Design Space of Networked Exertion Games Demonstrated by a Three-Way Physical Game Based on Table Tennis

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Physical leisure games can be beneficial to physical as well as mental health and offer a means to connect with others socially. However, players have to be in the same physical location to play. Recent trends in the gaming industry and research labs have started to embrace exertion games: physical games that are expected to be exhausting because they require intense physical effort. However, there is still a lack of a design space that can guide in evaluating such exertion games, help designers in creating future games by maximizing their potential, and inspire new directions in this domain. We present such a design space for exertion games, based on the characteristics of traditional physical games but extended to support distributed interactions. Our motivation is based on the belief that the physicality found in traditional leisure games contributes to facilitating social bonds. We used this design space to develop a networked table tennis-like game called "Table Tennis for Three." It is played with a real paddle and ball and augmented with a large-scale video-conference. Our prototype shows how the application of the design space can leverage the potential for novel exertion gaming experiences such as supporting three players in three geographically distant locations. An evaluation with 41 participants indicated a successful application of some of the ingredients of the networked exertion games "cocktail"; however, some participants did not enjoy the game, and we present informed interpretations to explain their reactions. With this work we aim to provide other researchers and designers with a practical design space of the main components that can create a networked exertion game, and hence inspire and guide them in designing and evaluating future networked exertion games.

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1. INTRODUCTION

Physical leisure activities such as table tennis are an important part of people's lives. The benefits of leisure activities on personal well-being have been widely discussed: from a mental health perspective, leisure is believed to have a beneficial effect on psychological well-being by promoting positive moods and in helping to overcome loneliness [Coleman et al. 1993]. From a physical health perspective, athletic leisure activities contribute to a healthier body, reducing the risk of obesity, cardiovascular disease, diabetes, and more [Pate et al. 1995; Bauman n.d.].

In particular, table tennis helps to develop hand-eye coordination, agility and reflexes, and can contribute to general fitness [Letts n.d.; Shriver et al. n.d.]. It is a popular leisure activity, played worldwide by people of all ages and capabilities. Like many other leisure activities, it has a relatively low entry barrier, and it often serves as ice-breaker for social interactions. In fact, research has shown that many of the benefits of leisure are the result of its capability in fostering companionship and friendship [Coleman et al. 1993]. It has also been pointed out that while these social benefits can increase participants' well-being and mental health, they also encourage the growth of social capital [Huysman et al. 2004; Putnam 2000]. The author of the book *Bowling Alone*, Putnam, argues that social capital requires social networks, which are most effectively developed through participation in shared activities [Putnam 2000]. In particular, casual exertion leisure games can provide a focus for social activity. An exertion game is expected to be exhausting because it requires intense physical effort to play [Mueller et al. 2003]. However, such games can be helpful in facilitating social introductions, provide an opportunity to develop networks, and reduce social isolation, and hence have potential to support the development of social capital. These activities can facilitate bonds between individuals, resulting in loyalty and team-spirit. However, the players have to be in the same physical location together to play a game. In other words: users who are geographically apart from one another most likely miss out on the many benefits leisure activities provide. Our current work aims to make these benefits available for distributed participants.

2. OVERVIEW

We now describe the structure of the article to guide the reader: First, we introduce the concept of networked exertion games, based on traditional physical games but extended to support geographically distant participants. We describe a novel networked table tennis-like game called *Table Tennis for Three*, which we developed to demonstrate that the concept combines the advantages of networked computer games (supporting multiple geographically distant players) with the advantages of traditional exertion leisure games (health and social benefits). We detail in the subsequent section our central contribution, a design space for networked exertion games, which we used to inform the creation of *Table Tennis for Three*. We start by illustrating the prototype before going on to the design space because for each abstract component of the design space, we describe how it can be applied in a practical development scenario by using our prototype as an example. Our prototype illustrates opportunities to support novel experiences for social interaction such as supporting three players in three geographically distant locations. We conducted an evaluation of our prototype, using observation, questionnaires, and interviews, that points out the applicability of our design space as well as remaining challenges. We conclude with an analysis of our design space and give possible future directions on how our contribution can be used by others to inform their future designs of networked physical games.

3. RELATED WORK

Other researchers have investigated the convergence of computing technology and exertion gaming activities. Derived from a sports perspective, the term, *computer supported cooperative sports* [Mueller et al. 2007] has recently been coined from related work.

Within the domain of CSCPlay, designers built networked computer games to support cooperative play between geographically distant participants, mostly controlled with mouse and keyboard. Based on the social success of traditional leisure games, others have augmented board games with computational power [Magerkurth et al. 2004]. The tangible interaction with dice and physical game pieces afford a different kind of interaction, the designers of this system argue, and some researchers have built sportive interfaces [Ishii et al. 1999] to augment existing games with artistic visuals.

Mueller et al. [2003] have shown that an *exertion interface*, defined as one that deliberately requires intense physical effort, can be superior in facilitating social connectedness between distributed participants to a mouse-keyboard interaction. Other work has used physical activity as input to promote and facilitate a healthy lifestyle through exercise, in particular to address weight issues often associated with more traditional sedentary computer work [Lin et al. 2005]. Such interfaces have, for example, been used to offer a training effect through the use of virtual adaptive coaches [Yourselffitness n.d.] or by providing encouragement through feedback on achieved exercise performance, such as calories burnt [Eyetoy n.d.]. Physical exertion as input has also been utilized for entertainment purposes [Wii Sports n.d.]. Gaming companies have discovered that they could target a new group of consumers previously resistant to computer games by offering an alternative to the hardcore gamer input devices such as gamepads with dozens of buttons, which often confused novices. Computer games can also make exercise more entertaining, thus reducing the perceived duration of the exercise.

In an experiment with non-interactive pedometers, previous research demonstrated that technological support for an active lifestyle can be most effective for people who are at an intermediate level of the transtheoretical model [Grimley 1994]: that is, users who are currently not actively pursuing a healthy lifestyle but are motivated to change their behavior, in contrast to people who lack this motivation or users who are already regularly participating in physical activity [Lin et al. 2005]. Users have self-reported similar experiences with *Dance Dance Revolution* and other activity-based gaming devices: these games supported the users' intentions to lose weight but got "boring" once a certain level of fitness was achieved [Kuchera 2007].

Dance Dance Revolution Ultramix [2005] is a home version of the popular exertion arcade game, in which 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." In general, the console game market shows a trend towards full-body movement as input device for leisure purposes. *Dancing Stage Fusion* [n.d.] was the first game that combined the use of the dance mat with a webcam, demanding more sweat from the players by making them dance with both their feet and hands. The *Bodypad* [n.d.] also supports larger body movements as input control through pressure sensors on the hands and legs, replacing the button presses in console games. Two players can fight each others' avatars, but only in front of the same screen. Nintendo's Wii console [Wii Sports n.d.] comes with a controller that contains accelerometers to support physical activities in its games. Although network-enabled, the Wii does not offer networked versions of the full-body interaction games as yet. Due to the nature of the implementation, the devices do not provide any force feedback besides a rumbling pack. Sony EyeToy's initial games were single-player only, but recent advances support up to eight players simultaneously, which gives them the attribute of being "lifestyle" or "social" games [Altizer n.d.]. Unlike our approach, these games are not networked to support geographically distant players, and the skills required to operate them are targeted at users who are new to exercising, thus keeping the physical skill requirements low.

More complex physical exertion is supported by only a few products from sports domains. *Long-Distance Sports* are described by Marriott [2004], but the author focuses on products that have limited capability in terms of distributed interaction. Networked prototypes exist in research labs, but they often lack a communication channel for social interaction between the participants and do not support more than two locations. Most of them were opportunistic designs enabled by advances in technology, and were not accompanied by a universal design space that could inform future systems. The following examples give an overview of prototypes that support at least some sort of exertion in a networked setting.

Telephonic Arm Wrestling is an early example (built in 1986) of a networked exertion interface [White n.d.]; there are now several of these installed in museums that include a video-conference to arm-wrestle another visitor over the distance, but only two can wrestle at the same time [Gizmag 2004]. *NetGym* [Brucker-Cohen et al. n.d.] 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* [Mokka et al. 2003] uses a similar approach with exercise bicycles. The physical movements are used as input to modify the representation of 3D virtual environments from map information. The map information affects the pedaling efforts in reverse. The networked rowing machine [Netathlon 2007] is another example of networked exercise equipment that focuses on individual performance: the participants can see their opponent's progress, but they struggle on their own to reach a winning time. Each participant aims to be faster than his/her counterpart, but independently. This is in contrast to sports games in which players adjust their tactics in order to physically interfere with their opponent's actions (e.g.,football).

Airhockey over a Distance [Mueller et al. 2006] is an air-hockey game that is playable by players in different locations; it uses a physical puck that is shot out at the remote end by puck cannons whenever the player hits the puck across the middle line. It uses a physical object that can exist only on one table at a time, creating a shared playing area over a distance on which players either attack the opponent's goal or defend their own. However, it is only playable by two people simultaneously. Push'N'Pull is a networked exercise machine, which the players use as an interface for a cooperative game, supported by a high-definition video-conference [Mueller et al. 2007]. *Virtual Tug-of-War* [New York Hall of Science n.d.] 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. Unfortunately, no documentation of the participants' feedback exists. A game that supports video-conferencing for multiple players was shown by Faust et al. [2006]: Players use wooden batons augmented with vibration elements to control a bouncing ball on the screen, however, the games has not been scaled beyond two locations. Lawn and Takeda [1998] define an "action interface" which enables remote participants to play a virtual reality table tennis game together. The players make an arm-movement as if they were trying to hit the ball, however, the ball exists only on the screen, so they never experience force feedback, regardless whether they hit the ball or not. Three players can play ping pong with *TriPong* [Stanton 2007], but they need to be physically around the same table.

Several researchers have built virtual reality [Lawn and Takeda 1998] and augmented reality versions [Bianchi et al. 2006; Woodward et al. n.d.] of table tennis. However, they either lack force feedback of the ball hitting the paddle or are not playable by distributed participants.

Some researchers have started investigating theoretical frameworks for movement-based interactions: Benford et al. [2003] created a framework for "sensible and sensable" systems, however, this framework focuses on ubiquitous computing applications and does not consider the interactions between distributed artifacts or actors. It also does not encompass exertion as a distinct component, nor does it address the social aspects of gaming between users, but centers on interactions between users and pervasive objects. Bellotti et al. [2002] provide another framework for physical interaction, highlighting communicative aspects of interactions. The authors took ideas from social sciences and studied human-human interactions to inform the design of human-computer accomplishments. For example, just as in human communication, humans and systems must also establish a shared topic and reestablish it once communication breaks down. The approach does not consider augmented physical interactions between humans though. Larssen et al. [2004] tested both frameworks against two EyeToy games, but did not come to a conclusion as to which framework is more suitable. Dourish [2001] developed foundations of embodied interactions; however, he is more concerned with any type of tangible interface rather than focusing on physical exertion or networked play.

4. MOTIVATION

Gaming and Telecommunication Technologies

One way for allowing players in geographically distant locations to enjoy leisure activities together is through networked computer games. These games offer participants a shared experience, however, computer games are often associated with the social isolation of their players. They often fall short in providing a personal, casual interaction. Such types of interactions, on the other hand, are often seen as characteristic to collocated physical leisure activities. Computer games are also often criticized for their support of a sedentary lifestyle, in particular in regards to their gamepad interactions. In contrast, traditional leisure games often encourage physical and athletic interactions such as jumping, kicking, throwing, and running.

In our current work we utilize a physical, exertion interface in a networked environment to facilitate and support the creation and maintenance of social bonds between people. Traditional physical games are often considered as universal facilitators for social interaction and as ice-breakers between individuals and groups. We believe the physicality of the interaction combined with a compelling gameplay can positively contribute to this effect, and we aim to leverage this characteristic in a networked environment.

Conventional telecommunication technologies such as video-conferencing, email, and mobile phones are known to support task-related focus-driven activities, however, they often fall short in establishing intimacy and bonding that are characteristic of social relationships [Liu et al. 2006]. In order to support the forming of such relationships over a distance, we are aiming to leverage the social rapport-building characteristics of physical gaming activities in a networked environment.

Bonding

Nardi [2005] defines *affinity* as a feeling of connection between people: “Affinity is achieved through activities of social bonding in which people come to feel connected with one another, readying them for further communication.” She lists activities that promote social bonding: “informal conversation” and “sharing experience in a common space,” among others. According to this research, designers can facilitate social bonding by supporting such activities in their designs. Our approach is not the only way to support affinity between people. Nardi gives an example in which the raw presence of bodies in a shared space seems to heighten intensity, and therefore encourage bonding: she postulates that the charged atmosphere of a funeral might make bonding especially effective. Our aim is not to create funerals over a distance, but we do believe that sportive leisure activities can also lead to a “charged atmosphere,” and thus have the potential to make bonding more rapid. The gaming activity in our approach serves the function of a shared experience, which in turn can serve as catalyst for interpersonal conversation, as indicated by the use of traditional leisure games.

Exertion

We believe that physical interactions supported by traditional exertion games play an important part in facilitating an engaging social experience. We define exertion games as physical games that require intense physical effort. By displaying not only cognitive but also physical skills to their partners, players open themselves up in a different fashion than they would in nonactive interactions. Furthermore, we believe that physical interactions can facilitate emotional engagement with the game because “an emotion begins *as the perception of the bodily change*” (italics in original) [Lehrer 2006]. Exerting oneself in a game can easily generate this perception (through an increase in the heart rate or sweating, for example) [Lehrer 2006]. Damasio [2000] describes this in terms of a view of an embodied mind, in contrast to the more traditional view of an exclusively *embrained* mind. In order to prepare a player for an upcoming physical interaction, the brain triggers a wave of changes in the physical viscera, such as quickening the pulse and releasing adrenaline. Once the game has started, these effects are exaggerated because the muscles need oxygenated blood [Lehrer 2006]. Supporting this constant interaction or loop between brain and body is believed to create a more emotionally engaging gaming experience [Lehrer 2006]. A theory of body-subject was described by Merleau-Ponty [1945]: he considers the consciousness, the world and the human body as a perceiving thing that is intertwined and mutually 'engaged" with the human body. This "thing" also considers a correlate of the body and its sensory functions. It is not only that physical activity evokes emotion, but that physical exertion loosens cultural rules; this was investigated in work on touching in sports [Kneidinger et al. 2001]. We believe that the decrease in the impact of social influences can also positively affect bonding between participants.

5. CONCEPTUAL POSITION

We consider our work to be situated in an interactional approach. Our focus is not on supporting computers to better understand the complex social interactions of people during their daily activities, but to help users experience their own interactions in a specific situation while participating in physical leisure activities. We believe we can contribute to this approach by enabling novel experiences that create social interaction opportunities that are not traditionally available to multiple users separated by distance.

Within any engaging gaming experience, emotions play an important role. Boehner's recent work describes such emotions as partially mediated through physiological signals but also substantially constructed through cultural interpretation and social interaction [Boehner et al. 2007]. Physical games, in particular international sports, have served as a platform for exchange between different cultures for many years, the Olympics being probably the most prominent example. Participants interact with one another, often without even speaking the same language. The emotions generated during these activities are not pre-existing facts, but develop over the course of interacting with one another. In particular, we work out what we feel through expressing our feelings and through seeing how others react to them [Boehner et al. 2007]. We are motivated by this loop between expression through bodily action and emotion constructed through social interactions. We believe dedicated physical activity can contribute to such interconnection; with this specifically in mind, games can be designed to achieve the aforementioned benefits for the players.

6. THE APPLICATION OF DESIGN SPACE

We now describe a prototype game we implemented on the basis of our design space. At the same time, its development and evaluation helped to reaffirm the design space. Our focus was on combining the advantages of networked computer games (supporting multiple geographically distant players) with the advantages of traditional leisure games that require exertion (for health and social benefits). In the subsequent section we will detail how we made our design choices on the basis of our design space. First, however, we describe the game.

We incorporated mental and physical interactions similar to a table tennis game with telecommunication technology to create a novel experience that allows participants to enjoy a casual physical leisure activity together, although separated geographically. We oriented our design on a traditional colocated social leisure game because our aim was to create an enjoyable physical activity that players could associate with and use for social interactions, similar to a game of table tennis. In order to support distributed participants, we adopted the gaming idea from *Breakout for Two* [Mueller et al. 2003], which uses virtual targets to simulate the experience of a shared goal for the distributed players. This game demonstrated that a physical leisure activity (kicking a soccer ball) can be enjoyed by two geographically distant participants. Evaluation showed that the physical activity was superior in promoting a social bond between players compared to a similar mouse-keyboard interaction. We were interested in the experience beyond the two locations that supported this game, and therefore designed our game to be playable by three players in three locations. In doing so, we aimed to highlight the possibilities of supporting novel experiences for social interactions in order to demonstrate the unique opportunities such an approach provides. We can envision adding more players, but we consider the initial work of this extended game concept an important step in beginning to understand the relationships between multiple geographically distant participants when offered an augmented physical leisure activity.

7. TABLE TENNIS FOR THREE

Fig. 1. *Table Tennis for Three*.

In order to demonstrate the practicability of our design space, we used it to prototype a networked exertion game. This game can be played from three geographically distant locations, and although it has different rules than table tennis, the use of a tennis table, a paddle, and ball inspired us to name it *Table Tennis for Three.* It provides a health benefit by encouraging physical activity and training reflexes as well as hand-eye coordination. The gameplay is based on the successful elements of *Breakout for Two* [Mueller et al. 2003]; although we developed modified rules that allow for supporting three locations. So far our design space has not been tested with a scalability aspect, so we are using this opportunity to explore supporting three players in three locations and we present users' feedback on this particular aspect.

Just like table tennis, our aim was to make the game easy to learn in order to support a sense of achievement quickly. By including a video-conference apparatus, we aimed to support benefits similar to those provided by traditional physical leisure activities such as exercise, enjoyment, and bringing people together to socialize. It should be noted, however, that *Table Tennis for Three* did not aim to replace traditional table tennis, but rather to be the "next best thing" when the participants could not be at the same location together.

The main advantage provided by *Table Tennis for Three* is that it is built of off-the-shelf, low-cost components. We give evidence that the concept can support at least three stations simultaneously for minimal cost. Such advantages make the system easily replicable for other researchers. We are planning to release instructions on how to set up a table to invite others to build their own stations in order to investigate how many players can play at the same time.

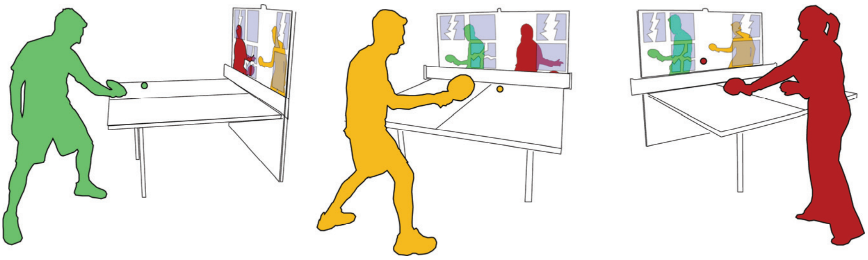

Fig. 2. The blocks are shared across the stations; a hit is visible to all players.

7.1 Gameplay

Each player has a paddle and a ball and steps up to the table. The table is set up so that the ball can be hit against the vertically-positioned opposite half of the table (Figure 1). This setup is familiar to table tennis players who practice on their own by playing the ball against the board. The vertical part of the table is painted white to also serve as projection surface for a video-conference of the other two players. Projected on top of the video-conference are eight semitransparent targets that players have to hit with their ball. These targets, or blocks, “break” when hit by the players. The blocks are synchronized across the three tables, so the other players see the same block layout and the same block states (Figure 2) If a block is hit once, it cracks a little. If it is hit again (regardless by which player), it cracks more (Figure 3). If hit three times, it breaks and disappears, completely revealing the underlying video-conferencing: the player has broken through to the remote players. However, only the player who hits the block the third and final time makes it disappear and receives the point. This adds an element of strategy to the game: a player can try to snatch away points by hitting blocks that have already been hit twice by the other player. Each broken block scores one point, and once all blocks are cleared, the player with the most points wins the game (Figure 4).

Fig. 3. Shared virtual targets are overlaid on top of the video-conference.

Fig. 4. A player enjoying the competitive aspect.

7.2 Technical Implementation

7.2.1 *Video-conferencing.* The video-conferencing implementation is deliberately kept independent from the technical gameplay component. Developing a video-conferencing system is not a trivial task, and many open-source and commercial systems claim to offer the best compromise between bandwidth limitations and image and audio quality. These implementations balance the most efficient compression codecs with en- and decoding CPU requirements, deal with varying network lags and congestions, provide circumventions for firewall issues, and aim to reduce noise and echo effects. In order to utilize the latest advances in video-conferencing technology, we implemented the gameplay independently and placed the application window on top of the running video-conference as a half-transparent layer. This ensures that any researcher who wants to recreate the system can take advantage of their existing video-conferencing infrastructure and is not locked into a proprietary system that might become quickly outdated. The gameplay software is programmed with a transparent background which allows the players to see the underlying video-conference; however, the hardware acceleration of the graphics card needs to be turned off to allow for this transparency effect to work. We are not using any special graphical effects that require hardware acceleration, and have not noticed any delay affecting the gameplay due to the deactivation.

In our current setup, we are using a video-conference resolution of 640x480 pixels with 25 frames per second to support the fast-moving actions exhibited by the players during gameplay. The images are captured by consumer webcams equipped with wide-angle lenses and attached on top of the vertical half of the table tennis table. The camera is able to capture most of the participants in the space while they are hitting the ball, however, if the ball drops below the table, the player is out of view. We had considered mounting the camera through a hole in the middle of the vertical half of the table, but the difference of perspective was marginal compared to the top position. This position was also closest to the eye level of most of the participants.

The audio is captured with Bluetooth headsets worn by the players. We were experimenting with directional microphones, but the impact noise of the ball was often captured on top of the players' voices. Furthermore, the nature of the game requires the players to move around intensively, and talking when collecting balls behind the table or at the remote end of the room was hardly picked up at all by the stationary microphones. So we decided to ask the users to wear a Bluetooth headset, which for our purposes is a low-cost wireless way to transmit audio. Due to the fact that we only used the microphone functionality of the headset, the user could also wear the device on his or her shirt collar, which was often preferred to the time-consuming adjustment required to position it on the ear. The audio-out is sent to speakers located under the table in order to allow spectators to hear [Esbjornsson et al. 2006] and for us to observe (with a hand-held video camera) what was being said during the evaluation. This setup, however, often created echoes, with the microphone picking up the audio coming from the speakers. Several users commented on this, and a proposed alternative setup would be to route the audio through the headset to avoid this problem. Although we carefully tried several Bluetooth models, we found none entirely suitable due to battery issues, inconvenient buttons, pairing problems after recharge with the PC, and awkward fit to the ear.

7.2.2 *Gaming.* The game of hitting the blocks and the accompanying score is implemented in Flash, which synchronizes its game state through a Flash media server. Flash provides a familiar visual development environment for Internet-based game developers, and hence our choice of framework should make developing additional games appealing for game designers. Each table acts as a client, which talks to the server that is responsible for distributing the latest block states and scores among the other clients. Our approach supports uncertain networking conditions because we are using an HTTP fallback mechanism in case network ports are blocked due to firewall restrictions. Although we have not tested our system across large distances, the aforementioned provisions of using external software packages that support varying network conditions make a public Internet-based implementation feasible.

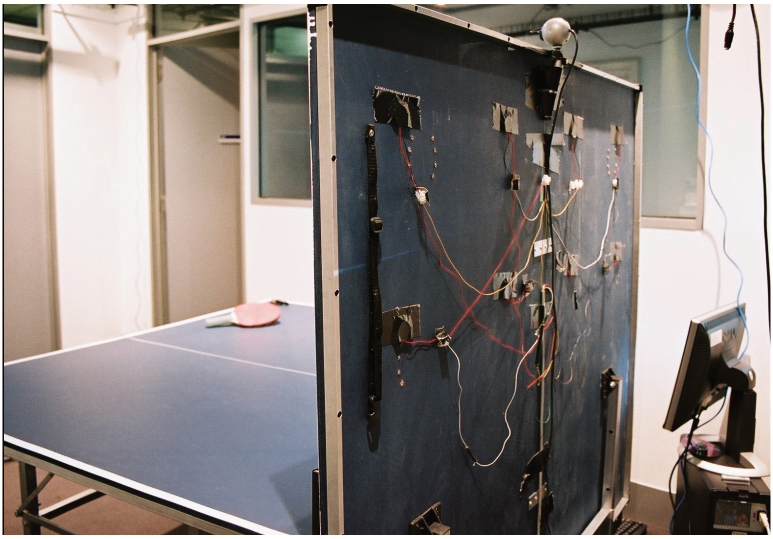

Fig. 5. The sensors attached to the back.

7.2.3 *Impact-Detection Mechanism.* In order to detect the impact point of the table tennis ball on the vertical part of the table, we experimented with high-speed vision-detection cameras. However, the speeds that a table tennis ball can reach [Turberville 2004] require a high shutter speed, which in turn profits from bright illumination of the area. Additional lighting affects the projection of the video-conference, so we decided against this approach and chose an audio-based detection system. Eight piezoelectric sensors were attached to the rear of the backboard in locations corresponding to the gameplay blocks projected on the front of the backboard (Figure 5). The sensors detect the sound vibrations in the wooden board created by the ball striking it. This approach is similar to the system described in Ishii et al. [1999], but we were not able to achieve a highly accurate system with four sensors (which should cover the entire surface through interpolation), and therefore opted for the use of eight sensors. Preliminary tests revealed that it was very important for the players that all of their hits were properly counted, and consequently we focused on a reliable, accurate detection system.

The sensor that receives the vibration signal first, exceeding a certain threshold, determines the location of the impact. After an A/D conversion and data acquisition with 25 kHz into a PC, the software decides which of the bricks should be cracked and sends it to the game engine.

7.2.4 *Network Delay.* Due to the separation of the video-conferencing component from the gameplay engine, we were able to update the video-conferencing software when technological advances become available. Hence any networking delay is determined by the quality of the implementation and the condition of the network. The additional bandwidth which will be required when game data is transmitted consists of a few bytes, and is therefore negligible. So we expect no greater lag than in a traditional video-conference that is conducted over an Internet connection.

8. DESIGN SPACE FOR NETWORKED EXERTION GAMES

In the following section we lay out a design space for networked exertion games, which we draw from our own previous experiments as well as related work. We believe physical interactive activities have recently gained increased attention, and so it is important to identify emerging theoretical components to generate an informed approach for future designs that will combine physical exertion and networked interaction. Where applicable, we also include the components we focused on during our latest project, *Table Tennis for Three*, and how we applied them to practical implementation details. We understand that due to various limitations (mostly of a technical nature), not every component can be integrated in every design. However, our aim is to present a mix of salient ingredients that allow designers to make informed decisions on networked exertion interfaces. These ingredients are not mutually exclusive, and just like the many pieces of a puzzle, not all of them are needed to identify the final picture. We believe that the more pieces of the puzzle are laid out and the more pieces fit together, the clearer the end result will be (Figure 6).

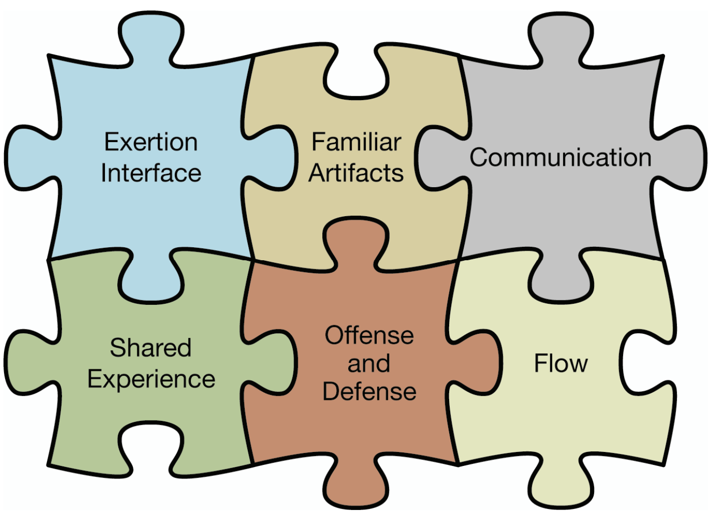

Fig. 6. The puzzle pieces form part of a bigger picture.

Exertion Interface

Utilize an exertion interface to elicit emotions and engage users

Although our design space originated from the need for a conceptual model of exertion network games, we emphasize an *exertion interface* as one of the components because its definition draws attention to an important element that is worth highlighting. Traditional co-located physical exertion that is believed to facilitate social interactions, such as soccer, football, often requires a physically demanding full-body interaction as part of the activity. Exertion is often intertwined with body coordination, reflex, and, notably, skill. The definition of *exertion interface* states that it "is an interface that deliberately requires intense physical effort. [It] can be expected to be physically exhausting when used for an extended period of time." It requires skill, which "might take a short time to pick up, but a long time to master" [Mueller et al. 2003]. By actively encouraging physical activity, the interaction might support a "felt" experience better than one without such an experience. Supporting the development of bodily skills can engage the players in sport-like behaviors, which in turn can contribute to an emotional effect relevant to the previously described loop of engagement.

Applications to Table Tennis for Three. We decided to draw from the characteristics of traditional table tennis. Although table tennis isn't generally considered the most physically demanding sports activity, enthusiastic players will probably disagree with this, and professional players show extraordinary physicality. Even on a social club-level, competitive games can be very physically demanding, require fast reflexes, and produce sweat quickly. In particular, we were inspired by the many different skills table tennis players exhibit when interacting with the ball. Mastering this ball is a challenge to which many players have dedicated their lives. Our aim with *Table Tennis for Three* was to retain, at least to some extent, some of these challenges by providing opportunities to support comparable exertion motor skills.

Shared Experience

Provide a shared experience, in which players would feel like they have "done something together"

Nardi [2005] describes "sharing an experience in a common space" as a way for people to come to feel connected with one another, "readying them for further communication." Previous work on social jogging has emphasized the importance of a shared experience for enjoyment, rapport, and motivation [O'Brien et al. 2007]. The idea of team-building is grounded in the belief of personal bonding through shared experiences, in particular through challenging experiences that are often more easily achieved when tackled with others rather than alone [Glover et al. 1992].

The "common space" Nardi describes can be physical or virtual. We believe that in our networked approach we realized the "shared experience" through a "shared activity," that is, a networked game. It can provide players with behaviors to enact and a ritual to follow with the other person. Feedback from a networked airhockey table showed that users valued the feeling of a "shared court," in this example a shared table and puck. The users described a physically shared game even though they were separated by geographical distance [Mueller et al. 2006]. Nardi documents user accounts in which users were "actuating a field of connection via a simulated shared physical space,", which allowed them to meet each other "*somewhere*" [Nardi 2005] (italics in original). A networked game should facilitate this notion of a shared space in order to enable people to feel connected with one another.

Applications to Table Tennis for Three. In our game, players aim to hit virtual targets projected onto the vertical half of a table. The easiest implementation would be to simply count the number of hits, make each hit score a point, and the winner is the player with the most points. However, we aimed to include a sense of "shared experience" by sharing the blocks across the network: if player A hits a block, the same block is clearly marked as being hit, and also visible to players B and C. All players aim for the same blocks, which they share in a virtual world through the network. This game element aims to support a shared experience in which players can feel that they are breaking the blocks together to get through to the "other side."

Familiar Artifacts

Utilize familiar artifacts to support immediate engagement

Benford et al. stated that in their framework for sensing-based interaction, pre-existing functionality is important [Benford et al. 2003]. Utilizing familiar artifacts can decrease the time needed to learn how to interact with an artifact, and consequently how to play a game and make engagement immediate by supporting familiarity with existing skills. Ishii et al. have previously used existing sporting equipment for an augmented experience in their early work on "computer supported collaborative play" and an "athletic-tangible interface" [Ishii et al. 1999]. We draw on these approaches by recommending designers to use and support recognizable equipment and their associated physical actions, which we believe can be advantageous for two reasons. (1) Users may already be familiar with the artifacts, thus possibly making adoption easy and engagement immediate. Artifacts such as balls have been successfully used for social leisure for many years across the world. The mere use of these artifacts might contribute to a social experience, either through their familiarity or their physicality. (2) Using physical body interactions that support exertion by kicking a ball can provide a greater feeling of connectedness than a non-exertion interface [Mueller et al. 2003].

Applications to Table Tennis for Three. We opted to use conventional table tennis paddles, a table tennis ball and table. Table tennis is played all over the world by young and old, and thus provides a very familiar setup for most players, who could start interacting almost immediately. We wanted to support a nontechnical approach for the user, so neither the paddle nor the ball underwent any modifications. This has three advantages: (1) players could exert physical force with the equipment without being concerned about technology, not limiting their bodily expressions and therefore their emotions; (2) with unmodified equipment users could utilize their existing and their newly acquired table tennis skills and transfer them to collocated matches; (3) the design of table tennis paddles has undergone so many technological advances that we now have an almost perfect paddle, and we can assume that many ergonomic, durability, and feasibility issues have been addressed, freeing the designer to concentrate on other aspects of the design.

Offense and Defense

Support the concept of "offense and defense" to encourage interaction

In order to provide a taxonomy for games, Vossen [2004] borrowed the concept of "offense and defense" to differentiate games in which players interact with one another during gameplay from those in which players perform independently of one another and are assessed by comparing the results at the end. A game is one of offense and defense if a player can actively prevent another player from achieving his/her goal. This concept is one of three core elements that Vossen uses to categorize games, and it can play a significant role in competitive, physical games. For example, a 100m track and field event, although clearly physically demanding, is not one of offense and defense, since it prohibits participants from physically interfering with one another according to initially agreed rules. These rules make up the collaborative aspect of the activity; nonetheless, the winner is determined by competition and offense and defense is not relevant. In contrast, football also has collaborative and competitive aspects, but the element of offense and defense prevails. Many traditional physical leisure activities can be described in terms of offence and defense, and we believe it contributes to their success. Hence, designers should consider leveraging this aspect in their distributed environments.

Applications to Table Tennis for Three. The concepts of a *shared experience* and *offense and defense* go hand-in-hand. The blocks are shared across the stations to support a shared experience. There are three stages in breaking the blocks: one hit breaks them a little, two hits break them more, but only the third hit breaks them completely and scores one point. This was implemented to allow for the notion of tactics and strategy to support the concept of offense and defense. Players can either act defensively by waiting for a block to be hit twice and then targeting that one, or play more offensively by quickly hitting the same block three times. It should be noted that controlling the ball simultaneously does not make either approach an easy task, so that players have to balance their skills with the chosen offense or defense approach. This often leads to the players adjusting their strategy based on the other players' skills and scores.

Flow

Support and facilitate a Flow state for the players

We propose that a networked physical game should allow for and support the players in entering a *flow* state [Csikszentmihalyi 1990]. This state of being "in the zone," in which the participants are focused on the activity at hand, is often associated with a joyful experience [Chen 2007]. Sport activities in particular are considered supportive for *flow* experiences [Jackson et al. 1999], hence a networked physical game that offers a sport-like activity should leverage this potential. In particular, *flow* is defined as the optimal zone between the player's abilities and challenges she/he faces during the activity. If this area is missed, boredom or anxiety can occur, for example if a professional tennis player faces a hobby player, he/she might get bored with the activity very quickly, but if the same player is facing a marathon without any prior long-distance training, he or she might experience anxiety regarding this task. This example points out that the optimal *flow* zone is different for each person, making the design of experiences that support and facilitate entering and also staying in the zone a challenging task [Chen 2007].

Applications to Table Tennis for Three. Our approach to supporting a flow experience is as follows: We believe that by offering a shared multiplayer experience in *Table Tennis for Three,* in contrast to a single-user game, the players themselves have a high chance of putting each other into their respective optimal *flow* zones. Furthermore, their game partners are also involved in adjusting any parameters to keep the required ability/challenge balance. Traditional sports competitions might illustrate this approach: championships often produce results that outsiders (and sometimes even the players) would not have considered achievable based on the individual's skills; however, the other player(s) might have pushed her/him to achieve what was not possible for the individual alone. This extraordinary achievement is often associated with a *flow* state [Jackson et al. 1999]. By providing a networked environment that allows distributed players to interact, we believe the *flow* state can be positively influenced by the remote players, for example by pushing the opponents towards their limits and to excel in the game. In *Table Tennis for Three*, players can push one another by being able to communicate at any time. This is facilitated by the fact that the participants can assess their partners' actions through the video-conference and consider their current relative gaming status by examining the score to determine the effort required to win the game. The addition of the third player can increase the opportunity of finding a challenging situation in the game because each player can decide at any time to at least beat player A, or at least beat one player, or beat both. This can support finding a suitable spot in the challenge-ability space that enables entering the *flow* zone.

Communication

Support a communication channel to allow for social interaction

Previous research has emphasized the importance of social informal communication for effective workplace communication [Kraut et al. 1990]. The authors provide technology recommendations, but they assume that the actors have a reason to communicate. Outside the work environment, people have not always been assigned a shared task that provides grounds for communication, but an ice-breaking activity might present a reason to interact, facilitating getting-to-know one another. Team-building exercises target this situation [Glover et al. 1992]: participants get to know one another while engaged in physical activity, and once a personal bond is created, the team can address a collaborative task more successfully than previously.

Our motivation is to support social interactions between geographically distant participants that are not adequately addressed by current task-focused telecommunication technologies. Communication applications such as email, instant messenger, and text-messaging were originally invented to optimize the execution of a work-related task. They were not designed to establish a social bond. However, current social usage of this technology indicates that people want to communicate with distant others on a social as well as a work-related level.

Nardi [2005] has pointed out the role of informal conversation in creating a feeling of connection between people. We believe a physical game can support this approach by initiating, supporting, and facilitating rapport-building interactions, especially in combination with a shared activity that the participants can talk about, thus providing a common topic all players can relate to. In order to enable such bonding interactions, participants need to be able to communicate with one another across a distance. We would recommend the inclusion of a video stream to allow for the display of visual signals such as body language, particularly in combination with physically strenuous interactions.

In order to capture the other person's movements and display them, adequate vision-capture technology that can span a large area is required, and displays should be close to real-size for physical immediacy. The video-conference functionality should always be "on" to offer communication opportunities independently of a particular game, as suggested by Schmidt et al. [1996]. As demonstrated in a distributed airhockey game [Mueller et al. 2006], designers can expect the display of nonverbal behaviors during, before, and after actual gameplay, such as the raising of hands in triumph or lowering the head in defeat, as a form of expressivity that should be perceivable at the remote end.

Applications to Table Tennis for Three. The use of informal conversation is supported by the addition of two video-conference streams to the remote ends, capturing most of the participants' actions with the use of a wide-angle lens. This video-feed can also support awareness of general activities on the remote end [Borning 1991], for example during and in-between gameplay. The video-conference mechanism is always on to support serendipitous games. The position of the camera and the position of the table in the room allows for bystanders to watch the game as well as be seen at the remote end, thus facilitating audience involvement [Reeves et al. 2005]. The audio channel could be improved by capturing all audio in the room, but technical limitations allowed us to capture the player's voice only.

9. EVALUATION

We were interested in feedback from players about their experiences with *Table Tennis for Three,* and so undertook an evaluation. In order to understand the players' reactions to the game better, we decided on a mixed methodological approach for the evaluation. We used existing questionnaire surveys to gather quantitative data and made use of observations and interviews for qualitative data, mainly because it did not yet seem apparent which approach is best suited for novel gaming experiences like ours (as current research indicates [Bernhaupt et al. 2007; 2008]. With our evaluation, we aim to investigate how our design space served its purpose in the development of *Table Tennis for Three*, and how users perceived and valued the individual ingredients of the networked physical exertion/gaming mix. We hope to provide other researchers with insights in the areas of physical activity, gaming, and social interactions, and we hope to inform their future design choices.

9.1 Participants

42 participants were recruited through personal contacts, email lists, and word-of-mouth. None of the volunteers knew about the study beforehand nor had they any prior experience with *Table Tennis for Three*. Although we support physical skills that are not only targeted at beginners, we did not specifically ask for any prior sports experience.

The volunteers were asked to organize themselves in teams of three. If they were unable to do so, we matched them up randomly so that there were always three people participating in an experiment at the same time.

We had one last minute cancellation; in this case we replaced the third player with a participant who had played with the system previously. This player's data from this second instance was not collected; hence we had 41 distinct survey results.

9.2 Procedure

The three participants were introduced to the game as a group and given a detailed explanation of the game. They were then escorted into three separate rooms which had a game station each. The microphone was attached and the audio was tested. The volunteers had several practice runs with the game and help was always available in case of questions or technical difficulties. They played several rounds, lasting in total between 20 to 30 minutes. The game was followed by questionnaires the players were asked to answer. Subsequently, the three players were brought back together into one room and interviewed as a group about their experience. The total experimental time for each team was around 75 minutes.

9.3 Measures

9.3.1 *Questionnaire.* After the participants played *Table Tennis for Three*, they were asked to answer a questionnaire, containing 94 items. Almost all questions were adapted from questionnaires used in related work to strengthen validity, provide consistency, and allow for comparisons: Most questions were taken from a questionnaire in *Breakout for Two* [Mueller, 2002], 19 questions were derived from the evaluation work in Lindt et al. [2006], and 10 questions were items from other previously used questionnaires [Banos et al. 2000; Basdogan et al. 2000; Kim et al. 1997], minimally modified when necessary to suit our experimental design.

The questions were presented in random order to minimize a sequence effect. They were also partially negatively formulated in order to avoid repetitive response patterns, but were inverted again for the analysis (marked with an "n"). To avoid the Halo effect, instructions were given asking each participant to pay special attention to different contexts posed by each question, as suggested by Rotter [1967]. The questions were to be answered on a scale from 1 to 5, ranging from "strongly agree" to "strongly disagree" on a common Likert scale.

9.3.2 *Interviews.* Following the questionnaire, the players were asked to take a seat on a couch, where we conducted in-depth interviews with all three of them together. The interviews lasted for about 20 minutes at least; they were semistructured and videotaped for future reference.

9.3.3 *Demographics.* The participants were between 21 and 55 years old (arithmetic mean 31.63 years), 27 were male and 14 female. Their previous exposure to table tennis varied: One had never played before, 14 had played less than 5 times, 18 between 5 and 100 times, and 8 had played more than 100 times. One participant played in an organized club. More than half (53.7%) of the participants had not used a table tennis paddle for more than two years. their general sport participation was also very varied: 5 participated in some sort of sports more than 3 times a week, 10 participated 2 to 3 times a week, 8 once a week, 10 participated 1 to 3 times a month, and 7 less than that (one participant did not answer).

These demographics can be seen as indicators that most people in our target group had some sort of exposure to table tennis in their lives, regardless of age or general attitude to sports: only one participant had never played table tennis before. Table tennis equipment seemed to be a *familiar artifact*, as suggested in the design space.

9.4 Results

Not all participants answered all questions; the total number of answers can be seen in the graphs. All correlations are bivariate, two-tailed, and use Pearson's correlation coefficients. They are compared across questions, and the significant results are measured at the level of $p \leq 0.05$. The two outermost responses in the Likert scale were combined in the textual description of the analysis; the individual answers can be seen in the graphs.

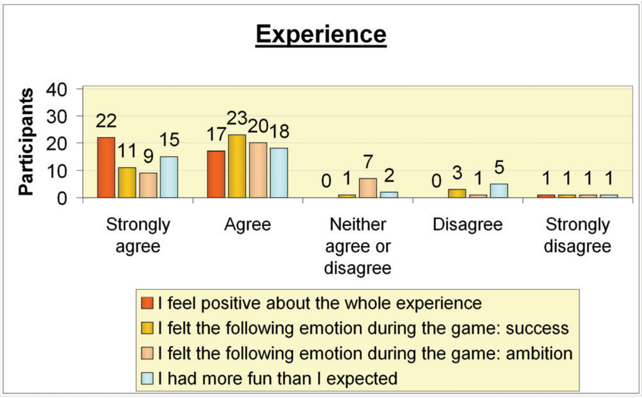

Fig.7. Enjoyment levels.

9.4.1 *Experience and Enjoyment*. There were 39 players who said that they felt positive about the experience, 22 of them even agreed strongly with this statement. The players also experienced a feeling of success and ambition, and said that the game exceeded their expectations; 80.1% said that they had more fun than they expected (Figure 7), There were 21 out of 39 players who said that they wanted to play longer, which indicates that the game supports a sense of *flow* and avoids the boredom or anxiety trap. Of the 85.4% of players who would play the game again, only one player preferred not to (five were unsure). There were 40 players who said they had fun, only one player did not; 37 players liked the game, three did not (Figure 8).

Fig. 8. Fun.

Overall, most participants enjoyed the experience (median 80) on a scale from 0 to 100 (best). However, some clearly did not enjoy it (Figure 9).

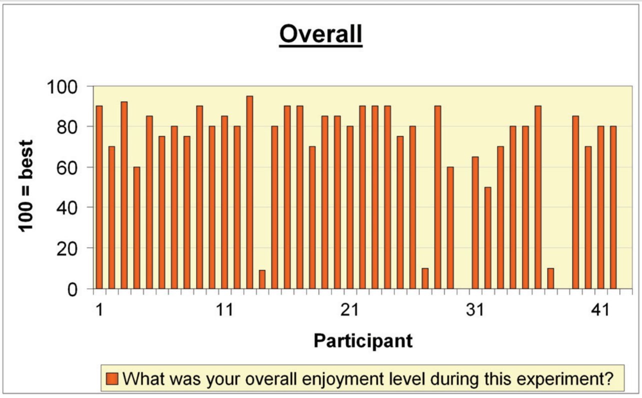

Fig. 9. The overall enjoyment on a scale from 0 to 100.

The statement "During the game, I never forgot I was in the middle of an experiment" (n) was used previously in questionnaires to measure the level of a player's immersion. A large majority (65.9%) could identify with this statement; 36 (87.8%) players thought the time passed by very quickly during the game, another indicator for *flow*, only 3 (7.3%) players did not think so. Furthermore, 33 (80.5%) forgot the outside world while they were playing (Figure 10) also indicative of *flow*.

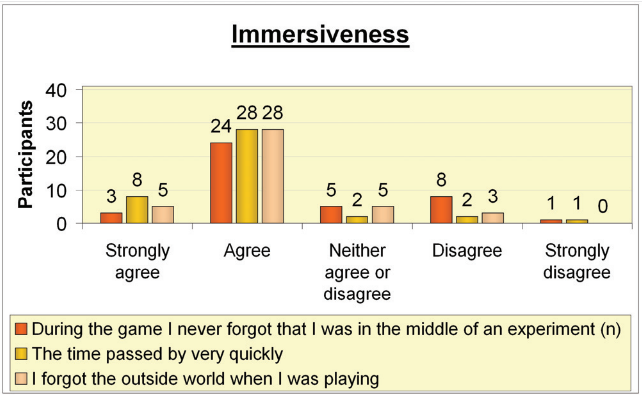

Fig. 10. Participants forgot the world around them while playing.

9.4.2 *Prior Relationships.* Nine participants played against two total strangers; 11 played against a stranger and a person they knew beforehand; and the rest played against people they knew already. We were interested if the presence of a stranger or a friend influenced their experience, but we could not find any indication of this in the questionnaire. It seems that the participants' experience was not affected by their relationships to their game partners. The only significant correlation for both game partners we found was in regard to the statement that "we did not talk a lot before the game," which is understandable because the players who knew each other before the game were more likely to find a common topic of conversation. Consequently, there was no significant correlation with how much they conversed during and after the game, indicating the game influenced how much they talked, and not their previous relationship. This adds weight to the design suggestion of providing a shared experience that participants could use as facilitator for interaction, as the next section illustrates.

9.4.3 *Shared Experience.* The players were asked to rate their sense of playing together compared to playing in a co-located setting on a scale from 0 to 100, where 100 represents playing on the same table. The median was 70, and an arithmetic mean of 65.46 for the answers (Figure 11).

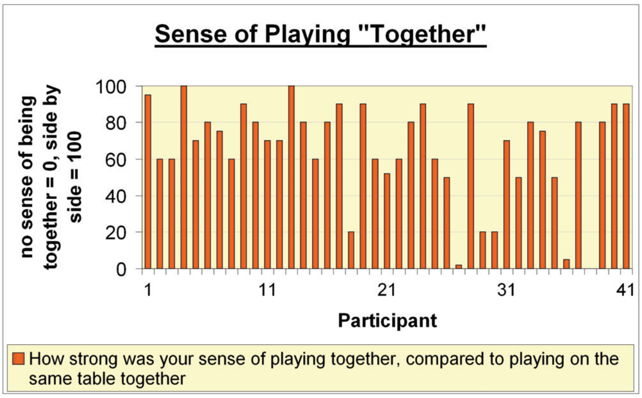

Fig. 11. The participants expressed a sense of playing together.

The answers were affirmative for the provision of a *shared experience*, especially in combination with the fact that most players (28 out of 40) thought the game created a social bond among them (average rating 3.6); 35 players had the feeling they were doing something together, directly addressing the notion of *togetherness* (Figure 12). This was statistically significant if correlated with "I liked the game" ($r=0.64$, $p<0.01$) and "The game created some sort of social bonding between me and the other players" ($r=0.49$, $p<0.01$). The two players who disagreed with the "together" statement were among the three that disliked the game, indicating that there could be a link between the enjoyment of the game and the feeling of "doing something together."

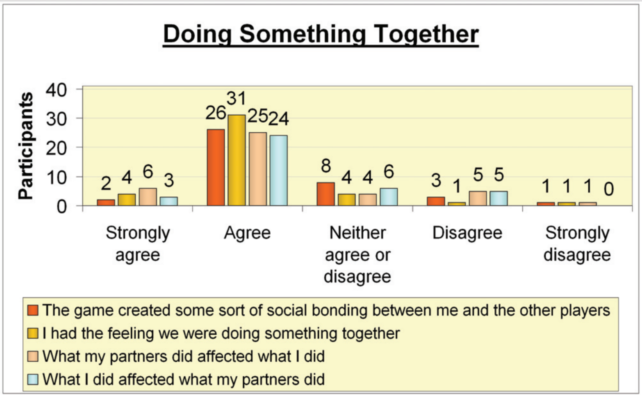

Fig. 12. The players reported a shared experience.

9.4.4 *Offense and Defense.* "What my partners did affected what I did" as well as "What I did affected what my partners did" correlated significantly with a positive experience ($r=0.51$, $p<0.01$ and $r=0.33$, $p<0.05$); with social bonding ($r=0.33$, $p<0.05$ and $r=0.41$, $p<0.05$); with whether they had fun ($r=0.47$, $p<0.01$ and $r=0.37$, $p<0.05$); whether they played "together" rather than against each other ($r=0.39$, $p<0.05$ and $r=0.35$, $p<0.05$); and whether they thought the interaction felt natural ($r=0.35$, $p<0.05$ and $r=0.47$, $p<0.01$). This appears to strengthen the validity of including elements of offense and defense in the game; however, we are aware that this is not a direct indicator.

9.4.5 *Exertion.* There were 31 players who agreed with the statement that the game was a workout for them, but not all of them felt tired afterwards (Figure 13) The majority (28) disagreed with "I had expected that I would be more exhausted." Furthermore, the players assessed that skill is more important than strength in the game (39 out of 41). This highlights the importance of considering physical skills when designing for exertion activities.

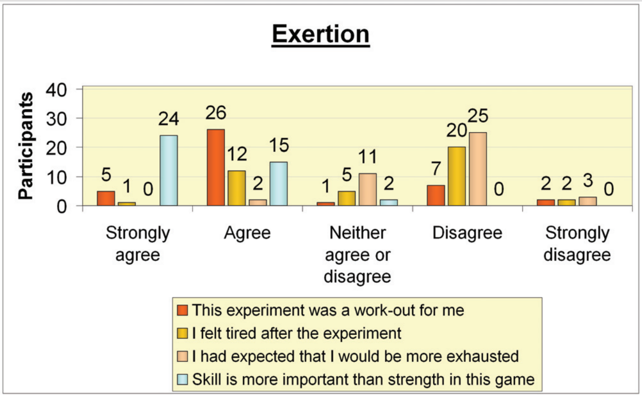

Fig. 13. Exertion.

9.4.6 *Video-Conferencing Quality.* The majority of the participants were familiar with video-conferencing before being introduced to the game (30 out of 41). For 28 players, the video quality was sufficient, only 7 were not happy with it (Figure 14); 27 said they were able to see the other person properly; 21 experienced a delay in the video-conferencing, and 13 found this disturbing, a technological shortcoming which should be improved. Although the video-conferencing software was a commonly used implementation designed for high-bandwidth e-learning, the audio quality was a major concern for the participants, 23 of whom were not always able to hear what the other person was saying. The statement "the audio quality was not sufficient for me" was confirmed by 25 participants.

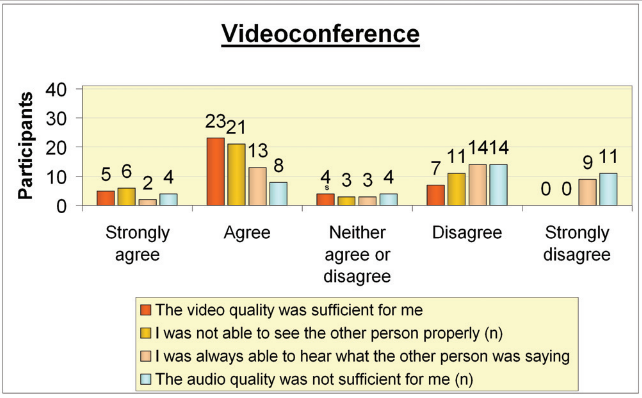

Fig. 14. Video quality was rated higher than audio.

Of the participants, 27 out of 41 said that the interaction with the other players felt natural; some also found it easy to express emotions over the video-conference (24 agreed, 9 disagreed, with 8 being indecisive). The *communication* channel seemed to enable interactions; but there is room for improvement, especially in terms of audio quality.

9.4.7 *Social Activity.* Our prototype was considered a social game by 34 players (out of 41), and 29 participants thought it was more of a social game than a sport (Figure 15). Although the players had only half an hour of playtime, 19 believed that they got to know their remote partners (combined score). There were 26 who did not agree with this and 27 were undecided, indicating that the game has the potential to support social bonds, but its success may depend on the persons involved.

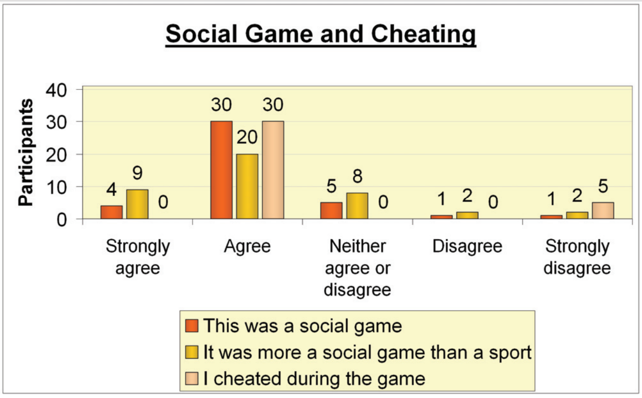

Fig. 15. Most players considered the game to be social.

9.5 Why Did Some Participants Not Enjoy It?

There were two points in the questionnaire that might explain why some of the participants did not like the game as much as most of the other participants did. For some players, the audio quality was not sufficient, and they complained about the lack of opportunity to converse adequately. It seems some people are more forgiving of the shortcomings of video-conferencing systems (such as echo, delay, and compression) and are willing to compensate for this by speaking louder, slower, and/or by repeating themselves. Whereas others are more easily frustrated: the three participants who said that they strongly did not like the game agreed with “The audio quality was not sufficient for me” and disagreed with “I was always able to hear what the other person was saying.” They were as experienced with video-conferencing systems as most participants, so previous exposure could not have been the main influence for their dislike. The three video quality questions did not show a correlation with a positive experience or whether the participants wanted to do it again, but they were correlated with the question as to whether the participants wanted to play longer ($r=-0.49$, $p<0.01$, $r=-0.41$, $p<0.05$, $r=0.34$, $p<0.05$).

People who answered the question about the audio quality negatively also said that they "(I) forgot about the other player, and concentrated only on playing as if I was the only one involved" ($r=-0.38$, $p<0.05$) and "played together rather than against each other" ($r=0.42$, $p<0.01$), confirming that the audio quality could be a major contributing factor to a *shared experience*.

Furthermore, players who reported a low level of enjoyment also disagreed with the statement "It did not matter to me who won." The majority (31 out of 41), however, were not as competitive. Possibly losing games as well as being unable to understand their game partners seems to have affected the competitive participants' experience negatively. At this point, we need further investigations into understanding the relationship between being in *flow* and losing or winning. A collaborative game could have less of a winning/losing character, however, competitiveness in a game is often the trigger for getting into the *flow* zone in the first place.

9.6 Interviews

We also conducted interviews to gain a deeper understanding of the players' experiences. Here we report only new findings which were not touched upon in the questionnaire. During the interviews, participants pointed out the importance of the physical skill required by the game, especially hand-eye coordination; some players liked to stay after the end of the experiment to practice different shots or their serves, targeting specific blocks. Such voluntary continuation of play and practice to master skills could be seen as an indicator that the game posed an interesting physical challenge to the players, which they feel comfortable engaging with. We believe we can compare these reactions to situations we have encountered with traditional casual physical games, and are pleased that our design supports similar engagement through *familiar artifacts* and a skill-based *exertion interface*.

The participants who showed signs of exhaustion, such as sweaty T-shirts, taking off layers of clothing and faster breathing, commented that part of their exertion came from picking up stray balls as fast as they could in order to continue playing. Although winning was not of major concern for many participants, as indicated in the questionnaire, this exhaustion shows that the players took their participation seriously and tried to "be their best," even if this meant breaking a sweat. Future designs should support this notion, and aim to avoid any technological hurdles that can hinder people's efforts. This finding indicates the possible existence of another component for the design space, but this needs further confirmation.

The team that seemed the most exhausted also commented the most about the bonding effect: the game was good for “talking to people … it gave something to talk about,” as described in the design space as a common ground for dialogue.

The participants also made suggestions on how to improve the gameplay: for example, two teams proposed a game in which the blocks are assigned different roles, depending on the various stages of the game, so that “you have to defend them.” This indicates that the concept of *offense and defense* can be developed still further within the game. The participants also suggested keeping the blocks colored if hit by the opponent, which could serve as simple visual indicator as to who is winning, instead of reading the score. Scoring was a game component many participants commented on: it did not seem obvious which score corresponded to which player. This point affects the *shared experience,* in which players should always be aware of their partners’ states. We learned it was possible to address this by displaying players’ names instead of “Player 1,” etc., thus avoiding ambiguity.

Some participants commented that video was more important than audio because “people are dancing when they win,” which is contrary to the results from the questionnaire, in which audio was given higher importance. It seems that both audio and video contribute to the *communication* channel.

When it was explained that the table tennis game would be played by three players, several participants said that they could not imagine how such a system could work. However, as one participant expressed it: “once I started playing, it was immediately clear what I had to do and you don’t think about it anymore, you just play and interact,” emphasizing the role of the *familiar artifacts* component.

10. FUTURE WORK

Nardi identified *touch* as one aspect of social bonding by which people come to feel connected with one another, readying them for further communication. Although touch is a common occurrence in physical leisure games, for example body contact in contact sports or signs of triumph such as a “high five,” the aspect of touch has not been part of our investigation. Identifying the role of touch and body contact during exertion activities could be a valuable extension of our design space.

For *Table Tennis for Three*, we are planning on implementing some of the suggestions given by our participants; some, like an easier scoring display, a catching net, and improved visuals, are easy to implement. We would also like to see the tables installed at geographically very distant places and investigate how people coordinate to play games with distant friends or whether they would play with passers-by instead. The social interaction between strangers who might not even speak the same language could be an interesting subject to study, too. Such an experiment could further inform the role of audio in the *communication* channel. We also envision scaling the system more and installing four or five tables; the visual display of several video-conference streams could be an interesting *communication* challenge.

In addition, we are currently investigating how to support multiple local players. It is easy to envision two players sharing one tennis table at the same location playing doubles. However, how does the interaction between the players change if you swap the team partners: if the player next to you is no longer your teammate but an opponent, and the remote person becomes your teammate?

We are also currently working on confirming our design space with other networked physical games, modifying various aspects to investigate if we can assign conceptual weights to some of the components to provide prioritized guidelines for future instances of networked exertion games.

11. CONCLUSION

We have presented a design space for exertion games with a focus on supporting distributed gameplay based on traditional physical leisure games. We defined exertion games as physical games that are expected to be exhausting because they require intense physical effort. We acknowledge that our approach rests on the belief that the exertion in traditional leisure games contributes to facilitating social bonds among participants. However, we also believe that the team-building and rapport-strengthening experiences valued by players of traditional exertion activities worldwide justify our approach. Our design space is a mix of ingredients for a networked exertion game. It aims to guide the evaluation of exertion network games, help designers in creating future games by maximizing their potential, and to inspire new directions in this domain.

We have developed a networked table tennis-like game that is grounded on this design space, called *Table Tennis for Three*. It is played with a real paddle and ball and augmented with a large-scale video-conference. *Table Tennis for Three* aims to combine the advantages of networked computer games (supporting multiple geographically distant players) with the advantages of traditional physical leisure games (providing a social and health benefit). Our system shows how the application of the design space can leverage the potential for novel exertion gaming experiences such as supporting three players in three geographically distant locations. An evaluation with 41 participants using observations, questionnaires, and interviews indicates that the players of *Table Tennis for Three* enjoyed playing and that they saw such an exertion network game as helpful in facilitating rapport among people who are physically seperate 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,” indicating a successful application of the *shared experience* component. However, awareness of the remote players’ scores could be improved, and we received easy-to-implement suggestions from the participants on how to fix this problem. Although our players did say that it was not important to them as to who won, they still “tried their best.” We found other indicators in regards to *offense and defense*, but this might need closer investigation. The virtual blocks allowed for strategic elements, but it was suggested that more of a defensive element be included. Players reported that they had fun, that they forgot the world around them when playing, that game-time passed quickly, and that they wanted to player longer -- all indicators of *flow*. However, losing a game could bring people out of the flow state, confirming that the competitive aspect has advantages and disadvantages. Three players did not enjoy the game, which was correlated with an insufficient audio *communication* channel (distributed audio is a common technical problem when capturing large audio spaces). Some players wanted to practice their physical skills after the experiment, which we take as an indicator that the skill component of *exertion interfaces* is a valuable one. Although table tennis interactions are not considered the most strenuous compared to other sports, players considered it a workout, adding weight to the notion of the *exertion interface* component. The familiarity of the game allowed participants to quickly engage and interact, indicating a successful application of the *familiar artifacts* component.

We believe that further investigation of the reasons why some participants did not enjoy the game might be fruitful in extending the design space, Similar to sports in general, networked exertion games are not for everybody, and not all networked exertion games are the same. However, the people who enjoy such bodily interactions have the opportunity to benefit from a health and social aspect. We hope to inspire other researchers to consider physical gaming in their work, in particular to incorporate multiple-location support and exertion activity in their designs to facilitate social bonds between friends and strangers.

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