Games over a Distance: Playing Together Although Apart Using Exertion Interfaces

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Abstract.
In our modern, often nomadic society, people increasingly lack the opportunity for social leisure activities, such as social gaming, although beneficial to mental and physical health. We aim to work against this trend by recreating the social experience known from existing games in a distributed environment. Our approach utilizes the physicality of existing leisure games in a networked environment to support social interactions between geographically distant players. We present four pervasive games of this concept, each with a different focus on this approach. Based on our observations with these systems, we believe the physicality of the games facilitated by an Exertion Interface contributes to a compelling experience, which can support social interactions and connectedness between geographically distant players.

Keywords: Table-tennis, ping pong, Exertion Interface, physical, tangible, videoconferencing, sports, active, exhausting, sweat, team spirit, social interaction, air hockey, computer-supported collaborative sports

1 Introduction

Social interaction is an essential human need. Our interactions with others are crucial for a fulfilling work and social life, and add meaning to our existence [7]. However, in modern society people are often faced with the challenge of having to live and work apart from family, friends and colleagues. Today's lifestyle with its associated physical distribution of personal contacts and work arrangements decreases the chances of engaging in social interactions [7].

We are interested in enabling social interactions between friends, future friends, family and co-workers separated by distance. Our initial investigations on social interactions took us to social spaces such as pubs, backyards, garages and community clubs where casual games including airhockey, pool, table tennis, table football and darts are played. Games have always been valued "as social experiences, as a way for people to relate to each other […]" [8]. The benefits of leisure games on personal well-being encompass physical and mental health [1, 9, 10], in particular, leisure may

help overcome loneliness. Furthermore, most social games can be enjoyed by novices and experts alike, making them suitable as "ice-breakers".

Many of the benefits of leisure games are the result of their capability of fostering companionships and friendships [1]. Through leisure activities, people are able to meet and connect to one another. Leisure activities can build bonds between people, resulting in loyalty and team-spirit. Leisure sports can be especially helpful in facilitating social introductions. Sports clubs, for example, not only function as a place to exercise, but also as a social space. Team sports are a great way to meet new people, and joining a sports club is often recommended if one moves to a new city and wants to make new friends. Social leisure activities have also been used as a learning tool to teach children and teenagers social skills [2]. Positive effects are not exclusive to younger people, leisure participation also demonstrates a high contribution to life satisfaction in older persons 55 years and older [3].

Social Games

There has been a growing interest in the research community on the role of fun in human-computer interaction [11], and researchers in this field suggest that leisure activities, based around the concept of social engagement, could build suitable environments to create bonds between people that have to work in a team. Some surveys have even found that a majority of employees believe that laughing on the job makes them more productive [12, 13].

Games are not only fun, but can be played by people even if they do not speak the same language. This type of "communication via game play", in which the game becomes a "context of stylized communication", has the power to bring diverse people together [8]. People also enjoy the same multi-player games worldwide, with table tennis probably being the most prominent example, an indicator that they have the ability to span different cultures and backgrounds.

Challenge

Social leisure games, specifically athletic ones, typically require players to be collocated. Unfortunately, the modern nomadic lifestyle makes it increasingly difficult for people to meet to play. People relocate for work and personal reasons [7]; this relocation often results in disrupting connections with family, friends, and teammates. This disconnection can ultimately result in the loss of relationship bonds. Cummings [4] confirms that friendships are fragile and require active maintenance and quotes Rose (1984) who found that when people change residences and move away, personal ties often dissolve. Telecommunication technologies have the opportunity to work against the disintegration of friendships due to geographic separation, however, as Cummings [4] notices:

"…even if distant friends communicate frequently by phone and e-mail, the distance itself makes it difficult for them to spend leisure time together, to share common activities, to be physically intimate, or to exchange certain types of social support."

Games over a Distance

To provide the opportunity to establish and maintain connections with long-distant friends, we are incorporating interactions supported by traditional games with telecommunication technology to create new computer interfaces that allow participants, even though geographically apart, to enjoy leisure activities together. These interfaces promote similar mental and physical health benefits as collocated activity, with the aim of supporting social connectedness between the geographically distant players. We employ the term connectedness that has been described as the intangible bond between human beings that contributes to both psychological and physical wellbeing [5]. Our approach focuses on two components: providing the players with the ability to engage in a conversation at any time, and supporting a physical (in contrast to virtual), playful game experience that can result in social connectedness between the players, even in a networked environment. By utilizing the benefits known from collocated leisure games, we believe that these types of pervasive games have the potential to support social interactions between remote players and hence facilitate and maintain the bonds of friendship.

Connecting People through Networked Exertion Games

The following gives an overview of our projects on providing people with physical leisure activities that support them to socially connect across the distance. All systems are designed to model traditional collocated experiences, in order to keep the barrier for participating low. They make use of an *Exertion Interface* [14], an interface that deliberately requires intense physical effort, which we believe to be beneficial in creating a sense of connectedness between geographically distant participants.

- *Breakout for Two* is a soccer-like game that uses distributed targets on a life-size videoconference to enable a sports experience between two players who each kick a real physical ball.

- *Airhockey Over a Distance* creates an increased sense of a shared space across the distance by creating the illusion of shooting a real puck "through" the network for a game of airhockey between geographically distant players.

- *Push 'N' Pull* uses isometric exercise equipment to encourage users to complete a cooperative, not competitive, game whilst performing intense muscular actions.

- *Table Tennis for Three* demonstrates that the concept of *Games over a Distance* scales to three locations, supporting an experience that is not possible if players are collocated: allowing three players to play table tennis simultaneously.

Our work ranges from supporting one-to-one interactions to multiple locations. Some are designed to be played on a dedicated court, while others only require the space of a table. A few involve sharing a virtual object, while another incorporates the passing of a real, physical object across the distance. With these systems, we hope to

encourage further work in the area of distributed physical games with the aim of supporting social interactions between geographically separate players.

Breakout for Two

Fig. 1. Breakout for Two

Breakout for Two (Fig. 1) is a combination of tennis, soccer, and the computer game Breakout. It is played by two geographically distant players with two real, physical balls and a large-size videoconference [15]. The name derives from the classic computer game Breakout, in which a player destroys blocks in order to "break through" to the other side. The players, who can be miles apart from each other, both throw or kick a ball against a local, physical wall. On each wall is a projection of the remote player, enabling the participants to interact with each other through a life-sized video and audio connection (Fig. 2).

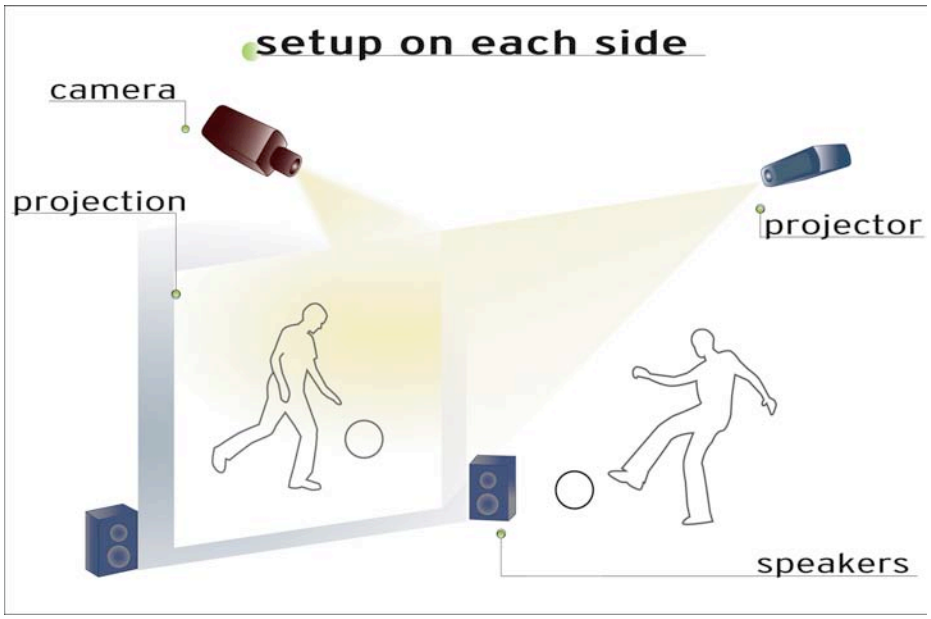

Fig. 2. Setup on each side

The two players can talk and see each other at all times. For the players, it feels like they are separated by a glass window that splits the two parts of the field (Fig. 3).

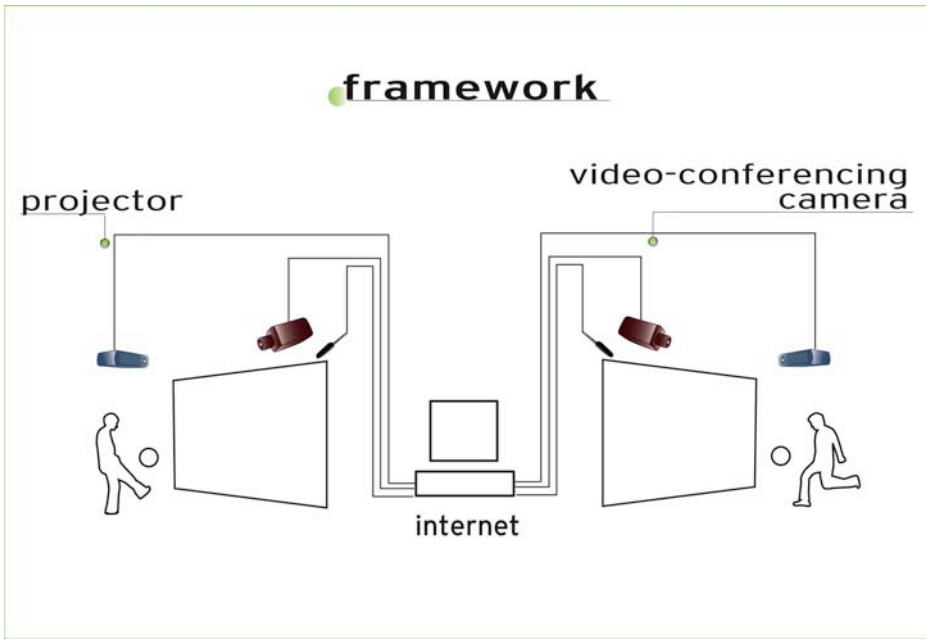

Fig. 3. Framework for *Breakout for Two*

The players kick or throw the ball in the direction of the other player, but it comes back, bouncing off the wall. Eight semi-transparent blocks are overlaid on the video stream, which each player has to strike in order to score (Fig. 4).

Fig. 4. Semi-transparent blocks overlaying the video

These virtual blocks are connected over the network, meaning they are shared between the locations. If one of the two players strikes any of them once, they "crack". If that block is hit again, it cracks more. On the third hit, the block "breaks" and disappears. This analogy was chosen to portray the idea of "breaking through" to the other person on the remote end. The player would only receive a point if the block breaks. This scoring theme creates an interesting, strategic game because the players can watch what the other player is doing, waiting for her/him to hit a block for the second time, so they can then snatch the point by hitting it for the third and final time. In order to avoid a purely tactical game and encourage intense physical activity, an impact-intensity measurement component was added. If the player hits the block hard, it would not only crack a little, it would crack twice. A really hard strike could even break the block completely in one go. For this, the impact intensity was measured and mapped onto a three-point scale. The harder the player hits a block, the more it cracks. For a description of the technical implementation, see [6].

Fig. 5. Two-on-two is also possible

Evaluation

Breakout for Two was evaluated against a keyboard-controlled networked computer game [15]. 56 participants were split up into pairs, and were either asked to play *Breakout for Two* or an analogous computer game controlled with a keyboard, which utilized the same life-size videoconference. For each game, the two players were in two different locations and had not met each other before; in fact, the first interaction they had was through the videoconference.

The statistically significant measures showed that the exertion-game players rated the interaction with their new game-partner higher in contrast to the keyboard players: they said they got to know the other player better, had more fun, became better friends, and, surprisingly, were happier with the transmitted audio and video quality although the quality was identical between the two games. Almost all of the players in the exertion group were very exhausted after the game. Most of them told us that it was much more exhausting than they thought it would be. Indeed, the game can be very demanding and fatiguing. Some players were getting so involved that they were seriously out of breath and their shirts heavily sweaty. We had to put a water-cooler close by, because we got concerned that some participants might become dehydrated.

This evaluation showed that if a pervasive game like Breakout for Two requires intense physical activity, it can work better at fostering connectedness than one that

lacks it. Physical activity encourages social interaction and can affect one's overall well-being, and *Breakout for Two* was the first instance that demonstrated that this is possible over a distance.

Airhockey over a Distance

Airhockey is a leisure game that exists in arcades all over the world since the early 1970's and has outlived most of the other arcade computer games [16]. Part of the reason for its success could be that airhockey is an accessible game as it does not require special skills nor does it have complex rules or a steep learning curve, making it suitable for social game play for players of all ages. Airhockey is played by two competing players that are trying to score points in the opposing player's goal with a small round bat. The puck on the table glides on a layer of air, pushed through hundreds of small holes, minimizing surface friction and thus enabling quick game play.

Airhockey requires fast hand-eye coordination and reflexes, and, just like *Breakout for Two*, relies on the physicality of the puck and the players' attempt to master its deflections. In *Breakout for Two*, the two players are separated by the wall with the videoconference over which they communicate, just like the net splits the court in half in tennis or volleyball. The players in these sports stay on their half of the court, and never cross the middle line. The ball, however, travels across the net, and is the main object of physical activity. *Breakout for Two* uses virtual blocks to emulate the experience of an object traveling across the boundary line, but ideally, the ball should hit the videoconference, travel across the distance, and come out the other end. We were interested in how would players respond if they could in fact "pass" a ball through the network back and forth between each other. *Airhockey over a Distance* demonstrates a simplified version of this concept by limiting the interaction area to the 2D surface of an airhockey table, making an implementation more feasible [18].

Fig. 6. Airhockey over a Distance

Airhockey over a Distance allows the object of interaction, the puck, to replicate its appearance across a network to support geographically separate players (Fig. 6, 7). The puck is a real, conventional airhockey puck, unlike in virtual simulations such as [17], that disappears on one end, and is shot out on the other. The players literally shoot it “through the network”.

Fig. 7. The setup of Airhockey over a Distance

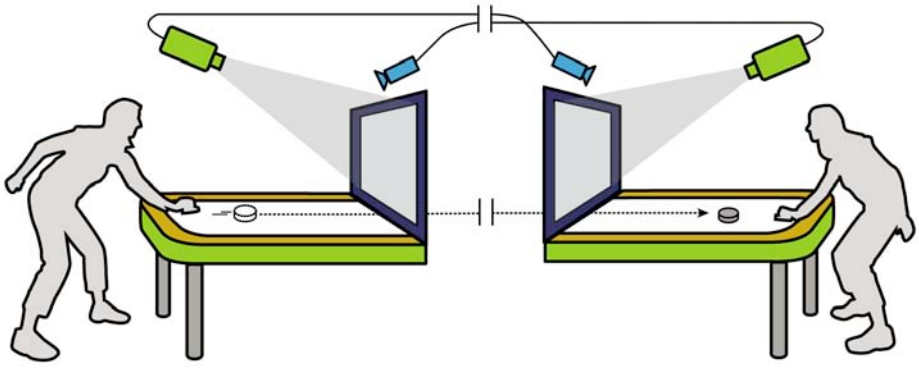

Fig. 8. The puck travels “through” the network

The table is figuratively split in half and the two ends are networked. Each player is recorded by a camera and the video is projected onto the screen of the other player, creating the illusion of playing together on one table (Fig. 8). This videoconferencing screen is placed in the middle of the table, with a small area of space for the puck to slide under it. When a player shoots a puck across the half-way line, it disappears under the videoconference projection surface and is collected in a catchment tray behind the screen. At the instance it crosses the centre line, the puck is detected by a sensor which triggers the networked software. Once the software receives the signal, it triggers one out of four rotating puck cannons on the other table to fire out a puck (Fig. 9). These cannons rotate around an axis, and a trigger mechanism pushes a puck out of a stack of pucks towards a spinning disc, which shoots out the puck. The cannons hold enough pucks for several games. For the players, it appears like they are passing a real, physical puck back and forth between each other, through the network.

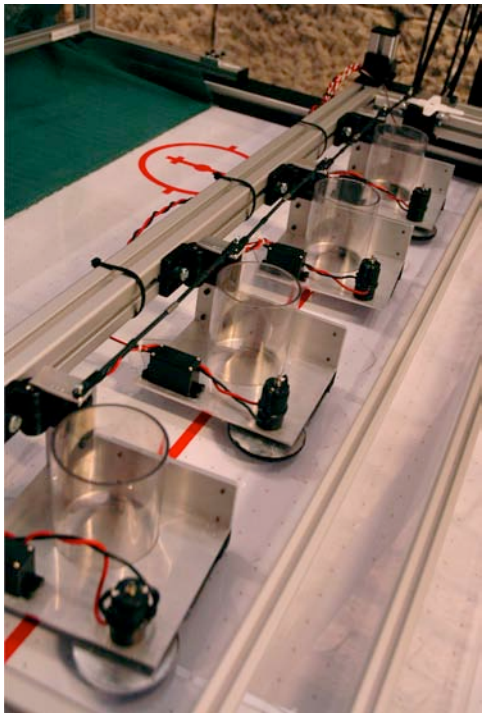

Fig. 9. The puck cannons

Evaluation

Fig. 10. From a player's perspective

The aim of *Airhockey over a Distance* was to demonstrate that a physical activity can contribute to a social experience between geographically distant players, just like in *Breakout for Two,* and the physical passing back and forth of a real, physical object can facilitate an enhanced sense of a shared space for the players (Fig. 10). Mechanical details like the precise replication of the puck's movements were not the goal of this demonstrator, but the concept of physical replications of objects, based on peoples' traditional experiences when playing games. We therefore focused on acquiring feedback from players to comprehend their experiences while playing and interacting with the system to inform future designs for pervasive games.

Airhockey over a Distance was initially demonstrated to an audience of 100 researchers (who were not part of the development), of which 40 played the game. Subsequently, the system was stress tested at a public event with ca. 30,000 visitors. The airhockey tables were set up in two different rooms, from which participants could neither see nor hear each other. At both events long queues indicated the popularity of the system. The quick game-pace of the system evoked an excited response from participants. Many players coordinated their friends' waiting time so they could play together; this indicates to us that the game experience differs whether you play with strangers or people you know. Although the audio environment was less than perfect, we observed a relaxed atmosphere between the players, who showed "thumbs up" to each other or swore at one another. We recorded comments such as

“This feels like playing on one table”, as being supportive of our initial objectives. Also, sometimes really hard hits made the puck fly off the table, which triggered laughter and amusement by both players. These “accidents” are an essential part of the physical game experience, which computer games are lacking. A puck flying off the table elicits a different social response from the players than a software error in a networked computer game, we believe.

Although the puck’s trajectory was not replicated at this stage, the participants took it with bemusement and one participant in particular found an interesting viewpoint: “This feels like my first salsa lesson, I’m slightly confused, but it’s a shared experience to talk about.” Another participant exclaimed, “If you could get pucks to line up, I think that’s the only thing that’s missing, other than that, I think it’s pretty cool… very cool.” Other players took things “in their own hands” and stopped and placed the puck with their hands in position, which is illegal by the airhockey rules and elicited complaints by the remote player. Especially those “cheats”, facilitated by the physical presence of the puck, often lead to social interaction between the players, hence contributing to a positive experience.

We also distributed a questionnaire amongst the players and analyzed 32 responses [19]. 26 participants agreed with the statement that even if the returned puck did not have the anticipated trajectory as expected from the videoconference, it did not affect their interaction with the other player. The majority (31) stated that they had fun with the game. 24 said that they wanted to play longer, and 15 said that the game created some sort of bonding between them and the other player (8 were indecisive). 22 players confirmed that they had a sense of being in the same room with their opponent (4 were indecisive).

Even though this was an informal evaluation, we were able to observe that participants had a shared experience with their game-partner. When being interviewed about the game experience, an enthusiastic participant commented, “I’m taken with this.. you could have a true interaction with someone, they could make you laugh, they could make you swear.. that kind of interaction is unique, without abusing the word.”

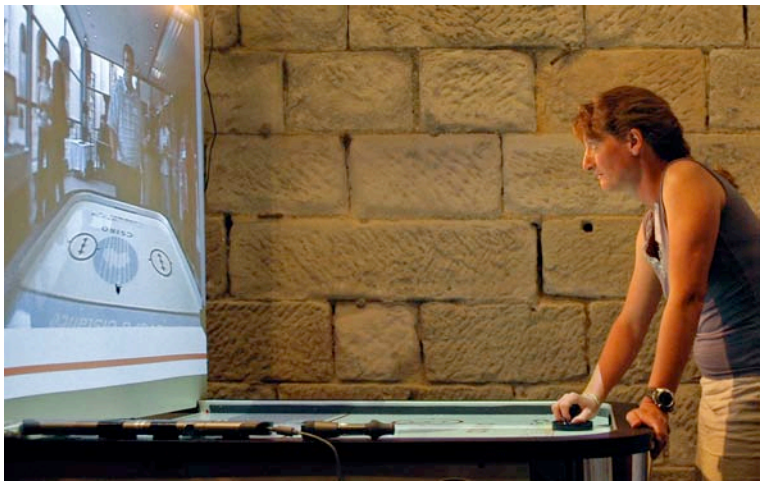

Fig. 11. Side-view of *Airhockey over a Distance*

Table Tennis for Three

Table tennis is one of the most popular sports in the world in terms of player numbers [20]. Table tennis is also a social leisure activity, played by players of all ages and capabilities. Table tennis helps to develop hand-eye coordination, agility and reflexes and can contribute to general fitness. However, the players have to be in the same physical location to enjoy a game. Furthermore, three players cannot play at the same time in a way that is fair or equitable to all players. In order to address this, we have built a table tennis game that can be played by three players simultaneously, although being geographically apart (Fig. 12).

The focus of this game is on the scaling of the concept of *Games over a Distance* to three locations and the use of table tennis for social interaction. Breakout for Two can support multiple players, but has not been demonstrated with more than two locations. To address this, we developed Table Tennis for Three. This game enables three people who are all distantly located from one another to play a table tennis-like game while simultaneously engaging in social conversation.

With our design of Table Tennis for Three, our objectives and questions were:

- Can we benefit from the social potential of table tennis if the game is transferred into a networked environment?
- Can we support three players, something that is not possible if players are collocated?
- Last but not least: is such a game enjoyable and fun for the players?

Our aim was therefore not to replace traditional table tennis as a leisure activity, but rather provide an alternative if players would like to play, but are located in geographically distant locations. Furthermore, we wanted to demonstrate that if users are geographically distributed rather than collocated, this can be an advantage rather than a shortcoming.

The Game

Table Tennis for Three [21] involves many of the physical skills of table tennis. Game play includes hitting a table tennis ball with a table tennis bat on a table tennis table against a backboard. This backboard is one half of a table tennis table, which is usually pushed together with the other half to create the playing surface. By tipping one of these halves from the horizontal to the vertical position it is possible for players to play the ball against the backboard created. This setup is familiar to table tennis players who have practiced by themselves by repeatedly bouncing the ball off the backboard with their bat.

Fig. 12. Table Tennis for Three

The game play is adapted from the Breakout for Two game, but extended to three locations: with Table Tennis for Three, the players also have to hit virtual blocks, superimposed over the videoconference, however, each player is playing against two

opponents (Fig. 13). A projector mounted to the ceiling projects two video streams of the other players side by side. The blocks are identical for all three players, i.e. they are synchronized across all three stations (Fig. 14).

Fig. 13. The elements of gameplay overlay the video conference streams

Unlike the Breakout for Two system, which utilizes vision detection with two cameras to determine the ball's impact, Table Tennis for Three uses piezoelectric sensors mounted on the back of the hitting surface. The sensors detect the sound vibrations in the wooden board created by the ball striking it from the front (Fig. 15). This approach can handle the very fast-flying table tennis balls. Although high-speed cameras can deliver fast frame rates, we encountered problems acquiring a contrast-rich image of the small table tennis ball using such cameras. The environment light needed to be limited for the projection, which proved to be not enough light for a reliable vision detection, hence we decided on an acoustic approach.

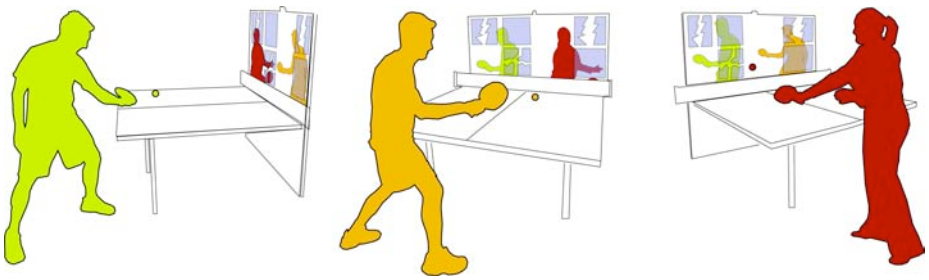

Fig. 14. The blocks are synchronized across all three stations

The blocks 'break' when hit by the ball because the sensors register the location of the impact. All players see the same block layout and the same block states, like in *Breakout for Two*. A block also needs three hits before it breaks, however, the intensity of the impact did not affect the block state, because hitting a table tennis ball affords different physical activity than hitting a soccer ball, we found in preliminary tests. Hence the game focuses more on tactical, hand-eye coordination and fine-motoric skills than on brute force. Each block that is completely broken scores one point, and the running score is displayed along the top end of the projection. Feedback from *Breakout for Two* revealed that it was not always clear to the players who hit which block. We therefore implemented a feature that when a block was struck by a remote player, the local block flashes in a color corresponding to the remote player.

Play continues until all blocks have been cracked three times and been removed from play. At this point the player who has scored the most points is announced as the winner and after a delay of 15 seconds, the game resets all the blocks and play can recommence.

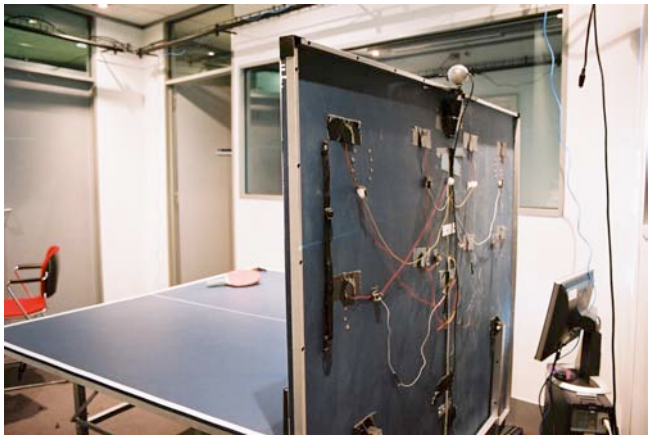

Fig. 15. Backboard with sensors

Evaluation

We were interested in feedback from players about their experiences with playing Table Tennis for Three and therefore undertook an evaluation. We were particularly interested in whether the system supports the social interaction between the players, although they are in different locations. An evaluation with 41 participants using questionnaires and interviews indicated that the participants enjoyed playing Table Tennis for Three and they could imagine such a physical network game being helpful in facilitating rapport between people who are physically apart but want to stay in touch. In particular, they expressed a strong sense of "playing together" and

commented on the fact that it “gave them something to talk about”. The affordance of the table tennis game allowed participants to quickly engage and interact, and most players reported that they had fun, considered it a work-out, used the game to build social rapport, forgot the world around them when playing, and wanted to play again.

Push’N’Pull

Push’N’Pull [22] uses the physicality of an exercise machine to facilitate social interaction between remote participants. Similar to *Breakout for Two*, it supports very exertive interactions. However, *Push'N'Pull* is not centered on competition, but cooperation between the geographically distant players. It requires two users to exert synchronized actions at varying physical intensity to complete a cooperative game. The players must communicate in order to succeed, while integrated high-quality videoconferencing software supports these efforts (Fig. 16).

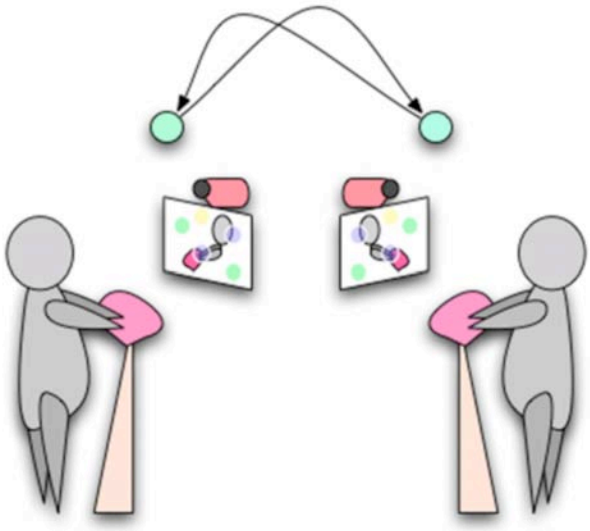

Fig. 16. Concept diagram of *Push’N’Pull*

Game Play

To play the game, the two players stand at a controller station that is connected to each other via a network. Each of these controller stations contains a “Power Grid” [23] exercise machine, a video camera and a monitor providing a digital-video (DV) quality videoconference with the other player (Fig. 16).

The “Power Grid” device contains an isometric exercise bar which requires physical exertion of different muscles [24]. Although the bar does not move when pushed, it measures the force that is applied and outputs it to the computer. This was used as the controller of a cooperative game in which two participants command a shared virtual object on the screen in front of them. The task is to use the shared object to chase and capture graphical particles on the screen that have an avoidance behavior before time runs out. These particles are harder to catch if only one player is acting on them, encouraging the cooperation and communication of both parties to complete the task. If both players push and pull in the same direction, their combined force makes it easier to win the game. The screen displays not only the game, but a real-time video of the other player, allowing the two players to visually and audibly communicate (Fig. 17).

Fig. 17. Setup of *Push’N’Pull*

Fig. 18. Facial expressions during gameplay

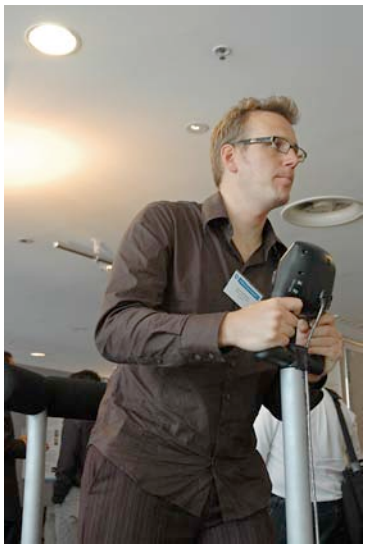

Fig. 19. Using full body input

Fig. 20. During the game

Fig. 21. Large body gestures

Evaluation

The system was presented at an internal conference with about 200 people. Around 50 participants of the system were videotaped and comments were noted. The demonstration showed that the interface of the game needs to have few instructions, allowing the participants to easily interact. We were encouraged to see that players interacted with the device with a wide range of forces. Some applied gentle pressure (Fig. 18), others a steady force and yet others applied full-body movement into pulling and tugging the device (Fig. 19). Participants communicated with their teammate through the use of contextual and expressive audio. For example, the participants gave specific directions on where they wanted their partner to push to, but also used more expressive ejaculations such as "Ouch!" to express their surprise. Furthermore, they used explicit (hand gestures indicating direction) and implicit (facial expressions, deliberate and accidental) video content to communicate. An extreme example of what kind of reactions the system elicited can be seen in Fig. 20 and 21. We believe the game would have not triggered such a response from the participants in a traditional non-exertion mouse and keyboard-based interaction.

Related Work

Supporting physical activity for entertainment and leisure purposes has increasingly gained attention in the pervasive games domain, in particular the sports market considers this an area of extensive potential [25]. The following examples focus on pervasive systems that facilitate an *Exertion Interface* to support social interactions between geographically distant participants.

From a research perspective, *Computer Supported Collaborative Sports* [22] investigates the design of computer applications which require sportive input activities to gain collective game experiences, mostly executed over a distance. An earlier mention of the term *Long-Distance Sports* appeared in [26], but focuses on commercial products. Most of the described interactions utilize an *Exertion Interface*, an overview of those can be found at [27].

Games that expand the users' interactions into the real world and utilize the physicality of their environment in combination with information technology have been explored previously. *Telephonic Arm Wrestling* is an early example (built in 1986) that supports players in two different locations without being bound to a screen or keyboard [28]. There now exist several instances installed in museums across the USA that include a videoconference to arm-wrestle another visitor over the distance [29]. A similar game is *Virtual Tug-of-War* [30], which is a group physical activity in which two teams of high-school students were involved in a tug-of-war 13 miles apart from each other.

The console game market recognizes a trend towards full body movement as input device for their games, extending the range of traditional button presses on game pads and joysticks to more physical actions as, in particular, known from sports. The Sony

EyeToy is a webcam for the Playstation that tracks the players' body movements through vision detection and hence allows the controlling of objects on the screen, simulating an experience such as heading a ball or performing martial arts. Initial games were single-player only, but recent advances support up to eight players simultaneously, which makes them marketable as "lifestyle" or "social" games. However, they are not playable over the network yet [31]. The researchers of the *action interface* developed a camera-based table tennis game for rehabilitation purposes that is playable between remote participants [42]. The players make an arm-movement as if they are trying to hit the ball, however, the ball exists only on the screen, so they never experience a force feedback regardless whether they hit the virtual ball or not. A similar non-contact virtual game is AR^2: Two players wear head-mounted displays to see a virtual puck on a table. Unlike our approach, the game requires both players to be in the same physical location [17]. The authors suggest a vibration force-feedback device to simulate the impact of the puck; however, we believe the physical impact experienced in *Airhockey over a Distance* is more exciting and creates the illusion of a shared space better than a vibration.

Dance Dance Revolution Ultramix [32] is a home version of the popular dancing arcade game, in which the players follow dance instructions on the screen with their feet on touch sensitive tiles. It can be very exhausting, but also quite social, drawing large crowds when good dancers "enter the stage" [41]. *Dancing Stage Fusion* [43] was the first game that combined the use of the dance mat with the EyeToy, demanding more sweat from the players by making them dance with their feet and hands. The *Bodypad* [33] also supports body movements as input control through pressure sensors on the hands and legs, replacing button presses in console games. Two players can fight each others' avatars, but only in front of the same screen. Nintendo with the introduction of their *Wii* console has made a step towards more pervasive interaction and away from traditional game pads: the console comes with a controller that contains accelerometers. In order to, for example, hit a virtual tennis ball, the player uses the controller like a racquet [34].

Augmenting an existing physical experience with computing technology has been attempted in several projects that centre on the exercise gym. *NetGym* [35] supports physical activity between geographically distant participants: two physically separated exercise bicycles are networked and the cyclist cycles with an avatar representing the remote user. The *Virtual Fitness Center* [36] uses a similar approach also with exercise bicycles: the physical movements conducted are used as input to modify the representation of 3D virtual environments from map information. Conversely, the map information affects the pedaling efforts. *PingPongPlus* [37] utilizes a table tennis table: a projection is augmented on the table that reacts to the impact of the ball; however, it supports only two collocated players.

A multi-player game that utilizes a large, although confined, space is *Virtual Arena* [38], in which the body movements of the players are tracked and mapped onto fighting avatars, so the players are able to hit one another without getting hurt. Although there is currently only support for local play, it seems plausible that this system could easily be expanded to work across remote locations. An even larger version is KickAssKungFu [39], which, although also not networked yet, shows how physical play can be supported in large spaces.

An example that supports force-feedback for multiple players was shown by Faust [40], also based on the classic game Breakout: Players use wooden batons to control the bouncing ball on the screen, trying to score more points than their game partner.

Future Work

The aforementioned systems are examples of pervasive games that utilize an *Exertion Interface* to facilitate the social interaction between geographically distant participants. They indicate that a pervasive approach to game design can be beneficial to the social experience between players that are in different locations. However, there are still many challenges ahead and many opportunities yet to be explored:

Asynchronous Interaction

The presented prototypes utilize a videoconference as main communication channel between the participants, hence supporting a synchronous interaction (besides a small network lag). However, if players from different continents want to participate together, they might encounter the problem of finding a suitable time for both of them, being in two different time-zones. Although the current advances eliminate the need of being in the same location, they do not affect the synchronous aspect of the games. Although technology probably holds potential to address this issue, the asynchronous realization of a shared networked physical activity has yet to be successfully demonstrated.

Scaling

Table Tennis for Three demonstrates that it is possible to support three players simultaneously. Breakout for Two, although initially designed for two players, can also be played with four players. However, how much does the concept scale? Does it scale further in terms of player numbers, or in terms of locations, or both? Technologically it is easily deployable to attach additional nodes to the network, but how does the game play need to adapt in order to support dozens of players? How about 100 playing simultaneously?

These open questions pose many opportunities from a pervasive viewpoint, but also from a games perspective, because the nature of how we interact in games with others is challenged by these novel concepts. We might have a different understanding of games in the future than we have today, and might not think twice about playing with others in remote locations, coming together with people far away.

Conclusion

This article described four pervasive games that utilize networked exerting leisure activities in order to create an increased connectedness between geographically distant players. *Breakout For Two* allows remote players to play an exerting game of

soccer, which resulted in a stronger bond between the players than a similar keyboard-based game. *Table Tennis for Three* is a networked table tennis-like game played with a physical bat and ball that supports three players on three geographically separate tables. It shows that the concept of distributed physical games scales to three locations, enabling an experience that is not possible if participants are collocated. An evaluation with 41 participants using questionnaires and interviews confirmed that the players had fun, used the game to build social rapport, reported a strong sense of playing "together", and had physically exerted themselves. *Airhockey over a Distance* focuses on the physicality of a shared play object between the locations. It is a casual game in which the players hit a real, physical puck back and forth between each other, which was not only described as very enjoyable and engaging, but also contributed to the perception of sharing a "real" space across the two locations. *Push 'N' Pull* allows geographically distant participants to exercise together, requiring them to physically cooperate in order to achieve a shared goal.

These games present a novel concept in combining networking, socializing and physical activity. They are based on the benefits of existing games, and aim to create a similar social experience between geographically distant players. The traditional games include physical activity as essential part of their game play, and we believe that the transfer of this activity into the network environment, facilitated by an *Exertion Interface*, contributes to the success of these pervasive games. They do not aim to replace collocated gaming experiences, but rather provide the "next best thing" if participants are in different locations. Providing remote friends and families a social physical leisure activity can contribute to maintaining their bond, and work against the dissolution of the tie.

Although leisure activities are only one way of supporting social interactions, the feedback we gained indicates that these pervasive games are able to facilitate an increased connectedness between geographically distant players. Players use the universal language of games to come together; and now they can do this with people all over the world.

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