot we only used its latest value. We continued until position data with a time stamp outside this time slot was found ($t_i \geq (ts_j + 50), \rightarrow ts_{j+1} = t(i)$).

We then interpolated the empty slots for each player with the x and y positions that were available. For values that had many consecutive missing values ($\geq$ 10, $\geq$ 500 ms) we kept the slots empty instead. We then calculated the speeds between slots and used a median filter (5 values, $\geq$ 250 ms) to filter out noise/outliers. We averaged the existing values over a period of 10 slots ($\geq$ 500 ms). We threshold these values to a realistic maximum value of 11.61 km/h (top 0.05 %), in order to minimize impact of extreme values for which Pearson's r is sensitive. We then correlated these average speeds between players.

Correlations. The correlations of teammates can be seen in Table 1. If teammates correlate their movement most, this allows one to attempt to automatically recognize teams using the optimal scores of correlations between player combinations from the correlations matrices. This optimum correlation combination resulted in 19 out of 20 proper combinations (one mismatch in the collocated versions #1), where the baseline would be 7.

Feeling slightly more confident in the applicability of the used correlations, we investigated our three expectations regarding coordination with the explained method. We expected (1) correlation values in *#1* > *#2*, (2) correlation values

[2] Ramseyer and Tsacher also incorporated Pearson's r as a core part in their automatic measurement of synchrony [19]. They used temporal correlations and nifty corrections for random correlations. For our study we will keep to correlating (windowed) average concurrent speeds over entire sessions.

Table 1. Pearson's correlations (r) of teammates in the different configurations. L1 or L2 labels Location 1 or 2. Each session (s#) has two teams shown left and right in the table. * *Not the optimal combination, r optimal non-team: .10 and .20.*

	Condition									
	#1 co.$_{ind.}$		#2 co.$_{con.}$		#3 dis.-opp.$_{con.}$		#4 dis.-team$_{ind.}$		#5 dis.-team$_{con.}$	
	r_{L1L1}	r_{L1L1}	r_{L1L1}	r_{L1L1}	r_{L1L1}	r_{L2L2}	r_{L1L2}	r_{L1L2}	r_{L1L2}	r_{L1L2}
s1	.15	.15	.57	.49	.45	.52	0.16	0.07	0.31	0.17
s2	.14	.15	.40	.45	.34	.56	0.11	0.24	0.38	0.33
s3	.13*	.10*	.48	.47	.44	.47	0.18	0.07	0.32	0.16
s4	.11	.13	.6	.43	.49	.30	0.10	0.12	0.30	0.33
Avg.	.14		.47		.45		.13		.28	

in *#3* > *#5*, (3) correlation values in *#5* > *#4* but due to the exploratory state of the research we also test for differences in the other direction using two-tailed test. Pearson's r is known to have a non-normal distribution and a Fisher z-transformation can be applied to transform towards a normal distribution [4]. Knowing the known non-normal distribution of Pearson's r we simply performed the more well known non-parametric two-sided Wilcoxon rank-sum test, all with $n_1 = n_2 = 8$.

In the collocated game, the used speed values have a significantly different Pearson's r correlation between teammates when their paddles are connected (#2 Mdn = .47) compared to individual paddles (#1 Mdn = .14), $W_r = 36$, $z = -3.36$, $p < 0.001$. This difference is in the expected direction of **higher coordination in movement of teammates if teammates are *connected*, when they are playing a collocated game,** #2 > #1.

With connected paddles the Pearson's r correlation of the the used speed values significantly changes between teammates being collocated (#3 Mdn = 0.46) or teammates being distributed (#5 Mdn = .31), $W_r = 42$, $z = -2.73$, $p < 0.01$. The difference is in the expected direction of **an increase in coordination of teammates if they are *collocated*, when they are playing distributed play where they are connected to their teammate**, #3 > #5.

In this distributed playground with distributed teams the Pearson's r correlation of the transformed and filtered speed values significantly changes between teammates when they are connected (#5 Mdn = .31) instead of having their individual paddle (#4 Mdn = .12), $W_r = 41$, $z = -2.84$, $p < 0.01$. This difference is in the expected direction of **an increase in coordination in movement of teammates if the teammates are *connected*, when they are playing with a distributed teammate**, #5 > #4.

5 Discussion

The method of correlation that we used seems usable to investigate the difference between distribution and enforcing team work. Our results suggest that forcing people to work together, to control/share an element together, increases a form of coordination. It would be interesting to investigate if these results would generalize to other games. It is important to realize that the FPS and the recognition seem to differ between locations. As the temporal character, linear interpolation and linear correlation are intertwined in the analysis results should be considered carefully. The collocated version did not suffer from these problems and still showed similar tendencies, larger correlation between teammates and especially larger when they are enforced.

Regarding the analysis of social presence it seems we set out a too broad investigation. More focused attention to aspects of interactive distributed play and core factors influencing social presence would be worthwhile in the future. The current reported values of the social presence are also leaning towards cherry picking results of such a questionnaire and show the shortcomings of having many hypothesis in an exploratory state of research. Nonetheless, there is a suggested trend towards a decrease in social presence constructs once teammates get distributed, asking for further investigations of these effects and possible ways to mitigate this decrease.

The game was enjoyed by many players. We think the collocated aspect in combination with distribution and the novelty of such a system were important reasons for this. The game itself could be improved, as suggested by some players, to trigger other more risky types of game play and providing a richer game play. For instance, adding a ball that speeds up or restricting the time that a player can be near to the goal. We found the idea of doing a Turing test with distributed interactive exertion games very interesting. Perhaps as a first step, future distributed exertion games could even become a combination of collocated players, distributed players, and computer players.

6 Conclusion

We reported on what to our knowledge is the first distributed embodied game with a focus on teams with collocated and distributed play at the same time, the Distributed Interactive Pong Playground (DIPP). We investigated if we could increase coordination, measured as correlation between speed of players, by more strictly enforcing teamwork in the game. This was done by letting both players control one end of a shared paddle (the main game object), as opposed to both players having separate paddles. Although the results should be taken with care, the comparisons strongly indicate that we could steer coordination between players in this way. Furthermore, we investigated the effect of distributed team play on the level of coordination. The results indicate that coordination goes down if the team mate is at another location. In this distributed team setting, enforced team work through a connected paddle still leads to a higher level of measured coordination. In contrast, our current analysis of self-reported social presence did not show a clear difference for either enforced team work or team distribution. Nonetheless, the combination of distributed and collocated games seems to be an interesting new avenue for distributed embodied play.

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