Exertion Interfaces: Sports over a Distance for Social Bonding and Fun

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Submitted to the Program in
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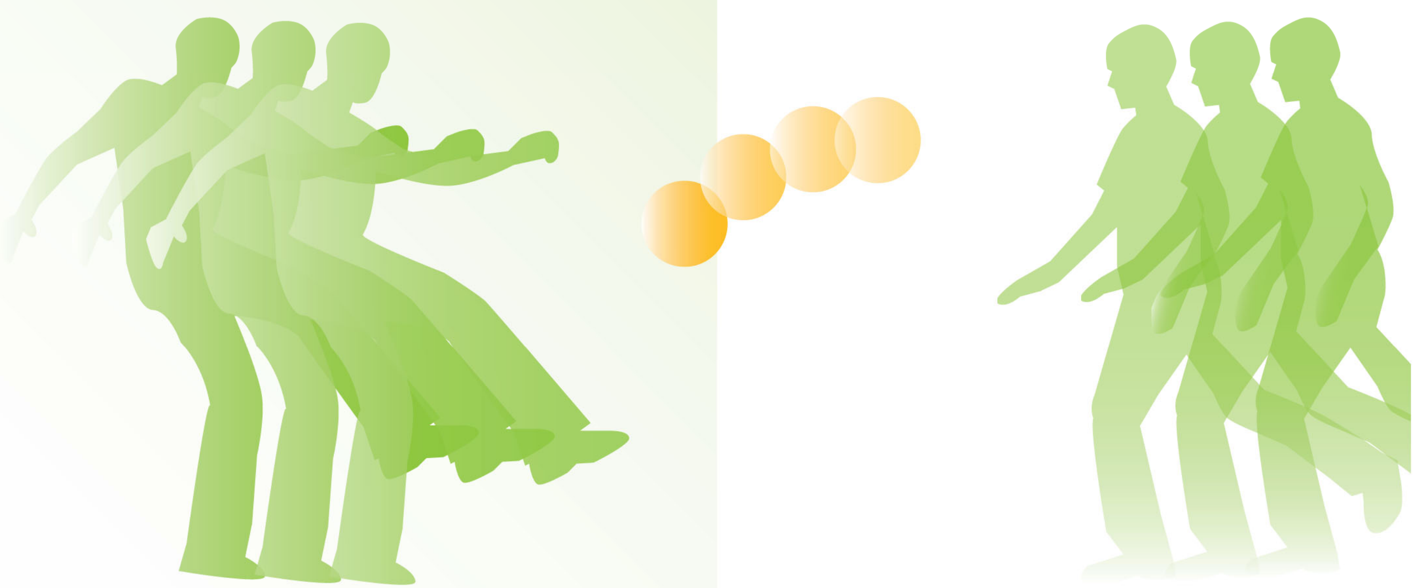

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Abstract

Social interaction is an essential part of human communication, however the participants are often miles apart. Technological advances strive to bridge the physical distances between people, but generally lack the social potential offered through activities such as sports and games. An Exertion Interface combines the strength of both: the ability of sports to connect people socially, and the ability of telecommunications to connect people over a distance. By requiring intense physical effort from the participants, an Exertion Interface creates a better social bonding experience than traditional computer interfaces. This assertion is tested through the creation of a system in which two remotely-located participants play a physically demanding ball game against each other while communicating through an overlaid life-size video-conference. A study with 56 participants showed that players who used the Exertion Interface played longer, said they got to know the other player better, had more fun, became better friends, and were happier with the transmitted audio and video quality in comparison to a control group playing the game with the same video-conferencing setup, but using a traditional keyboard interface. Exertion Interfaces, which are easy to learn, but hard to master, open a door to a new world of interfaces that facilitate social interaction between remote individuals.

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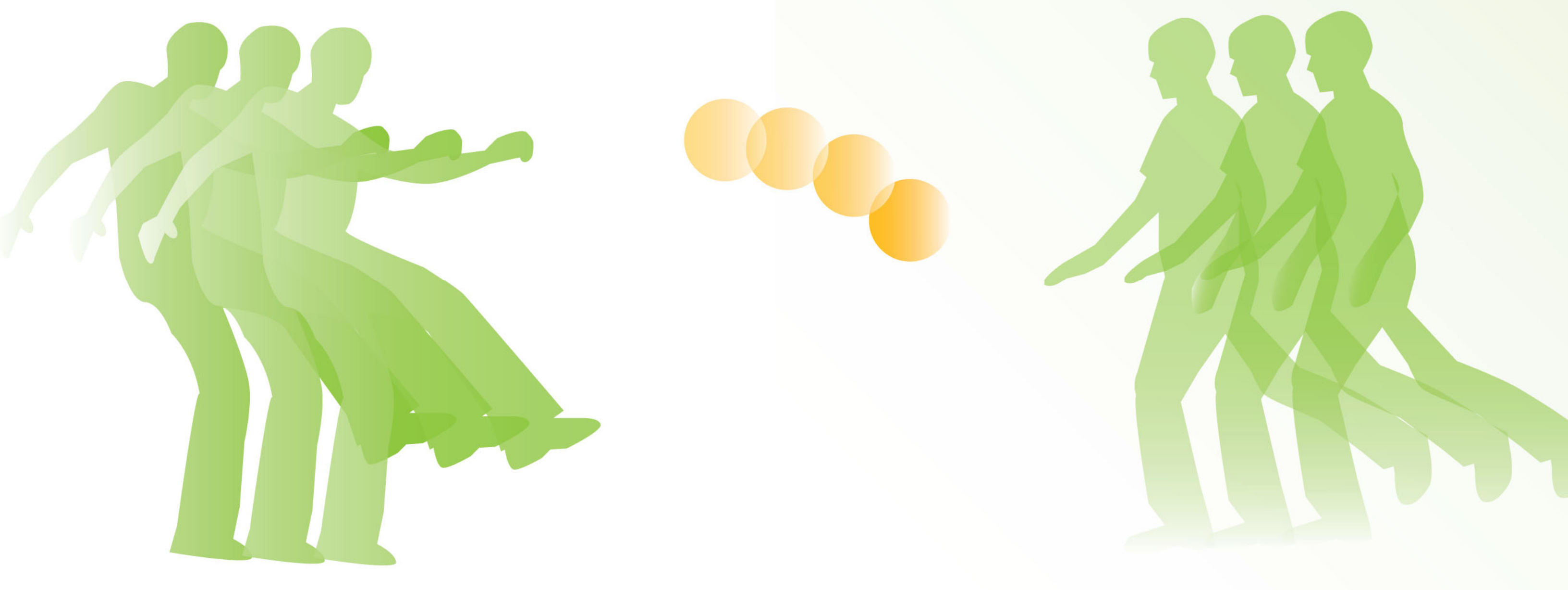

Acknowledgements

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Additional Information

Additional information about this thesis, which is not an integral part of the thesis requirements, can be found at

http://www.exertioninterfaces.com

Contents

Figures

Glossary

CSCW	Computer Supported Cooperative Work
TCP/IP	Transmission Control Protocol / Internet Protocol
UDP	User Datagram Protocol
I/O	Input / Output
PAL	Phase Alternating Line, the dominant television standard in Europe, 50 half-frames per second
NTSC	National Television Standards Committee, television standard in the United States, 60 half-frames per second
MiniDV	Mini Digital Video
LAN	Local Area Network
Voice-over-IP	Voice-over-Internet Protocol, digitized conversations transmitted using standard TCP/IP networking packets
Arpanet	The network developed by the Department of Defense's Advanced Research Projects Agency that was the basis for the Internet

Introduction

»You can discover more about a person in an hour of play than in a year of conversation.

Plato (427-347 BC)

1 Introduction

Sports and social games have facilitated bonds between people for thousands of years. What can telecommunication technologies do to support these social interactions?

1.1 Motivating Scenario

Tom moves to a new city where he does not know anybody, but by joining a basketball club, he meets one of his future best friends. This friend introduces him to a greater circle of friends, which makes him feel comfortable in his new environment quickly. Tom also started at a new company that seems very unfriendly, but at an after-work game of pool with his boss, he starts to see their human side. Tom's work requires him to collaborate within an established team that seems biased against him as a new employee. Participating in the company's annual bike-ride gave him the opportunity to talk to his team members about non-work related issues which made him feel much more accepted afterwards. The company also has a ping pong table, where Tom plays against someone who turns out to be an expert in the field he is currently working on. Through this, Tom receives immediate help on a problem he has been trying to solve for weeks.

One of Tom's coworkers has a short temper, but during a game of foosball in a bar after work, he realizes that it is not meant personally and vanishes quickly. After this tension is resolved, they work much more comfortably and rapidly together. Through playing the game, Tom learned more about how his co-worker thinks and works, and how he reacts in stressful situations.

A few months later, he is given the opportunity to put together a new team for a novel project, which requires all his creativity to develop an unconventional solution. The company operates internationally and he has been given permission to recruit all the experts he needs from the various branches. Tom nominates his preferred candidates, knowing that these experts, brilliant on their own, need to work together as a team in order to succeed. However, they have never met and live on four different continents. Tom knows that he has all the video-conferencing and other telecommunication facilities he needs, but none of his candidates has made use of them to meet each other. They said they do not know what to talk about, because the project has not started yet. Tom needs to find a way to introduce them to each other, make them familiar with each other's character and working styles so they work together well, and establish an atmosphere which facilitates creative ideas, all over a distance of thousands of miles. He decides to learn from what helped him to get comfortable in his new environment. Tom looks at the various social games and sports he played that allowed him to get to know so many people. He wonders if it would be possible for players, who are not in the same location, to have the same fun and social experience he had…

This scenario depicts the motivation for the present work. The problems described above are fundamental in modern society: how can we facilitate social interaction between people, especially over large distances?

1.2 Interaction over a Distance

Why is this important?

Social interaction is of uttermost importance for the well-being of individuals as well as society as a whole. However, as Putnam describes in his book "Bowling Alone", people increasingly lack these social interactions [1]. He describes this phenomenon as a nationwide sickness that is behind many national downturns. Since people have the opportunity to travel extensively, they lose the connectivity of a closed community that evolves over many years. It is not unusual these days to have friends who live thousands of miles away. This is welcomed because it brings the world together, making it a smaller place and supporting cross-cultural understanding and cosmopolitan thinking.

You can use the telephone, text-chat, video-conferencing and many more technological innovations to communicate with people who can live on the other side of the world. Being in touch with one another is part of human nature, and these telecommunication technologies help us bridge distances, connecting us to family members, work colleagues, old friends and new friends. Although they have improved tremendously over the last couple of years in terms of bridging vast distances in milliseconds, they fall short in other areas. Most of these innovations were designed with the practical goal of creating the technology to allow the communication rather than designing the interaction that would take place over it. Social interaction is often not the prime focus of a design, resulting in a lack of support for conveying the social components of an interaction. Video-conferencing, for example, connects people who have a reason to meet, but is not very good at encouraging social interaction between the participants, especially if they have not met before.

"Having something to do while on a date really helped", "You need something to do, some mutual activity" said in a class conversation where participants were asked to have individual introductory meetings using collaborative technology, (Workshop in Community-Maintainable Collaborative Online Spaces, MIT Media Lab and Media Lab Europe, 2002)

Most of these telecommunication technologies come from a world of work, designed to support users who already know each other and have a reason to communicate. Email, for example, was not designed with social communication in mind, but rather for delivering messages related to work to fellow engineers, who worked in the same building [2].

Very 'task' oriented

The tools are usually related to the execution of a specific task, falling short of encouraging the participants to interact socially with one another outside of the context of the work assignment. They are often not very fun to use, and lack the feeling of "doing something together".

1.3 People's Need for Social Interaction

However, people have always been trying to modify these technologies to make them suitable for their needs of social communication. Users create chat-rooms about pop-culture, utilize mobile phones to stay in touch with their friends, and use video-conferencing to talk to their children. One of the first messages sent across the Atlantic illustrates the potential connection between social interaction and telecommunication inventions: a computer scientist in Los Angeles made the first use of the Arpanet by telling his colleague to pick up his razor, which he had left in England while attending a conference [3].

These examples show the desire for social interaction: however, they fall short of trying to convey social components of the interaction because of their initial design. The most commonly known example is the :-), compensating for the inability to express a smile in text.

Media spaces and similar environments have demonstrated the ability to support informal communication [4] [5]. However, these tools often do not adequately address situations in which people do not know each other and the discomfort of interacting with strangers.

1.4 Physical Activity

In contrast, games and sports have been helpful in facilitating social introductions for thousands of years. Sports are fun, played by millions of people everywhere in the world, regardless of age, race or social status. They support social interactions and give the players "something to do", and something to talk about. Physical activity encourages social interaction, fosters friendships, and improves one's overall well-being and quality of life. International sporting events also demonstrate that sports have the ability to overcome the language barrier.

Sports clubs

Physical activity also helps foster bonding in communities. Sports clubs, for example, not only function as a place to exercise, but also as a social space. Games, and especially social sports, are a good way to introduce people. If one moves to a new city, it is often recommended to join a sports team to make new friends. The involvement in sports clubs has been measured to determine the interactions in communities and these social trends have then been used to learn about the health of a whole nation [6].

Children and sports

Participating in sports is also essential to children's growth. Many parents send their children to participate in sports not only to increase their health, but also to make new friends and learn about team spirit and team-work. Research has also shown that children who participate in sports also show more trust towards other people [7].

1.5 Business Setting

The benefits of physical activity have also been acknowledged in the business world and have been used to foster bonding and team spirit within the organization. The importance of social competence and compatibility is shown through the growth of team-based organizations [8], in which the team is the strongest part of the organization. Team-building exercises help foster bonding between employees, and are often used to support the creation of new teams, especially if they consist of people who have not met before. Golf weekends, tennis tournaments, kayaking and the like are intended to bring people together on a social level, before they start working together as a team in the organization. These activities try to teach about teamwork and to facilitate applying these newly acquired skills to ongoing work related situations [9].

However, a problem that many multinational companies have is that their members of a team are co-located in different branches, sometimes spread over several countries, yet they are supposed to work together as if they are in the same room. The element of trust plays an important role in these collaborations and is required between any transactions [10] [11]. The problem, again, is how can team-building exercises be carried out on a team that is distributed over large distances? In addition, how do you keep these teams socially connected during the project, continually supporting trustful relationships, and "How do you manage people whom you do not see?" [12]

Usually companies fly the participants in to a central location to let them spend some time together and get acquainted. However, these initial relationships might fade, and a way to keep them alive would be preferable.

1.6 Sports over a Distance

Combining technology and sports

Why not use the social potential of sports and games over large distances?

By combining the best of both worlds, people could use the advantages of communication technology to bridge distances between them and the bonding aspect of sports to connect to each other. Through this, many people could meet from different cultures around the world who otherwise might not have met.

In addition to helping businesses to flourish by supporting their team-building efforts, connecting people socially can also be a rewarding contribution to society. Creating bonds between people who normally do not have a chance to meet, can help reduce the fear of strangers and, in turn, prejudice against social groups.

Maintaining bonds

Sports and social games not only help players to meet new people and make new friends, but they are especially known for fostering relationships between people who already know each other. These game interactions can be of a spontaneous nature or planned; for example having fixed training times in a club. Players come together not only for the physical exercise, but also to enjoy the social contact [13]. These interactions can be very valuable for maintaining bonds, whether they are between friends, family members or acquaintances. Having a common activity might also help in starting a conversation if two people have not seen each other for a while.

Asserting that sports and games have these socializing effects, a game environment can be a valuable augmentation of what current collaborative tools try to accomplish in terms of social interaction. If physical exertion can put the user in a heightened state of arousal that supports bonding, it makes sense to leverage the same kind of arousal in a distributed setting.

For example, if strangers meet over a networked environment for the first time, a game can break the ice, as it provides rules to follow, an activity or experience to share, and something to talk about. A tool which supports and encourages these social interactions would not only help keeping friends in touch, but could also facilitate introductions to new people, supporting serendipitous communications with people who may have never met otherwise.

1.7 Approach

The current approach in interface design research is to build smarter, more sophisticated interfaces that require less mental and physical workload. As part of this thesis, I would like to introduce the opposite: Exertion Interfaces.

1.7.1 Exertion Interface

Definition of an Exertion Interface

An Exertion Interface is an interface that deliberately requires intense physical effort.

Exertion Interfaces can be expected to be physically exhausting when used for an extended period of time. They require effort and demand mental workload, and, just like sports, might take a short time to pick up, but a long time to master.

Obviously, they will not be of primary use in many computer-related tasks, but in the case of socially connecting people, the challenges they present might enhance the interaction. This idea is derived from sports and social games, but will be applied here in a distributed setting in order to overcome physical distances between participants, and facilitate bonding.

An interface that fosters bonding and team spirit in a social setting has to be fun to use and also encourage interaction with another person, or with a whole team. Many such interfaces have existed in the physical world for a long time, such as the use of balls in sports. I envision Exertion Interfaces being used in the same way traditional sports games function in social relationships. For example, when new members arrive in an organization or business, team-building activities are important in forming new relationships and getting a feel for how one's colleagues think and work. These activities might be formally arranged, but more often they take the form of one person asking another out for a friendly game of tennis, table tennis, golf, etc. Such a first-time encounter might spark a regular sports relationship with the other person, and with time, a new friendship.

The aim is to enable this kind of social relationship to develop when the participants are physically distant, perhaps even on opposite sides of the world. Instead of a traditional gym or sports club, players might go to a "virtual sports club" in their geographic area and engage in new kinds of "sports over a distance" that incorporate Exertion Interfaces.

1.7.2 Aims

I postulate that if a game or interaction requires some physical activity, it will work better at fostering bonding than one without it. The aim of this thesis is to build such an interface that facilitates connecting with a remote person and maintaining the feeling that the participants are doing something together.

This new type of interface naturally raises a lot of questions, but also provides many opportunities. These questions should only be seen as a sub-set of the many questions that could be worth investigating.

- Does an Exertion Interface facilitate bonding between people?
  If so, is it better than traditional mouse-keyboard interfaces?
- What kind of social interactions does an Exertion Interface support?
- How does an Exertion Interface support bonding? Can it convey the feeling of "doing something together"?
    - Can an Exertion Interface facilitate relationships between strangers?
    - Can an Exertion Interface help friends stay in touch?

- Can an Exertion Interface facilitate the complex phenomenon of friendship?
- Can an Exertion Interface convey additional information about a person, which traditional interfaces cannot?
- Can sports be played over a distance?
- Will the players see the activity as a sport, although their partners are not physically present?
- If an Exertion Interface facilitates Sports over a Distance, what kind of sports can it support?
- Can an Exertion Interface support competitive playing, collaborative playing, or both?
- What other effects does an Exertion Interface have in comparison to traditional interfaces?
- What other applications does an Exertion Interface have?
- How can the exertion be transferred over a distance?
- How does the interaction with an Exertion Interface differ from the interaction with traditional interfaces?
- How could an Exertion Interface be implemented?
- Can an Exertion Interface be fun?

1.8 Scope

This thesis investigates the effect of an Exertion Interface on two participants. Any higher number of participants might create more complex group dynamics, which could then develop independently from the interface used, rendering the results unusable. However, I provide suggestions on the creation of Exertion Interfaces that support larger teams and most measurements can be easily modified to accommodate them.

1.9 Thesis Statement

I hypothesise that an interaction with a distributed Exertion Interface would function better at introducing people to each other and creating social bonding than a traditional keyboard interface.

1.10 Overview of the Thesis

This chapter suggested combining the social benefits of sports with the capabilities for bridging distances of telecommunication technology. In this chapter an Exertion Interface was defined and the thesis statement presented. In chapter 2 related work is reviewed, and previous research in playing sports over a network is discussed. An initial study is presented that investigates the social impact of games like ping-pong and pool placed in a work environment. I designed a system that uses an Exertion Interface to connect people remotely, which is described in chapter 3, along with the technical details of two different implementations. Three different games are presented that can be played by kicking or throwing a ball.

In chapter 4, an experiment with 56 volunteers is described that compares their experience using this Exertion Interface to playing a similar computer game. Afterwards they were interviewed about their experience. They did not know each other beforehand, and I investigated how much they got to know each other after the experiment. The results from this study where obtained through a questionnaire, a Prisoner's Dilemma task, an interview and a ranked video analysis and are discussed in chapter 5. I conclude with a discussion in chapter 6 and explore what the findings suggest for future Exertion Interfaces.

1.11 Summary

This chapter suggested combining the social benefits of sport with the abilities of telecommunication technology to bridge distances. It defined what an Exertion Interface is, and suggested that such an Exertion Interface, which deliberately requires intense physical effort, can support this approach and facilitate a new social activity: Sports over a Distance.

Background

»Everything that can be invented has been invented.

Charles H. Duell
Commissioner, U.S. Office of Patents, 1899

2 Background

Is it worth building an interface that supports physical activity? What other physical interfaces exist? Can social games in a workplace facilitate informal interactions?

2.1 Benefits of Physical Activity

"Physical activity for better health and well-being has been an important theme throughout much of western history" [14]. Sports build healthy bones, reduce body fat, and reduce the risk of heart disease, colon cancer and high blood pressure, to mention just a few benefits [15]. Physical exercise has also been used to fight depression and anxiety [16], and in general sport can improve one's mood and quality of life [17][18]. Sport psychologists have investigated the relationship between physical activity, arousal and performance [19], and suggest a link between self-confidence, self-esteem and a person's involvement in sports [20]. The statement that "sport builds character" is an established piece of folk-wisdom.

The benefits of sport are far-reaching, and are not limited to a certain social group, in fact, physical activity is recommended for all age groups and both genders [14]. The American Surgeon General's report [21] warns of increasing physical inactivity and concludes that "Americans can substantially improve their health and quality of life by including moderate amounts of physical activity in their daily lives". It emphasizes that "every increase in activity adds some benefit".

In addition to the benefits to physical and mental health, sports also have social implications. For example, the importance of involvement in sports clubs for social interactions has been described as a valuable part of the social capital of a community [1]. Participation in sports is declining, especially in team and group sports, a worrisome indicator on how disconnected we have become [22].

Social support from family and friends has also been positively related to regular physical activity [14]. In turn, an early involvement in sports clubs can increase the trust children exhibit towards other people [7].

The reasons why people are motivated to participate in physical activity are manifold [13]. It has been reported that for young people, team atmosphere, fitness, skill development, friendship, achievement and fun seem dominant motivations across multiple studies.

2.2 Physical Activities and Computers

The concept of fun as a motivational factor has gained increased attention lately, and has emerged into the domain of human-computer interface design, where it is a growing area of inquiry [23]. Leisure activities, based around the concept of social engagement, could potentially be suitable environments to create bonds between people that have to work in a team. Such "entertaining" interfaces could serve as an initial starting point for building strong collaborations, before more traditional Computer Supported Cooperative Work (CSCW) interfaces are utilized to perform a specific task.

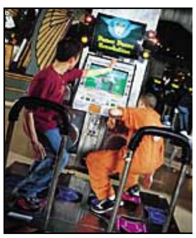

Boxing

Most of these entertaining interfaces, however, are only to be found in game arcades. There is skateboarding, snowboarding, boxing, even fishing. They all try to combine a known fun, physical experience with a computer game, but fall short in terms of social interaction, because most of them can only be played alone against a virtual computer opponent and do not support the creation of teams. The sensor technology is also inadequate. For example in a boxing game, a hit is a hit; the intensity of the input does not matter. You see people lightly tapping their glove in an unmotivated fashion, just because they get the same points as they would if they hit it hard [24].

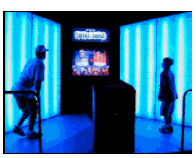

Nintendo Power Pad

Kick and Kick

The Nintendo Power Pad [25] mat is an early example of an Exertion Interface which achieved some commercial success in the home market. Power Pad is a carpet-like mat with 8 sensors that measure the position of a user's feet to control a game like Aerobics or Athletic World. A successor is the 2002 FIFA World Cup Football Stadium [26], which detects your kicking movements with three sensors on a mat, controlling a virtual soccer player. Another soccer game is Kick and Kick [27], where you kick a real ball on a screen. Sensors in the frame detect the trajectory of the ball, while the plastic screen measures the velocity of the shot. Due to its limited size (5' wide by 6' high by 8' deep), it is designed more to enable practicing penalty shots or corner kicks, than replicating the soccer experience of running around, which makes sense in an arcade environment.


Dance Dance Revolution

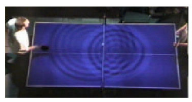
A more social activity is the Dance Dance Revolution [28], which generated great popularity. Players step on lighted platforms in time with the music as they try to match the dancing instructions on the screen. The difficulty increases with more beats per minute. This game can be played alone, but it is mostly played in pairs, because it attracts many viewers in arcades and teenagers use it competitively to determine who the best dancer is.


Virtual Arena

Another two player arcade game is Virtual Arena [29], where 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". The two players are standing next to each other, looking at a screen with their avatars in front of them. Although there is currently only support for local play, it seems plausible that this system could easily be expanded to work across remote locations. The social aspect of such a game, where the aim is to knock the other player unconscious, is questionable, however.


Hyperbowl

An arcade game that supports more than two players is HyperBowl [30]. Here, several players bowl together, taking turns on a "bowling ball interface". They control a virtual bowling ball on the video screen by "rolling" a regulation size bowling ball, as if it were an oversized trackball. The speed and direction of the spin is applied to the virtual ball, and the players have to dodge obstacles along the way to the pins. All players use the same interface, and although arcades have several of these bowling alleys next to each other, which could be networked or possibly connected to alleys in other arcade halls, each game is restricted to one particular alley. However, because the alley is virtual, its look can be modified, for example, the players can select if they want to bowl in the streets of San Francisco.


PingPongPlus

Instead of mimicking a sports experience, PingPongPlus [31] tries to augment one. It is a visual extension to a regular ping-pong table: the players play a regular game of table-tennis, but a projection displays visualizations on the table based on where the ball bounces off, for example animated water ripples. The authors also describe the idea of an athletic interface, here a table-tennis racket.


AR^2

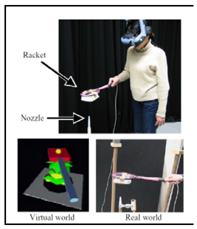
AR^2 [32] is an augmented reality air-hockey table with a virtual puck. The two players wear head-mounted displays to see a virtual puck on the table in front of them. They move a real shuttle around to keep their goal safe and shoot the puck into the opponent's goal. To present a haptic feedback to the player when the shuttle strikes the puck, embedded vibrating motors get triggered by a virtual collision. However, these systems require the participants to be present in the same physical space.


Mah-Jongg

Szalavari et al. [33] built a multi-user, augmented reality system that allows its users to play the board-game Mah-Jongg. It demonstrates social communication and the need for private space. The symbols displayed on the tiles are virtual, which means they can be turned on or off depending on which player is allowed to see them.


KiRo

KiRo [34] is a robotic foosball table, (sometimes referred to as babyfoot, table soccer or table football), which uses vision detection to determine the location of the ball on the table. Robotic arms control the handle bars accordingly, replacing the other player. A player basically competes against a robot. However, the system could be extended to allow playing over a distance: two coupled versions of the table could be networked, and the sensors on the human player's handles could measure the movements and transmit them as input for the distant robot. It would recreate the movements of the local player to the remote player, allowing two users to play against each other without being in the same location.



Strike the Kappa

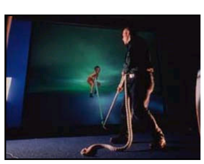
Strike the Kappa [35] is a game that uses air pressure out of a nozzle to provide haptic feedback. The player wears a head-mounted display to see the virtual target to hit. If the Kappa, "a friendly character", jumps out of his hole, the player has to try to hit it on its head with a badminton racket. This sounds like a very fun activity. When the racket in the virtual world hits the Kappa, the nozzle releases high pressure air to simulate haptic feedback. This system is also easy to envision in a distributed environment, where several players try to "hit all the Kappas".

AquaGauntlet

Another augmented reality game is AquaGauntlet [36], which supports multiple players shooting virtual creatures. They have to collaborate to succeed, but are constrained to the same local space.

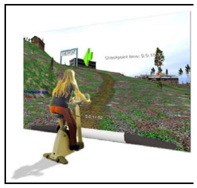
inTouch

There have been some attempts to connect physical interfaces but most of them are in their early stages, using prototyped force-feedback technology. inTouch [37] is a telepresence application that connects people by creating the sense of a shared physical object over a distance, enabling simultaneous physical manipulation and interaction. You turn rollers which feed back into the other person's physical input onto the same coupled roller, creating an in- and output device at the same time. HandJive [38] is a shared haptic device designed to create a light-weight pastime that could be undertaken while attending lectures. Two players "fold" distinct moves with the device, similar to a dance with predefined patterns. Its design sounds interesting and one can envision that it is fun to play. However, it is limited to two players, and does not allow for any additional interaction modalities.



Tug-of-War

A more physical activity is the Virtual Tug-of-War [39] [40], where two groups of high-school students were involved in a tug-of-war at


VIRKU

schools 13 miles apart from each other. VIRKU is a Virtual Fitness Center [41] that combines exercise equipment with an Internet based fitness monitoring system. NetGym [42] describes two physically separated exercise bicycles in a virtually connected gym with a highly physical interface in which a cyclist cycles with an avatar representing the remote user. If they move too far away from each other, they basically cycle alone. Walk the Dog [43] requires the player to use a treadmill in order to walk a virtual dog on a screen.


NetGym

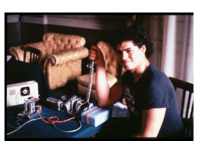
ImpactTV [44] is a fun-oriented interface; the physical part of the interaction plays an essential role in making it entertaining. In ImpactTV, an Exertion Interface controls media; if one wants to watch basketball, one throws a basketball at the TV. If one wants to watch baseball, one throws a baseball.


Walk the Dog

Throwing a ball is also essential in I-Ball [45], where two participants can play a simple game of catch remotely.


impactTV

An early attempt of a networked sport is Telephonic Arm Wrestling [46], in which you arm-wrestle your opponent over a phone-line. You push against an artificial arm that is hooked up to a motor which transports the applied force to an identical setup in a distant location. These last two examples demonstrate that expensive virtual reality hardware is not always necessary to create a physical sports interface.


Telephonic Arm Wrestling

A more technologically advanced system is Snowwars [47]. It is a networked physical game, which simulates a snowball fight using virtual reality technology. The players, who can see their opponents on the other side of the field through the use of either head-mounted displays or large screen projections, throw snowballs at them. The opponents, however, are in a different room, being captured by cameras. The snowballs are not actually thrown, but virtually shot out of a gun against the projection wall. On the other side, an array of shooting guns, equipped with real tennis balls, shoots them at the opponents. This system has the potential to yield a high level of immersion.


Snowwars

Most of these examples address the issue of providing an interface that is fun to use. They also often cause the players to exert themselves, and some of them offer remote interactions. However, not many combine these features in one system, and there is little information in terms of the testing of their effectiveness in supporting social interaction.

2.3 Media Spaces

iCom

Media spaces and similar environments are tools from the domain of computer-supported collaboration that were designed with the aim of supporting informal interaction [4]. iCom [5] is an example of an awareness tool that incorporates a video-conference. It is a system that, through its constant, live video-connection, is intended to form serendipitous bonds between individuals on both ends of the link. The system is in place at the MIT Media Lab and Media Lab Europe, and is used for both planned and ad-hoc meetings, the later being when people "bump into" others, who are near one of the system nodes. Informal tests I conducted with participants, whose tasks were to get to know each other through this and similar systems showed that once they had "something to talk about", their initial reluctance to communicate vanished. Some examples of topics discussed were physical objects to demonstrate their interests, or digital artefacts they shared.

The work from Pedersen [48] addresses the balance between too much and too little support for awareness over physical distance. The researchers suggest it is important to not expose users unduly.

Computer-supported social environments that support mainly keyboard interactions are described in [49], the use of video-conferencing is also addressed. However, "even video-conferencing adds only a simulation of face-to-face meeting, only a representation or an appearance of real meeting. The living, nonrepresentable face is the primal source of responsibility, the direct, warm link between private bodies. Without directly meeting others physically, our ethics languishes" [50].

Although most of these tools support informal interactions over a distance, they often do not adequately address situations in which people do not know each other and particularly the discomfort of talking to strangers, especially when they are lacking a reason to communicate.

2.4 Measuring Relationships

In order to evaluate an interface, one comes across the problem of how to measure the relationships that the interface supports or initiates. Most approaches use comparison studies and measure one specific outcome of the interaction which is conveyed over the distance, often showing the level of cooperation achieved between the partners.

2.4.1 Prisoner's Dilemma

This cooperation is usually analyzed by means of a game called "Prisoner's Dilemma" [51]. The two players in the game can choose between two moves, either "cooperate" or "defect". The idea is that each player gains when both cooperate, but if only one of them cooperates, the other one, who defects, will gain more. If both defect, both lose (or gain very little) but not as much as the "cheated" cooperator whose cooperation is not returned [52].

The original idea for the Prisoner's Dilemma is derived from the following scenario:

Bob and Alice are arrested, charged with a bank-robbery. Being isolated, they are both given two options: Each may either confess or deny the crime. If neither confesses, the police can only convict them of a lesser crime. If one confesses and the other denies, the confessor is rewarded with instant freedom and the other is given a harsh sentence. If both confess they are both punished but with a slight reduction for confessing [49].

In a study reported by Jensen et al. [53], participants were faced with a series of Prisoner's Dilemmas. Each player pair could either not communicate, had access to text chat, had access to a system that would read text chat out loud, or had access to voice communication. They found that players had a more positive image (likable and trustworthy) of those with whom they could communicate. In addition, voice communication was found to have an extremely powerful effect in fostering trust and cooperation.

Trust with*out* Touch [54] investigates the effect of prior communication before the computer-mediated task and concludes that various activities over a network are helpful in getting acquainted. Showing a picture of the other participant is better than doing nothing beforehand, but not as good as text-chat, which in turn is not as good as meeting in person. As described by Zheng et al. [55], the participants were told to “get to know each other” and therefore the results are not easily transferable to serendipitous encounters.

Straus [56] examines the effect of communication media on group processes. He found that computer-mediated groups expressed lower satisfaction: however, they had a higher proportion of task communication and greater equality of participation. They also exchanged higher rates of supportive communication.

Rocco [57] shows that if strangers who communicate only through email gather for a team-building exercise prior to the real task, they outperform strangers who have had no prior meeting. This finding corroborates the widely-held popular business opinion that people who meet before working together form better, more solid team relationships [54].

In order to investigate the effect of force feedback on computer-mediated communication Brave et al. [58] measured task performance in completing a screen-based maze with an alleged remote participant, using a force-feedback joystick. The investigators found that in a competitive task, the “participants felt more powerful and more positively overall when interacting through force-feedback than when interacting visually. They also liked the other participant more and trusted them more."

2.5 Pre-Questionnaire

In order to gain more empirical validation of the theoretical framework developed on the impact of social games on bonding experiences, I conducted a survey. Media Lab Europe purchased a pool-table, a ping-pong table and a foosball table for its employees. These games were purchased at a point where Media Lab Europe was very young and growing very quickly. This included the rapid addition of many new employees, who needed to work together. Bringing these people together so they form effective teams is a challenge for every fast-growing organization.

Did the introduction of these games actually influence the social climate within the organization? Studying the players and their social interactions and then comparing them to non-players would be the preferred way of investigation, but since the scope of the study was to gain a brief overview, an informal questionnaire seemed to be more appropriate. In this questionnaire, which was sent out to all employees via email, the recipients had to answer questions such as how often they played these games, and if they had met new people through these social pastimes. Having participants judge their own behavior is not without its problems and the results should always be treated with caution. However, I was not only interested in the facts about the use of these games, but also sought inspiration from the thoughts of the players. An open-ended question section allowed the volunteers to elaborate on their view of how social games could be used.

34 employees replied, a success rate of over 50%. 32 of those responding had played one or more of the games mentioned above and they form the user group I base my subsequent findings on. However, not all the returned questions were complete, not all respondents answered every question. Consequently, all numerical

results from this questionnaire are expressed as a percentage of the total numbers gathered.

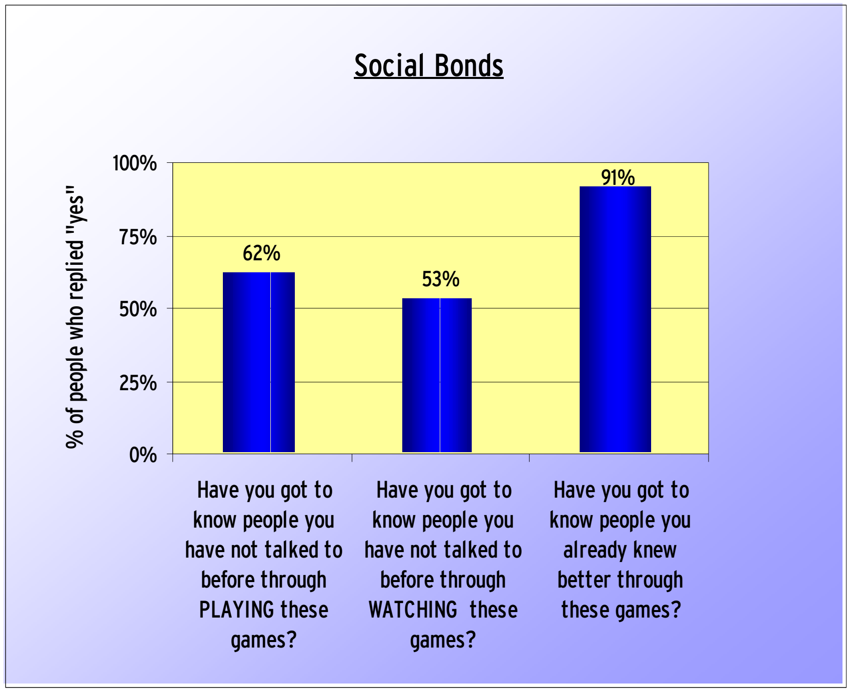
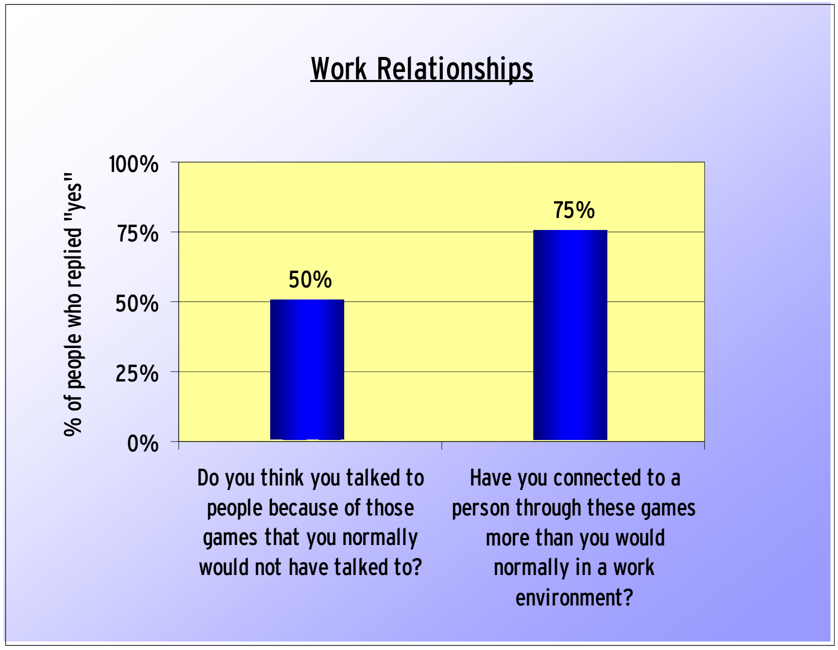


Figure 1
How employees meet new people through social games like ping-pong and pool at the workplace

62% of all players have met other people they have not talked to before through playing these kinds of games. I also observed many employees who do not necessarily always play the games, but often watch others playing, whether because they have to wait until it is their turn, or they simply use these breaks to chat casually. One respondent explained this with the fact that the games give him the opportunity to speak to people he would normally not have talked to because there was no reason. The games give him something to converse about which is non-business related, because “you don’t want to talk about work”.

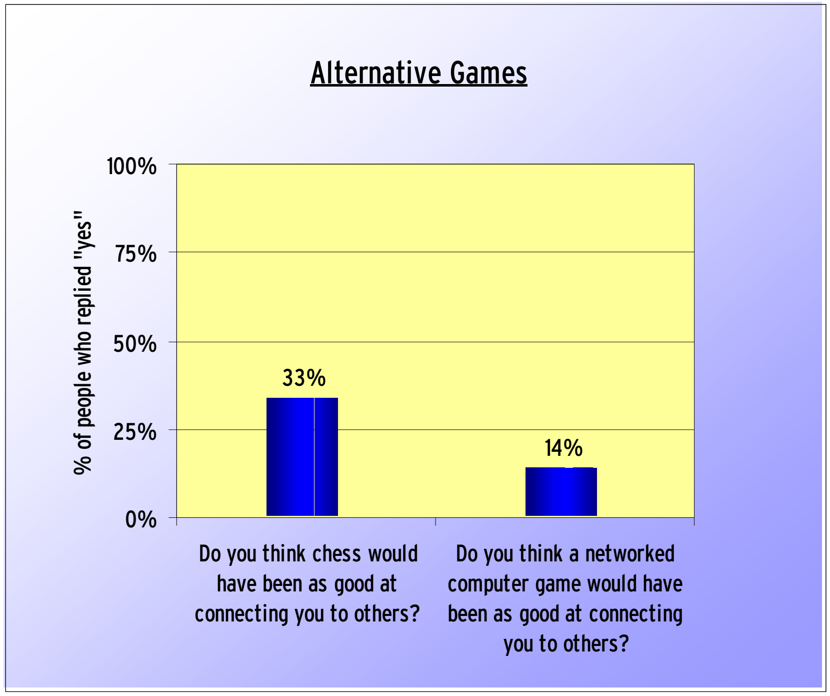
Although it is hard to measure how the growth of the social network would have differed if the organization had not had those games, the fact that 91% of the employees who played the games said it helped them to get to know people better seems to be a pointer in the right direction.

Figure 2
The kind of different relationships that social games facilitate



Every second player reported having met people she/he normally would not have talked to, an indicator to the vast potential for forming cross-discipline teams through the use of social games. The impact carries on outside a work-related relationship, 75% of the participants stated they bonded with their fellow employees beyond the usual workplace level.

Figure 3
People prefer a game with an element of physical skill



Alternatively, board games like chess and networked computer games would be welcomed by the respondents, but the current games were highly favored because they contain a “physical element”. It is “important in breaking down barriers. It's also missing the possibilities for laughter offered by the others - you can't really screw up in a funny way playing chess.” Being able to have a “quick game” is also an important factor for many players. They use it as a stress reliever and “power break”, and value the fact that they are not restrained or “cerebral” and everybody takes them very casually. Some respondents mentioned they were afraid of chess being taken too seriously by some players, which would make them feel uncomfortable. A respondent, who regularly enjoys a game of backgammon in the same area with the other games, noted remarkably “the process [of playing board games] requires a good bit of mental focus, which, I suppose, proportionally reduces the social interaction during play.”

Networked computer games were considered with suspicion. While many simply did not like to see them along with the other games, because they “get plenty of screen interaction all day long”, others would like to have them, but being set up in the same room. Respondents mentioned that they could see multi-player game consoles (where you play next to each other) taking a similar role in connecting players, but explicitly mentioned that they cannot see networked computer games, where the players are physically separated, having the same effect. (“Networked games are good for connecting if the other participants are in the same room” and “Something like Dreamcast: yes. Something like Starcraft: no.”) The physical presence of the other player seemed to be key, and the ability to “see and hear (and talk to) the other players” was a common request. “I think the presence is something that drives a lot of information” and “physical proximity (or a very good simulation thereof) is very important to [sic] establishing a conversational mood” the respondents commented. And further: “It also depends on the game.” It is “easier to talk during a pool game than during a foosball match. It is quieter, and the attention is focused on the wider environment.” Foosball was favored for alternative reasons, mainly because “you play it together with someone as well as in competition at the same time.” Additionally, the participants also liked the fact that everyone could easily play the provided games, without having to read an instruction manual first.

Deciding which game functioned as the best opener for social interaction turned out to be a very difficult question. Most respondents chose the game they played the most, but noted that each one of them has its advantages in respect to supporting getting to know other people. The options seemed to be balanced equally: “Pool leaves more room for conversation, but the table tennis loosens you up more so to speak - it's a more "expressive" sort of game (e.g. you can hammer the ball wildly at your opponent if you so wish).”

The tradeoff to be found seems to be between games that are very physical yet “simple”, encouraging interaction because they give "room for expression" and less intense games like pool, still "casual", but where there is "more room for conversation".

As one respondent put it: "In this room, you can see other sides of people, not the researchers, but the human beings, if not animals, that laugh, move around, jump, scream."

2.6 Summary

This chapter presented work on physical interfaces and pointed out that few of them support multi-modal input or output, have multi-user capabilities or can be physically distributed. It also reviewed work on how established relationships built over distances have been measured by other authors. An informal questionnaire showed that social games in the workplace can facilitate social connections between colleagues.

Design and Implementation

»This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us.

Western Union internal memo, 1876

3 Design and Implementation

How can you build a system that allows users, situated at different locations, to throw a ball at each other? Where does the ball go when it is thrown, and how does it appear to the other user?

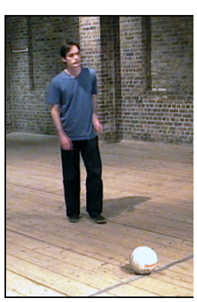
3.1 Introduction

In order to test my hypothesis, I developed a system called "Breakout for Two" which allows people in remote locations to play sports with each other in a social setting. It includes a video-conference that shows the whole playing area and supports non-verbal communication through body language. As part of the system, I built a setup that detects the location of the ball's impact and transmits it over a network, synchronising the data with a duplicated setup on the remote end where the other participant is playing. The system serves as a platform for experiments in Sports over a Distance, and has been successfully used by over a hundred players.

3.2 Design of Breakout for Two

I developed a system which allows two players in remote locations to play sports together. As an example of an Exertion Interface, it requires physical effort to play and encourages mastering specific skills. Furthermore, the design aimed to make it fun to play and also to support interactions between the players.

3.2.1 Decision on a Ball Sport



A lot of playing had to be done

I decided to model my system on a proven interface that has exerted people for years: the use of a ball in sports. Players kick, throw, bat, balance, strike, hurl, pass, dribble and shoot a ball in a vast range of sports.

Most of these games follow a basic principle: two or more players measure their skills in mastering the ball by some kind of point system. Without exotic force feedback technology, it is unrealistic to mimic the body contact that happens in Rugby or American Football over a distance. This unnecessary complication was avoided by focusing on sports that do not involve physical contact. Many sports deliberately try to avoid hard body contact with either strict rules (for instance, Ultimate Frisbee [59] follows these guidelines closely, however, Basketball strayed away from not allowing any contact), or by separating the players on the field. Games like tennis or volleyball have the players on two different parts of the field, allowing only the ball to cross the boundary or net. I oriented myself on these examples and decided to create a game which facilitates exertion while keeping distinct parts of the field for each player or team, supporting the goal of a functional long-distance game. The individual locations of the players would be on each end of the playing field. Most of these sports encourage the players to master handling a ball, a skill which can be improved upon over time.

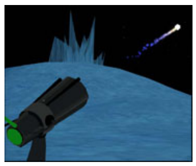
However, the decision on a ball sport required that the system be unbreakable, allowing the players to exert themselves fully and apply great force onto the system. Nothing is more frustrating than a fun new device that breaks after a couple of uses (HandJive [38] was an example where test users were too forceful).

3.2.2 Design Goals

The developed system had to satisfy all these requirements, generating a list of design goals for the proposed exertion game:

- playable over a distance
- facilitates exertion
- has a separate field for each player
- allows the players to communicate with each other
- involves mastering the skill of handling a ball
- is fun to play
- cannot be broken

3.2.3 Transmitting Exertion



Snowwars replicates a snowball-fight by shooting tennis balls out of ball-guns

If one could seamlessly transmit exertion over large distances, it would be the most realistic simulation of sports. How perfect would it be if one could throw a ball over a net, and have it come out somewhere else with the same characteristics, i.e. spin, speed and direction, all in real-time? The Snowwars system [47] tries to accomplish this on the remote end with an array of ball-guns. The local end, however, does not shoot out real balls, but virtual ones, because the investigators did not know what to do when the ball bounced back from the wall[1]. The throw and catch system described in [45] solved this problem by catching the ball in a basket, but transmits only a binary characteristic of the ball only specifying whether it was thrown or not.

Systems like this are still far from replicating the ball's characteristics in a digital form, as required for sports such as tennis, where high accuracy is an important part of the game.

Air-hockey requires quick reactions

Even in social games like air-hockey, the puck's precise movement and high speed is essential. A replication of air-hockey over a distance would require building a device which would shoot the puck out at the right angle and with the right speed on the remote end. Several problems arise with this:

- How can the speed, position, direction and spin of the ball be detected?
- How can the same characteristics be applied to a ball on the remote end?
- How can this be accomplished in real-time?
- How can the machine that shoots out the ball hold unspecified numbers of balls for a game?

---

[1] Personal conversation with Antti Törmnänen from the Snowwars [47] team.

- How can the system, after detecting the ball's speed etc. make the ball vanish and then reappear for the other player on their side?

Attempts to answer these questions have been made from multiple directions, for example through controllable ball machines in the Snowwars system described above [47]. It will probably take several years before technology is developed enough to approach these issues successfully.

3.2.3.1 The Result of Exertion: Virtual Outcome

To overcome these issues, an alternative solution is considered. Instead of trying to create the illusion that the exertion itself would be transmitted, the result of the exertion is sent. The "natural feedback" of the ball is applied directly to the player, not to the opponent, by exploiting the fact that it bounces back. Virtual objects are the link between the exertions of the players by responding to their actions; this is viewable by both.

These virtual objects are coupled to the local exertion by means of a connector between the physical and virtual world, in my case a wall that the ball bounces against.

Figure 4 illustrates this: instead of trying to transmit the exertion, a connector measures the outcome of the exertion, transforms it into a virtual outcome, and transmits it to the remote location.

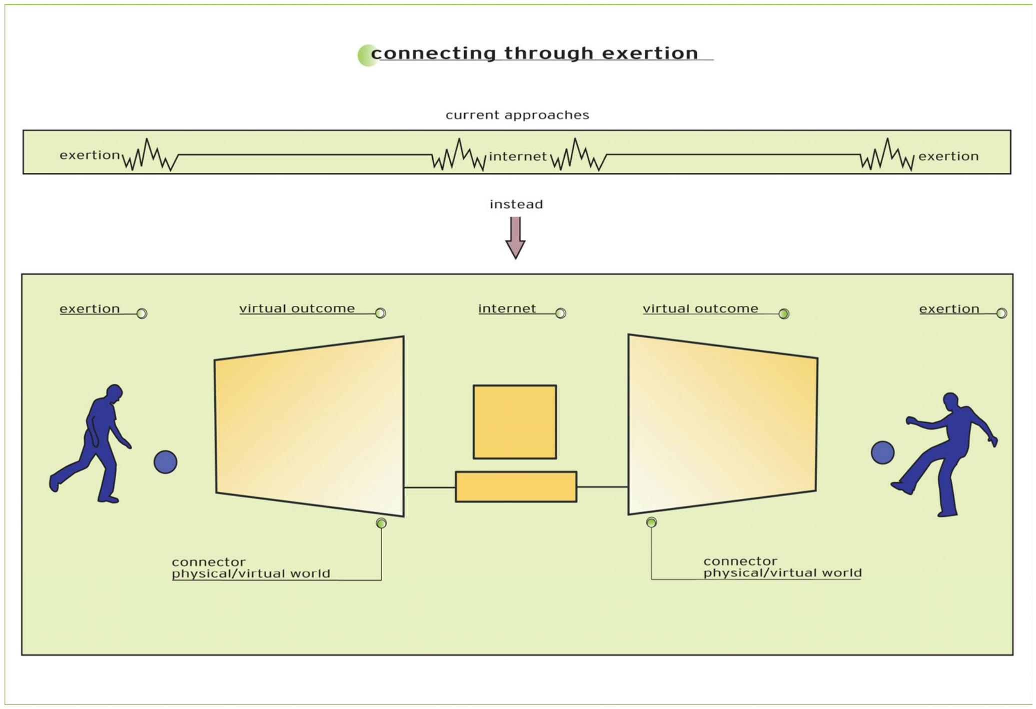


Figure 4
Instead of attempting to transmit exertion, the virtual outcome is simply transmitted, leaving the 'natural feedback' of a bouncing ball on each side

The player will throw or kick a ball against a wall, which functions as the connector between the physical and virtual world. The wall links the player to virtual objects in the form of targets projected on both walls which can be hit. Through these, virtual representations of the exertion are shared across both game stations. The real, physical ball is kicked or thrown against the wall and bounces back, providing a "natural" feedback and eliminating the need of a ball machine at each end.

3.2.4 Issues of Lag

Problems of lag in transmitted data can influence user interactions [60]. In a system that relies on direct in- and output of the player's physical forces, a delay might be very irritating and hinder game play. However, because the outcome of the exertion is transmitted here, a guaranteed in-time delivery is not essential. If the ball bounces off the wall and is kicked or thrown repeatedly, it serves an additional purpose: the physical feedback is instant for the users, while the virtual feedback on the projection is only secondary. A (small) delay is therefore unlikely to disturb the players as much, especially because they will have to focus on the returning ball, and might not even notice a delay in the projection. The "distracting" physical activity might even redirect the attention of the players away from the lag and towards the interaction.

3.3 Breakout for Two

The first prototype sports game is a cross between soccer, tennis, and the popular computer game "Breakout", which can be played by two players over a distance. For this reason, I call it "Breakout for Two".

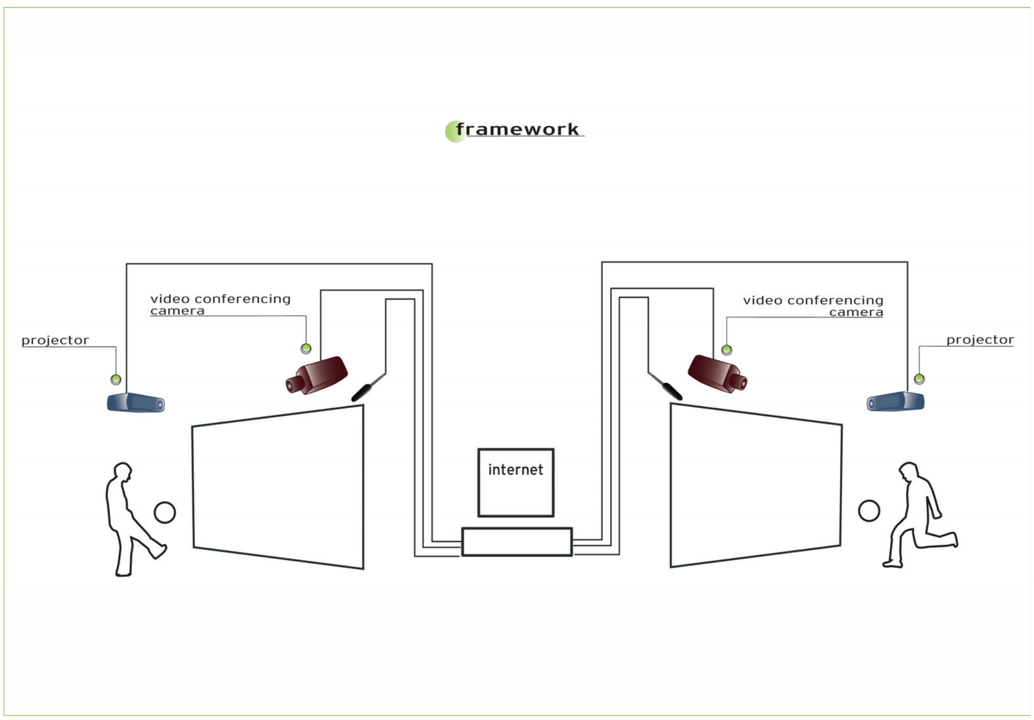


Figure 5
Both players kick or throw a ball against a wall, and are connected over the Internet.

The players, who can be miles apart from each other, both throw or kick a ball against a local, physical wall (Figure 5). 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. The experience is much like being on a tennis court – each player occupies his/her part of the field and the wall represents the net or boundary between the players, over which they can communicate. The two players can talk to and see each other at all times. This setup facilitates the social interaction and encourages conversations such as challenging the other person or discussing winning strategies.

For the players it feels like they are separated by a glass window, which splits the two parts of the field, similar to the ClearBoard [61]. They still hit the ball in the direction of the other player, but it comes back, bouncing off the glass.

ClearBoard

Semi-transparent blocks are overlaid on the video stream, which each player has to strike in order to score. These virtual blocks are connected over the network, meaning they are shared between the locations. If one person hits a block, this block disappears for both players, revealing more of the video-conference screen. The goal is to hit every block before the other player hits them, and the player who hits the most blocks wins the game.

3.4 Implementation

3.4.1 Technical Design

The implementation of Breakout for Two went through several iterations, based on user feedback from about 100 players. Breakout for Two was in use in the laboratory and was played by employees, friends and visitors before being exposed to further experiments.

The Breakout for Two system consists of three components: the video-conference between the players, the detection engine to identify the impact of the ball, and the networking software.

The conceptual idea is depicted in Figure 6.

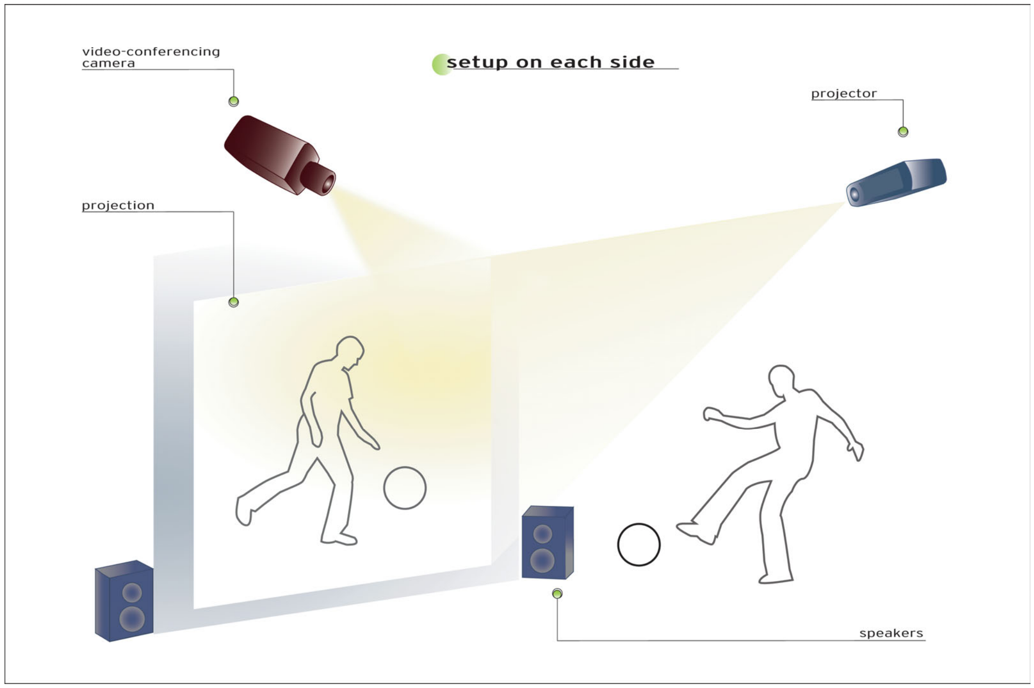


Figure 6
A concept for Sports over a Distance

The setup is identical on each side. The player, who is captured by a video camera, kicks or throws the ball against the wall. A projector displays the other person, as captured by a video-conferencing camera on the remote end, on this wall. This way, the players can see each other in full-body size. Speakers output the speech from the other person, as well as sound-effects from the game.

3.4.2 Detecting the Impact of the Ball

In order to allow for an interesting game, detecting the location and intensity of the impact is essential. How can this be achieved? For use in this system, the ball has the following requirements: it will be thrown continuously and very hard, it might need to be replaced, and it should be similar to balls in other ball sports. Therefore modifying the ball by attaching sensors to it does not seem feasible. A system was developed that does not require the ball to be altered, because it does not observe the ball's position continuously, but rather only when the ball hits the wall. The measurements are taken on the wall, instead of on the ball.

3.5 Breakout for Two - Initial Implementation

The initial system of Breakout for Two can be seen in Figure 7.

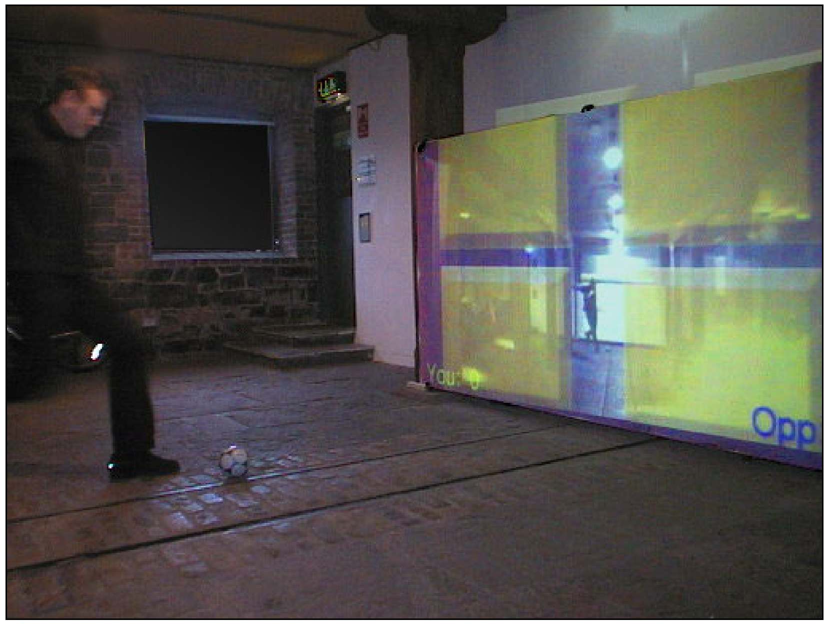


Figure 7
The initial Breakout for Two in action

Four microphones were attached behind a plywood wall in order to detect the impact of a ball on four quadrants. The games were rather short, since there were only four blocks to hit with this initial version. The intensity of the impact was a binary decision, hard enough or not, and most games ended up in a tie: 2-2, each person hitting 2 blocks. The video-conference was not distributed over a network, but rather a direct video-link.

About 40 people played the game during an open-house event. Most of these players had either not met before or only met briefly during breaks. These initial encounters with the system turned out to be very promising. Breakout for Two was well-liked, receiving comments like “best fun”, “great laugh”, “coolest demo I have seen”, and some players did not want to stop playing. Interviews with the players provided some direction for a new version, the current implementation. The players also suggested other ways in which the system could be used, such as having an international (soccer) competition or a virtual country club where members could still be in touch with each other after moving. It was surprising to me that, although a social game that most people did not take too seriously, players tended to get emotional if it seemed that the system had made a mistake in scoring. The detection algorithm was not perfect, and sometimes the wrong block was detected, or no block at all. The players were not upset if they lost a game fairly, but if they lost because a block they hit did not get detected, a heated but playful argument started. Similar debates can be found on sports fields all over the world, where players are unhappy with the decisions of a referee. In Breakout for Two, the system replaced the referee, but because most players did not feel comfortable arguing with a machine, they argued with me if they wrongly lost the game. In future interfaces, it might be beneficial to include a referee who is not only there to make decisions, but also to be yelled at if anybody feels they are being treated unfairly.

3.5.1 Detection of the Impact

Microphone, glued to the back of the wall

The impact was detected by having four microphones glued planar to the back of a wall, one in each corner. The ball is thrown at the wall from the other side and the sound travels through the wall to these four microphones. To reduce external noise, they were attached directly to the wall, thereby receiving the sound *in* the wall, rather than being placed facing each other, parallel to the wall and picking up the sound through the air. This first setup proved to be very noise-resistant. Sources such as the players' footsteps, voices, the ball, and sound effects from the game did not influence the detection algorithm. Additionally, hiding the microphones behind the wall made it more visually appealing and helped to protect the sensing system from being damaged by a fast-moving ball.

3.6 Breakout for Two 2

Figure 8
Breakout for Two 2

Following the success of Breakout for Two, I decided to develop a new, more sophisticated version starting from scratch. This new framework for Sports over a Distance was oriented at these design goals:

- Serve as a platform for multiple games
- Support several ball sports such as tennis or soccer
- Scalable to support more than two locations
- Detection should recognize the impact location with higher accuracy
- Detect the intensity of the impact
- Audio and video should be transmitted over a regular network infrastructure
- Protocol should compensate for various bandwidth situations

The new Breakout for Two 2 system tries to address these requirements through a component architecture (Figure 9).

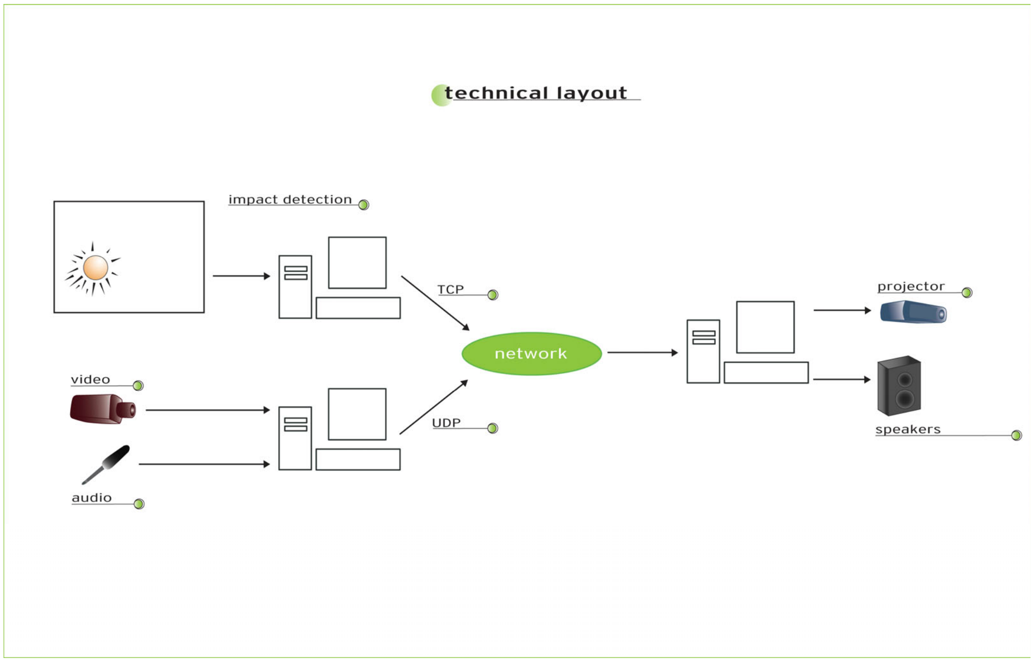


Figure 9
Individual components allow for different games and detection technologies

Multiple games are easy to implement with this version because the game is logically separated from the video-conferencing and detection software. The impact detection system sends its acquired data over the network to all participating stations using TCP/IP. The video-conferencing software was designed so that it can adapt to various bandwidth conditions and runs over UDP. The receiving station outputs the video via a projector and speakers. The equivalent data from one end, impact location and audio- and video-information, is then sent in the other direction to the other end.

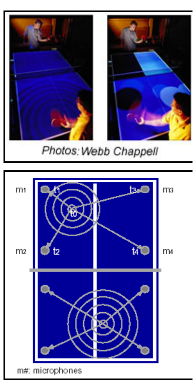
This architecture proved to be very reliable and robust. The video-conferencing software coped with very difficult network connections, and the big screen projection was praised by all players, although the compression left some visible artifacts, especially when scaled onto a large wall. Separating the detection system from the game allowed implementation of different detection technologies without major modifications of the software. Breakout for Two 2 even supports playing tennis together over a distance (Figure 10).

Figure 10
The detection system even detects small, fast-moving tennis-balls

3.6.1 Hardware

Detecting the impact of the ball is the first step towards designing the desired Exertion Interface. Two independent technologies were deployed to investigate the best approach and were evaluated. One system uses an acoustic model, the other vision detection, to locate the impact and intensity of the ball.

3.6.1.1 Audio solution



PingPongPlus

The audio solution is a more sophisticated implementation of the technology used in Breakout for Two, the original revision, and followed an idea employed in the Ping Pong Plus [31] system. In Ping Pong Plus, four microphones are attached below the table, one in each corner, detecting the location of the impact of the ball using triangulation and a lookup table.

Taking this as a guideline, the system for Breakout for Two 2 needed to be able to detect the following three characteristics: the impact, the location and the intensity of the ball's impact.

3.6.1.1.1 Impact detection

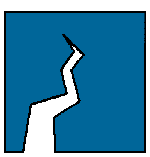
Using the sound of a ball hitting a wall in order to detect the impact has been demonstrated with ImpactTV [44]. In that system, the impact was binary, using a single microphone to detect if a ball hit a wall, which in turn triggered a vision detection algorithm that determined what object (ball or teddy bear) caused the impact. This worked well, but had to be extended for the current Breakout for Two 2 system.

3.6.1.1.2 Location

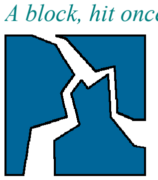
Not only is it important to know *when* a ball hits the wall, but also *where*. The location of the impact determines which target the player hit.

The sound of a ball's impact travels through the wall to all microphones. Depending on where the ball hits, the sound reaches each microphone at different times, which can be used to determine the impact location, as demonstrated by Checka [62].

3.6.1.1.3 Amplitude



A block, hit once

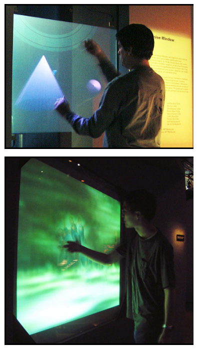


and twice

Based on the players' input on Breakout for Two, further complexity was added to make the game last longer. Introducing more blocks would have been one solution, but I also wanted to combine this with the incentive to play more vigorously. Measuring the intensity of the ball's impact gives you such an opportunity. The Breakout for Two 2 system uses this additional data to classify an impact. If the player hits a block softly, the block will stay, but show a crack to indicate that it is damaged. A further hit will crack it even more, until the final hit will make it fall apart.

3.6.1.1.4 System

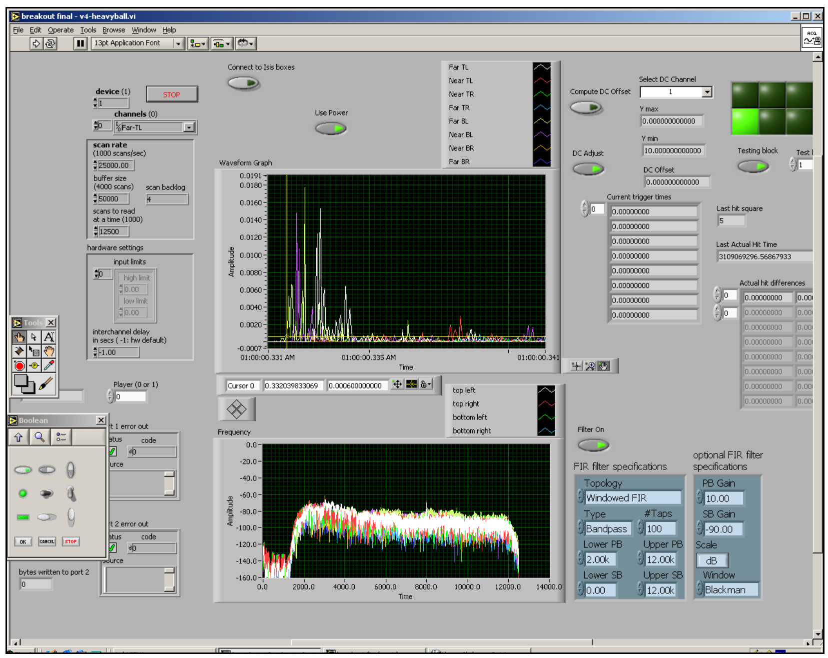
Although the concept of having four microphones attached to a surface to detect an impact was demonstrated successfully before [31] [62], the current system showed that it is not universally deployable in other applications without modifications. Unfortunately, a soccer ball hitting a wall is very loud and



The Window Tap System

inconsistent in terms of its acoustic characteristic and differs from a knuckle tap on a window, which is detected in the Window Tap system [62]. The sound characteristics of a larger ball, like a football on a wall, contain too many different frequency components, depending on the amplitude of the impact, to produce reliable measures as needed for this system. Also, the wall is made out of plywood and is clamped onto poles, which prevent the sound waves from propagating evenly and consistently. The wall is fairly large, 10 feet by 5 feet, and although supported by additional brackets, is not stiff after an impact. It vibrates quite intensively because of the hit, causing false triggers and also influencing the next input.

Figure 11
The application for detecting the impact through sound



Off-the-shelf Electret condenser microphone

An additional problem is that because the ball can hit the wall very hard, it creates a very loud noise (Figure 11). Some available microphones cannot handle this noise level, and could therefore not be used. Electret condenser microphones proved to be the best choice for us.

It would seem that the obvious solution for detecting an impact, rather than the player's footsteps and other background noise, would be to choose a high threshold for the microphones. This turned out to be unfeasible, because the sound waves and flexural waves produced by a ball hit proved to be inconsistent, even from hits in the same place.

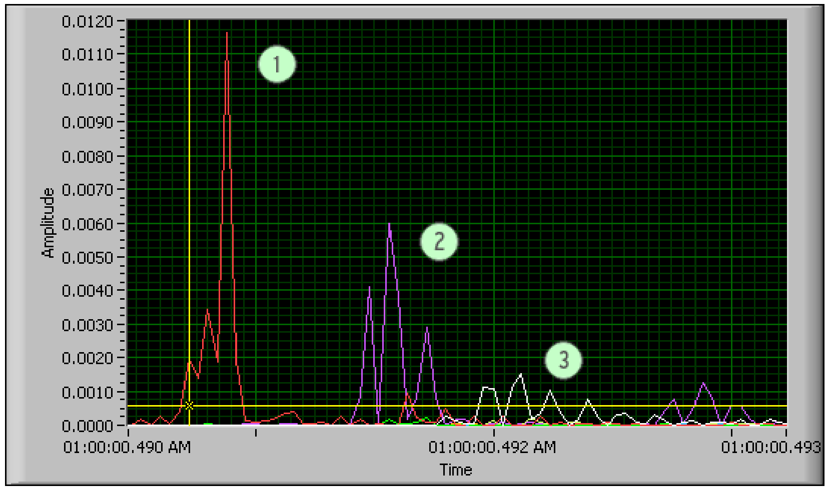


Figure 12
An easily detected impact, the ball hit the wall closest to the red microphone

This is illustrated in Figure 12: A ball hits the wall, very close to a microphone. A large peak indicates the first sound wave reaching the red microphone ①. Then, the purple microphone detects the impact noise, with smaller amplitude ②. Thirdly, the sound reaches the white microphone ③. A close look at the sound input, however, reveals that the noise we hear when a ball hits a wall is comprised of many frequencies of flexural waves, sound waves, and reflections of sound waves, which intensify each other. This makes the detection much more complex, and an example where the purple microphone is falsely triggered first ② can be seen in Figure 13.

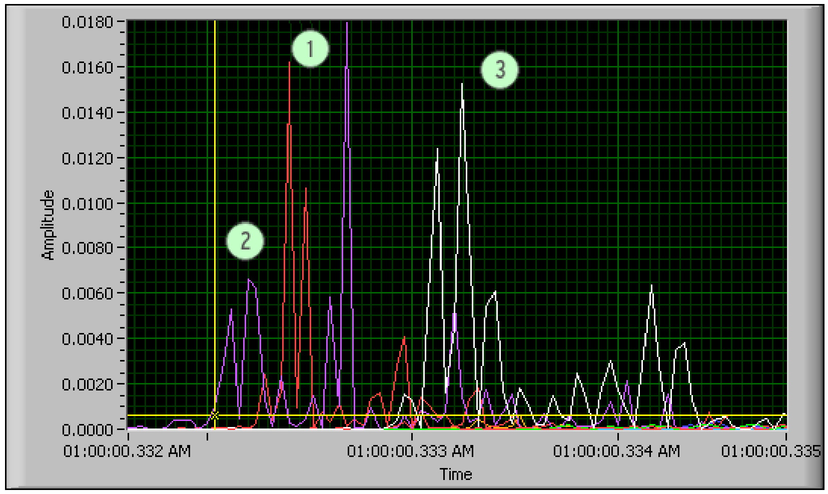
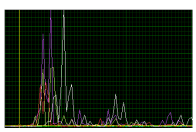


Figure 13
The impact is falsely classified, the red microphone was closest to the impact, but the purple microphone triggered the detection

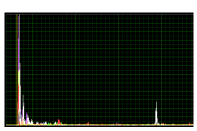
Another option would be to lower the threshold, which in turn causes many false positives. The noise level of players running around, shouting at each other, and a bouncing ball can be quite loud, especially indoors.



An impact very difficult to detect, all amplitudes equally high

To address this issue, a different approach was taken. A bouncing ball has a certain sound characteristic, and to distinguish this from unwanted background noise, its frequency band was analyzed. The results were used to create a band-pass filter, which eliminated all noise sources that did not match the frequency band of an impact.

However, the time between two detected peaks in the input signal still depended on the impact intensity. Flexural waves travel at an irregular rate, unlike the sound waves, creating an indistinct sound.

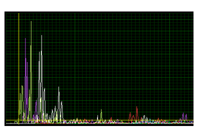


This is how the impact looks if the ball is hit very hard

The trigger level cannot be set too high, because the timings of the signal would not be accurate. The threshold cannot be set too low, because background noise would create false positives. Additionally, different balls make different impact sounds, and because the system should be universally deployable for multiple ball games, a calibration is necessary.

Figure 14
One microphone for each block

Being faced with all these issues, the location of the microphones was reexamined. Instead of just placing 4 microphones, 8 microphones were attached behind the wall. They are spread at equal distances, forming a grid of detection "panels" (Figure 14). This allows the use of a less complex detection algorithm. Additionally, the trigger level could be set higher, overcoming problems of background noise, wall vibrations and imperfect microphones, which are off-the-shelf components that are not highly accurate or uniform, and that tended to produce strange readings at high noise levels.



An impact which is straightforward to detect

This new placement of the microphones provides much higher accuracy in terms of location as well as impact detection. The location and the impact intensity (which is mapped on a 3 point scale suitable for the games played) of a hit on a 4x2 grid was successfully detected with this system. False negatives mainly occur if the ball hits the wall on one of its edges, causing the sound waves to propagate through the wall in unpredictable ways resulting in inaccuracies. Mounting guards around these critical edges solved this problem by redirecting the ball.

3.6.1.1.5 Results of the Acoustic Version

Advantages of the acoustic version:

- very high accuracy
- computationally inexpensive analysis of input data

- unaffected by external noise
- compensates for vibrations of the wall
- uses cheap and readily available components
- responds fast, no noticeable delay between ball hit and effect of the hit

Disadvantages:

- low resolution
- not easily expandable
- wall requires modification
- back of the wall needs to be accessible

3.6.1.2 Video Solution

Impact detection using sound gives reasonably accurate results, but has certain disadvantages. The number of microphones determines the granularity with which the location can be detected. New games that are developed have to be designed with the grid system of the microphones in mind. A new grid would require a rearrangement of the microphones, not a very flexible or elegant solution.

The audio solution also requires the construction of a new (wooden) wall that has to be mounted stably enough to withstand even the hardest kicks. The size is limited by the availability of such a large surface, and can only be extended by tiling an identical system.

In order to address these issues, a second version of the system was built. The goal was to reuse an existing, concrete wall, avoiding the need for additional construction. Furthermore, players should also be able to play sports like tennis against this wall; this requires a much larger surface than in the previous system, not only as game area, but also because stray impacts reach further out. The idea was to build a more mobile solution that could be mounted on any large surface without modification of the surface itself. One can envision a scenario where a tennis club rents the system to mount it against a practice wall for a network show game with a famous player, who is otherwise preparing for a grand slam on another continent.

3.6.1.2.1 Impact Detection

Camera used

Vision detection using two cameras is deployed to create a more mobile system. Two high-quality cameras (Baxall CDSP9313 [63]) continuously capture a narrow area just in front of the wall, about 5 feet in depth. One camera is mounted to the side of the wall, detecting the vertical dimension of any object entering this area. The other camera mounted on top, facing down, measures the horizontal component of a ball striking the wall (Figure 15).

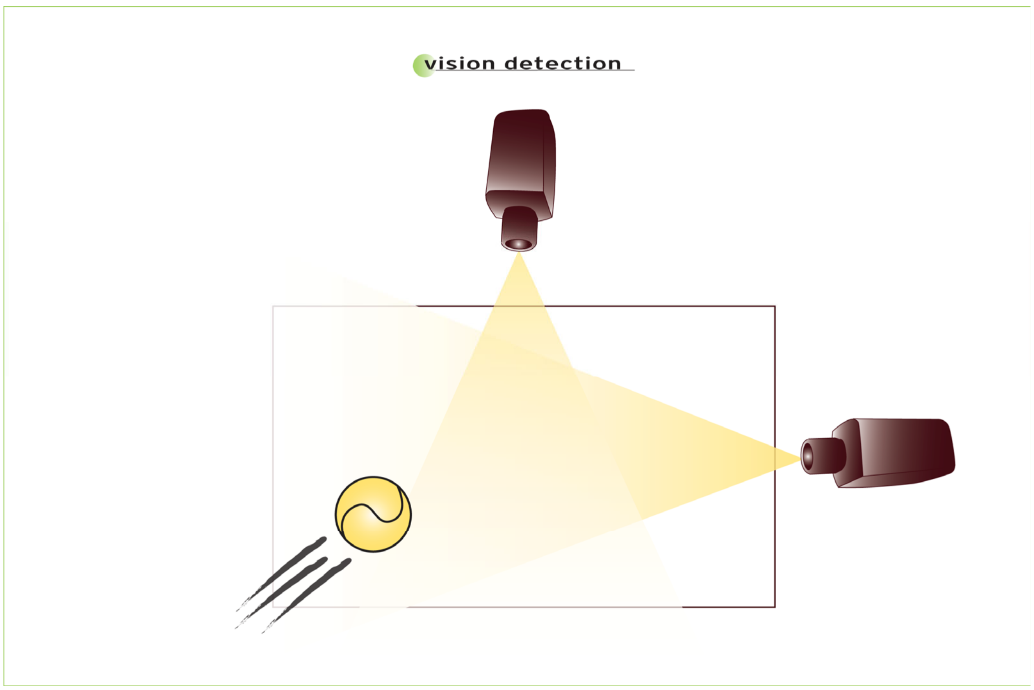


Figure 15
Two cameras detect the ball in the horizontal and vertical axis

Ideally, this camera should be sitting on the floor, pointing upwards, to allow for optimal mobility of the system. An L-shaped bracket with a camera attached to each end would be a very portable solution, which can easily be put in front of any wall. This turned out to be unfeasible, though, because if the camera is located on the floor, its lens angle would not be able to capture a wide enough area, which makes it impractical, especially for playing soccer, where the ball is mainly played along the ground. The camera was therefore mounted high above on the ceiling, equipped with a wide angle lens.

The captured image of both areas is clipped to a small strip, as seen in Figure 16.

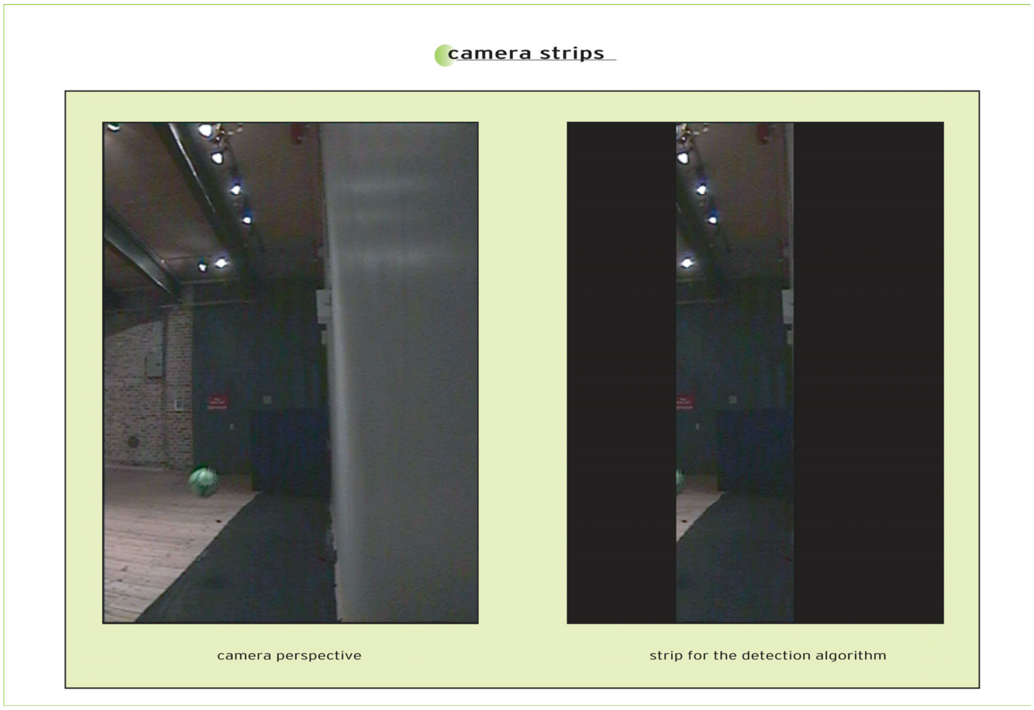


Figure 16
View from the side camera

A wider strip would improve the detection accuracy, but it might also detect the player entering this area. The players were told that they are not allowed to get too close to the wall because they could get into the view of the cameras and trigger false detection results. If a ball enters this area, it is detected by these two cameras. The software also considers the size of the detected objects and tries to classify them into ball-size objects and larger objects, reducing false measures in case the player does get too close. The top camera provides the X, the side camera the Y value of the impact. In combination, they provide the location of where the ball hit the wall.

3.6.1.2.2 Capture Technology

Both cameras are specifically designed for vision detection and provide high resolution images. The ball might travel at a very high speed, and in order to capture a focused image of the ball, a fast shutter speed was manually selected on these cameras.

The output of the cameras is fed into two mainstream capture cards, which operate on a common desktop PC (Pentium IV). The PC runs its vision detection software on Linux, written in Isis [64], a programming language for responsive media.

Capturing and analyzing the data resulted in an almost 90% usage of the PC's resources. The Isis program detects the ball in the images received, calculates its position on a two dimensional plane, and sends it to the game engine, all in real-time.

The video from the cameras are captured at 25 frames per second in YUV space. Only the Y component is kept by the detection program, the other color information is not necessary for the detection and puts unnecessary bandwidth load onto the I/O ports.

3.6.1.2.3 Detection Algorithm

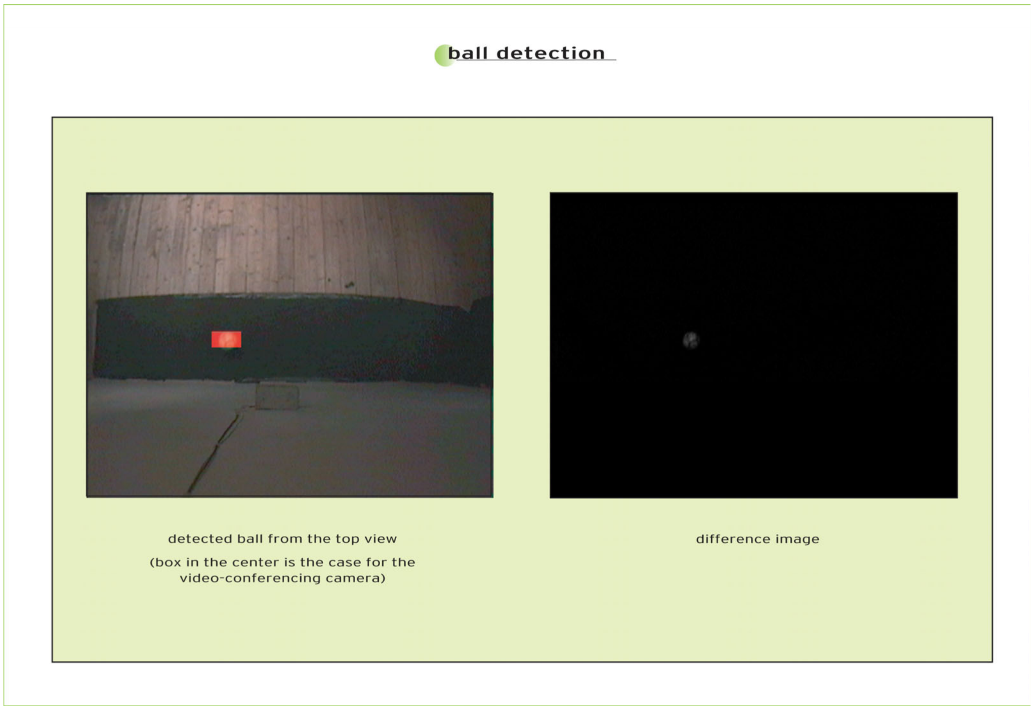


Figure 17
Ball detected from the top view camera

The detection algorithm to determine the ball in the image is identical for both cameras. Firstly, an image subtraction is performed between the current and the previous frame to detect differences in the image. These differences can be seen in Figure 17, which shows the ball. If the ball was detected in the previous frame, the difference image would also detect the non-existence of the ball at its previous location, resulting in two detected balls in the picture: where the ball is in the current frame, and where it used to be in the previous frame. To avoid this ambiguity, the difference frame is only calculated using the previous frame if there was no ball detected in it. If there was a ball detected, the most recent frame that did not contain a ball was used. Alternatively, one could compare each frame to the very first one, which could be deliberately arranged to be noise free. However, if during the game the background or the lighting changes, these differences will be continuously detected in every frame, causing wrong detections. Therefore, the former design was favored, and the resulting detection software is very robust against these changes in lighting, as it calibrates itself towards these environmental changes. If any of these alterations are detected and do not change over the period of an adjustable number of frames, they are considered part of the background and do not show up in the detected image anymore.

The location of the ball in the image is determined by applying a fuzzy-bounding box on the image [65]. This method takes the intensity values of a number of adjacent pixels and compares them to a threshold. If the calculated values are above this threshold, a bounding box around its maximal and minimal paired values in the two dimensional plane is calculated, encompassing the ball.

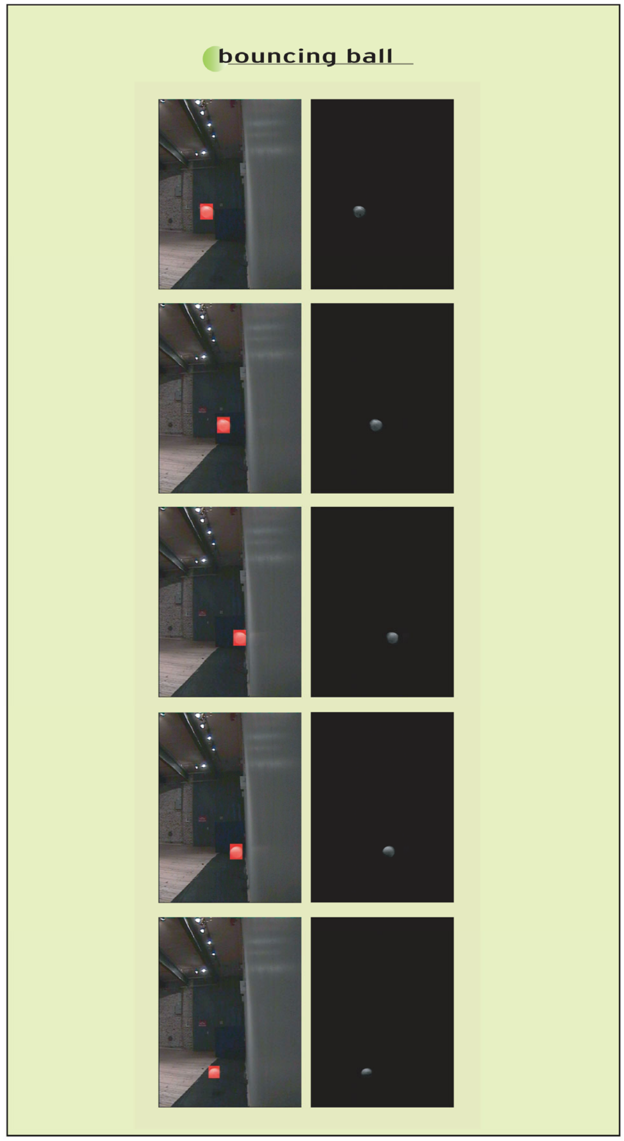


Figure 18
Ball bouncing off the wall, as seen from the side camera.
On the right is the corresponding difference image.

3.6.1.2.4 Location

The detection algorithm calculates two rectangles, representing the location of the ball as seen from each of the cameras. The centre of the bounding box is the centre of the ball. This centre is scaled to the dimensions of the projection screen, to have a uniform range to work with.

3.6.1.2.5 Triangulation

Video cameras, including the ones used in the proposed system, consecutively capture individual frames, resulting in distinct locations of the ball within the field of view of the camera. Ideally, one would be only interested in the specific frame of the ball bouncing off the wall in order to detect the impact location. Unfortunately, due to the speed of the ball and the limitations of grabbing the video frame by frame, the capture card might not capture this exact moment, but rather an image right before or after the ball hit the wall (Figure 18). This position might not match the actual position of the ball striking the wall, especially if the ball was hit at an angle (seen from the above-camera), or hit softly, so gravity changes the returning angle (seen from the side-camera).

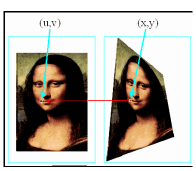
These captured frames can be used, however, to determine the impact location of the ball accurately enough for a game scenario. Even considering the gravity effects seen from a side view, the angle of incidence is approximately equal to the angle of reflection. Using two frames, one before the ball hit the wall and one after, provides an adequate approximation of where the ball hit the wall, but can be improved if one not only looks at two, but four consecutive frames. This enhancement results in a more robust algorithm, offering higher accuracy in detecting the ball's location.

Using triangulation to determine the location provides accurate results, but has the disadvantage of a delayed output. The location can only be determined after the impact, usually a couple of frames afterwards. This, in combination with the network delay to send the detected location to the game engine, might result in a noticeable delay when a block is hit. Some users of the system mentioned this delay in interviews. An alternative would be to trigger a camera at the precise moment when an audio signal detects an impact, as done in the ImpactTV project [44], but it would still leave the problem of the limited capture frame rate unsolved. The audio detection system has an advantage here.

3.6.1.2.6 Mapping

Detecting the location of the ball in the captured image is the first step to displaying the impact on the projection wall. Unfortunately, the mapping is not linear, because the cameras have a cone-like field of view, distorting the image. They also see only two dimensions, making calculations of depth rather difficult, because the size of the ball is an inaccurate measurement for determining its distance from the camera. In other words, if the side camera detects the ball at position x, it is not the same x on the projection, but rather depends on the detected y position of the other camera.

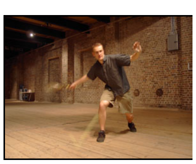
A look-up table that maps points in the captured image onto the projected viewing area is a simple solution to this problem. The size and speed of the ball makes an entirely accurate mapping system unnecessary, as it is sometimes hard for a human observer to tell which block was hit if the ball strikes in between two of them. Most of the games developed to be played with the Breakout for Two 2 system do not require an absolute position of an impact's location, but rather a classified output; for instance whether or not a certain block was hit. For these kinds of applications a look-up table proved to be sufficient.



Projective Mapping

To determine an accurate impact location, a precise mapping of the camera values to the projection plane coordinates is required. This problem is known in the computer graphics field as the difficulty of how to map a rectangular texture onto a quadrilateral [66] [67]. These calculations were implemented, but turned out to be too cumbersome; the less computational-intensive approach described above was more than sufficient and therefore used in the system.

3.6.1.2.7 Fast Balls



Fast tennis balls

A kicked football or served tennis ball, even if struck by an amateur player, can achieve a very high speed, for which a capture rate of 25 frames per second (PAL, 30 for NTSC) might not be sufficient. The ball might enter the visible strip of view of the camera, bounce off the wall and leave the area between two captured frames, resulting in a missed impact. To address this issue, an alternative detection engine grabs 50 (half-)frames per second, comparing every second frame with each other to compensate for interlacing. This, in combination with adjusting the size of the viewing strip of the camera proved to be sufficient for even the fastest balls during the games.

3.6.1.2.8 Amplitude

The vision system, like the audio version, has to be able to detect the intensity of the impact, or the force with which the ball hits the wall. This is achieved by looking at the surrounding frames that have been captured before and after the impact. Obviously, the faster the ball, the further apart the detected bounding boxes in consecutive frames are from each other. This distance is used to determine the speed of the ball, which relates to the intensity of the impact. However, special consideration is necessary for the two frames right before and after the impact. The distance between these bounding boxes represents the distance of the ball traveling to the wall and back, not the direct path between the two points. To address this issue in the detection system, the software disregards these values and takes into account only the distances before and after the impact. Of course, the speed of the ball decreases after hitting the wall due to friction and loss of impact energy. However, for most applications, the absolute impact force value is not required because typically a relative value is sufficient in order to classify the impact. Although it would be possible to look only at the distances between the detected balls in consecutive frames before the impact occurs, the former approach was implemented in favor of a more robust system.

3.6.1.2.9 Results of the Optical Version

The vision detection system was successfully tested with soccer balls, volleyballs, plastic balls and tennis balls. They were thrown, kicked, served, and smacked for social gaming during the evening hours of the laboratory by the employees. They played against a large, unaltered concrete wall, where the cameras can cover an area of up to 40 foot by 20 foot, big enough for even the biggest games.

12 meters by 6 meters

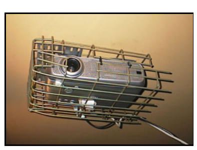
Advantages of the optical version:

- high accuracy
- high resolution
- wall does not need to be modified
- any wall material can be used
- highly scalable, wall can be very large
- wall does not need to be accessed from behind

Disadvantages:

- affected by objects entering the viewing area of the camera, players are not allowed to step too close to the wall
- computationally expensive, high usage on the I/O ports through the video capture
- expensive vision detection cameras needed
- fast balls require capturing at higher frame rates
- delay of feedback
- detection of the impact's speed is not as accurate as in the acoustic version

3.6.1.3 Protection

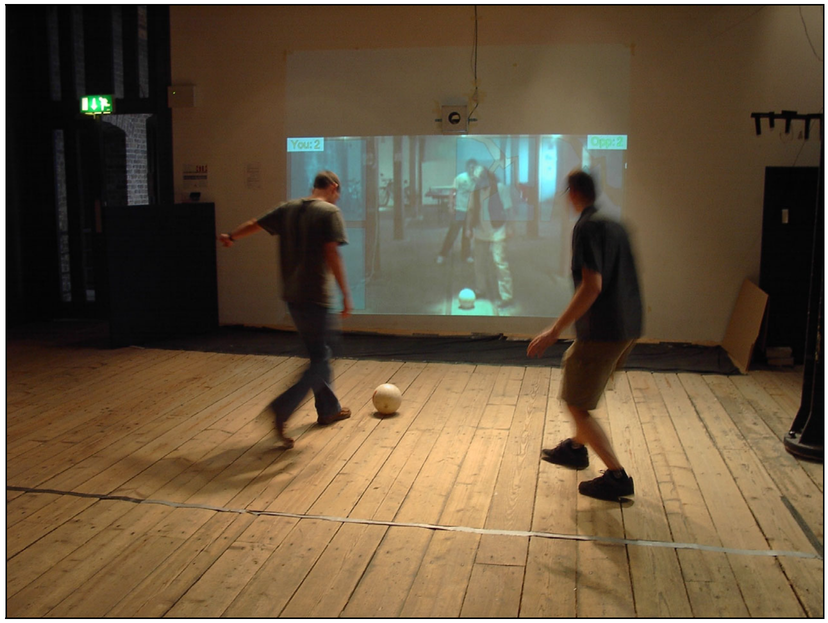


Projector case

In order to avoid stray impacts from fast flying balls, all the equipment needed to be protected. The projector and camera are encased in a steel grid and screwed to the wall, so that even a very hard kick will not change their position, requiring a recalibration. The camera lens is protected with a piece of clear plastic. The speakers are hidden behind protection panels, and the computers are located in a separate room. With this kind of physical activity, I learned that even if you think a ball will never hit something particular, it will. During the testing, we had to replace about 15 light bulbs and a fire alarm.

3.6.2 Software

Figure 19
You can even play two on two



The game engine is separated from the detection system as visualized in Figure 9, which allows for easy changing of games. Several games have been implemented which are called by a game engine. As soon as a ball strikes the wall, the location, amplitude and the wall number is transmitted from the detection software to the game engine, which can run in a separate process or on a separate computer. The wall number is important, because the game software is identical on all locations, allowing for easy updating or changing of the games. It checks for the wall number and reacts accordingly. With this setup, the detection engine broadcasts the impact to all stations. These stations all run identical software, which could also be stored on a central server. Modification to a game therefore requires changing only one file, making the system easily updateable.

3.6.2.1 Video-conference

Figure 20
The players are able to see each other full-size

The two players are able to see each other through two video cameras mounted above the projection, aimed at the players (Figure 20). Ideally, the camera should be mounted on eye-level to simulate a natural interaction more accurately. However, the camera, which needs to be in an enclosed case to protect against stray impacts, would not look visually appealing on the projection. Therefore, I tested several alternative solutions for placing the camera. The audio version of the setup already requires the construction of a new wall, drilling a hole in it to place a camera behind is straightforward. A simple piece of Plexiglas protects the lens. One of the requirements for the optical version of the system was to refrain from modifying the wall, however. Alternatively, the camera could be placed on the side of the projected area, which results in a rather unnatural point of view when talking to the other person. Mounting the camera centered at the bottom of the projection leaves the player with the feeling of looking up at the other person. The final placement turned out to be above the projection, centered in the middle. This is not necessarily at eye-level, but because most targets lie on or below this level, it proved to be sufficient and allowed for a natural position very close to eye-level. During the studies, only one participant criticized the position of the camera because he felt like he was looking down at the other person.

The importance of the right camera placement of a camera for video-conferencing has been demonstrated in [68]. If one wants to build a huge detection wall system with the camera mounted high above, the issue could be addressed by artificially changing the camera angle [69].

3.6.2.2 Audio-Conference

The design of the audio-conferencing setup turned out to be more cumbersome than expected. The aim was to allow the most natural interaction between players. Firstly, directional microphones were attached to the side of each wall, directed at the player. They picked up the speech of the player, which was sent over the network to the other player. Although the speakers were positioned apart from the microphones, facing in different directions, feedback was a permanent problem, irritating most players. The microphone settings had to be sensitive enough to pick up even the softest voice of a person speaking, and the speakers had to be loud enough to not only play the sound effects at an adequate volume, but also the other person's voice so they could be understood. This was doable in a quiet setting, but as soon as the game started, the noise of the players running around and hitting the ball overwhelmed the volume of the people speaking. To be able to understand the other person, the volume had to be set fairly high, which created a feedback loop.

Echo-canceling speakers

To address this issue, echo-canceling microphone-speaker pairs were used [70]. This prevents the echo effect, but only works well in a constrained space, where people sit close to the microphone, and the dominant audio is a human voice. As soon as the sound source moves further away, as the players might do when they are chasing the ball, the built-in microphones were not able to properly record these voices anymore. The echo-canceling also had trouble in processing non-human sounds from the other end like the bang of the ball hitting the wall. This solution turned out to be unusable in our setting.

Wireless boom-microphones attached to a headset would also address the problem of feedback, but were dismissed because of two reasons: they have a rather awkward look and are also uncomfortable to wear while running around. Headphones also isolate from the actual, real sound space the listener is in [71]. Wireless clip-on microphones, like those used on large stages, were chosen for the final system design. They provide all the necessary freedom for participating in a sports activity, do not isolate you from your sound environment like microphone headsets, and are quite small and easy to put on. Nevertheless, they take the system a step away from a media space which supports informal serendipity meetings. Instead of simply being able to step in front of the system in order to communicate and play with another person (as for example possible with iCom [5]), both players have to initially communicate to clip the microphones on.

Clip-on microphones

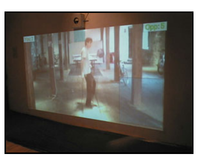
3.6.2.3 Sound Effects

Sound effects are an essential part of the game and bring it to life. Informal tests with the Breakout for Two 2 system have shown that sound effects make the playing experience much more enjoyable and exciting. They not only add an acoustic feedback, helping the users to determine whether they have hit the target, which can be difficult to see with a fast moving ball, but also foster the idea of playing a game. Several players commented that they like the sound of breaking glass when they hit a target, calling it a “stress reliever”.

Figure 21
An applause sound is played when participants win

If they win or draw the game an applause sound is played, if they lose, they hear a sinister laugh. Players were excited by these sounds either way, because they were novel, surprising, and funny (Figure 21).

3.7 The Games

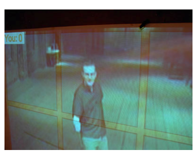


Players even played by themselves

Based on user input from the preliminary Breakout for Two game, three new games were developed. All three of them are fast-paced and require the players to act quickly, combining strength and skill. They all have in common that the players strike a ball against shared virtual objects. The trade-off between hitting the ball hard and probably not so accurately versus targeting more accurately, but with less force, has also been kept across all games. In accordance with the definition of an Exertion Interface, they all require intense physical activity confirmed by the amount of sweat they produced. The installation offers social game play in the laboratory, which was used in an informal setting by many people "having a quick game". They used the system after having received an introduction independently and created several variations on how the games can be played. Passing co-workers often joined in or simply kicked a ball against the wall to see if anybody was on the other end that might "kick back".

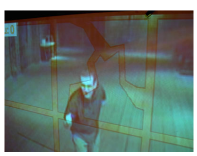
3.7.1 Breakout for Two 2

Figure 22 Breakout for Two 2 uses 8 blocks

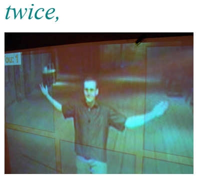


A block

hit once,



twice,



it's gone!

Breakout for Two 2 (Figure 22) follows the successful scenario of its predecessor, but adding a more sophisticated target scheme. Breakout for Two 2 has eight virtual blocks, which are shared among the distant locations. If one of the two players struck any of them once, they would "crack". If that block was hit again, it would crack more. On the third hit, the block would "break" and disappear, similar to the old arcade game "Breakout", invented by Steve Jobs and Steve Wozniak [72]. 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 entertaining and interesting 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.

The players enjoyed this very much and shared many emotional shouts commiserating success or failure.

The person who breaks the most blocks wins the game; the maximum score is therefore 8:0. The score is always visible in the upper left and right corner of the projection. When the last block is hit, the players are presented a message saying that they either won or lost (Figure 23).

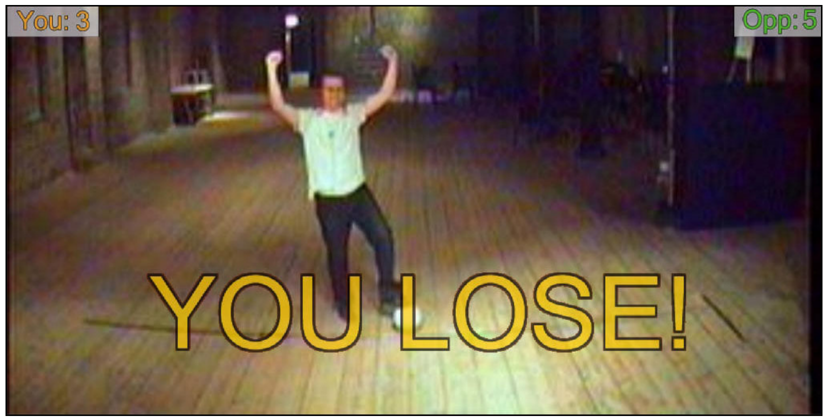


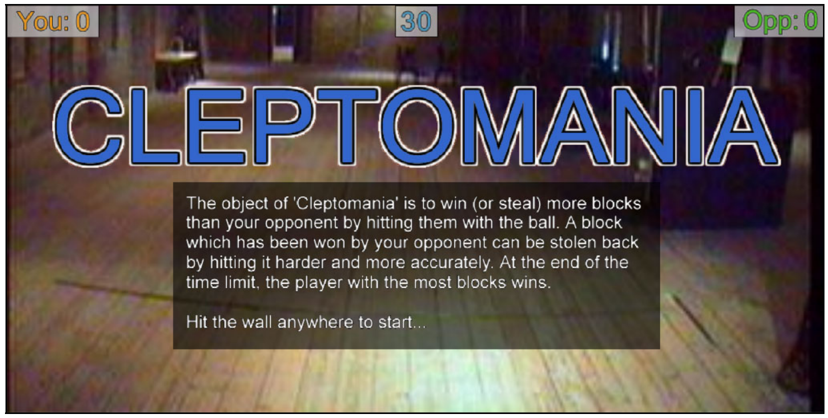
Figure 23
The loser hears a laughing sound

After a few seconds the game resets by replacing all the blocks, and the players have to strike a "restart button" to play again (Figure 24).

Figure 24
After the game is over, a player has to hit the restart button

3.7.2 Cleptomania

Figure 25
In Cleptomania, you have to steal the blocks from the other player



Cleptomania (Figure 25) can be seen as a version of Breakout for Two 2 that encourages the players to "steal" blocks from each other, subliminally encouraging watching the other person's actions more closely. All blocks start off with the same color, but based on who hit them, and how hard, they change colors. If a player hits a block for the first time, its color changes to green or orange, depending on which player hit it. This would give the player one point. The other player can "steal" this block by hitting it harder. If the measured intensity of the impact is higher than the one acquired on the previous impact, the "owner" of the block switches, indicated by a change in color (Figure 26). For example, if I hit a block it turns green, but if the other player strikes this block harder than I did at any point during the game, it turns orange. Of course, I can regain my ownership by hitting my own blocks harder, making it more difficult for the other player to steal them from me. Again, the difficulty for the players is the trade-off between hitting the targets hard with less accuracy, (meaning they would have to run back further to regain control over the ball) or being more accurate in their shot and requiring less time in between two shots, but not being able to "secure" the blocks with a dedicated hard impact.

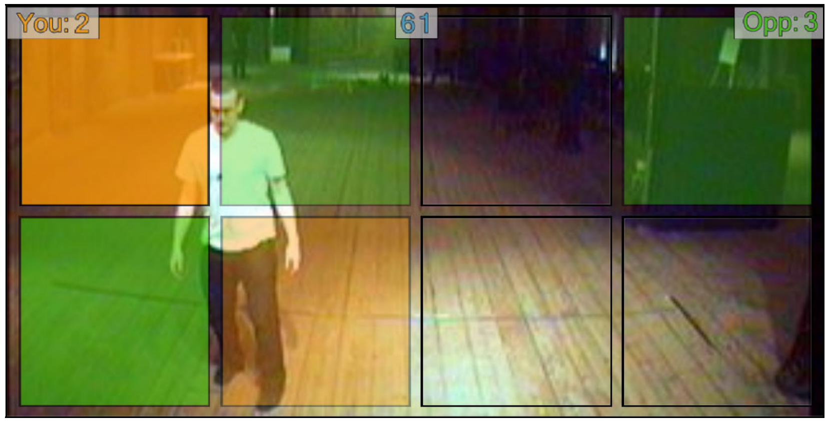


Figure 26
In Cleptomania, colors indicate who owns the blocks

The players play against a stop-watch, which runs on the top of the projection. The winner is the player who colored the most blocks in her/his color before the time limit is up. 10 seconds before the end of the game, a "bomb ticking" sound indicates the near end of the game.

3.7.3 Collaborator

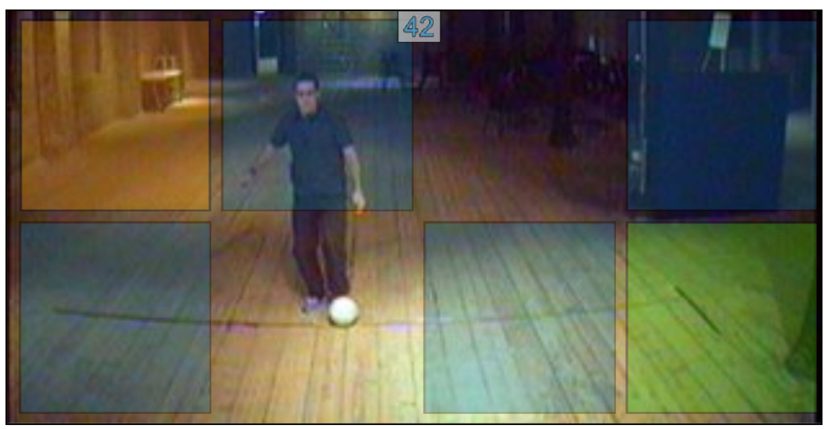


Figure 27
Collaborator looks similar to Cleptomania, but plays entirely differently

Collaborator is a collaborative game which encourages the players to play together in order to "break through" to the other remote side (Figure 27). Similar to the Cleptomania game, the blocks change color based on which player hits them. In order to make them disappear, however, a block has to be hit by both players. Otherwise, its color changes back to the neutral blue. For example, if the other player hits a block, it turns orange. If I manage to hit the same block within 3 seconds, it disappears. If I hit another block instead, this block changes its color to green, and has to be hit by the other player. The original block turns back to blue. Only if the two players collaborate and agree with each other which block to hit next, and whose turn it is, they can succeed in making the blocks disappear. As in the Cleptomania game a time limit encourages a fast-paced game. The players share the win if they manage to "break" all blocks together within the given time frame.

3.8 Summary

Figure 28 Breakout for Two supports serendipitous games

The design of Breakout for Two suggests using the "natural feedback" of a ball – the fact that it bounces back from a surface - to create a system that allows users to play a ball game over a distance. The implementation of two alternative technologies to detect the impact of a ball on a wall was described, and the technological framework for the included video-conferencing was outlined. Three different games allow collaborative or competitive play.

Evaluation

»When a team outgrows individual performance and learns team confidence, excellence becomes a reality.

Joe Paterno
American Heritage, 1998

4 Evaluation

Can an Exertion Interface support social bonding over a distance, and, if so, how can this be measured?

4.1 Participants

56 volunteers were recruited to take part in a one-hour experiment. They were approached through flyers and email postings at local universities, sports clubs and youth hostels. None of them knew about the study beforehand nor had they any prior experience with the system. Most of them have never taken part in such an experiment.

People's opinions on sports can vary from not liking them at all to practicing them every day. Therefore it was desirable that the participants of this study represent the whole of this spectrum. The recruitment approach was successful; the volunteers' experience ranged from little sport activity to playing sport everyday.

The participants were paid 10 Euro for their participation, and had to arrive at the test location at a certain time. Their performance in the Prisoner's Dilemma task had the potential to increase this guaranteed payment.

The volunteers were matched up in teams of two and no pair of participants knew each other prior to the experiment.

The average age of the participants was 26, the youngest being 17 and the oldest 44. 34 volunteers were asked to play the physical game and 22 played the non-exertion, keyboard controlled game. 77% of the participants were male in the exertion group, 64% in the non-exertion group. This equal distribution was not deliberate, but opportune.

Playing the exertion and non-exertion game was the only difference in the procedure of the experiment. The rest of the experience was identical for all players.

4.2 Experimental Design

The experiment followed a between groups design. There were two conditions, exertion and non-exertion, and participants completed one or the other of these. This design avoids issues involving order or practice effects, which, in this scenario, would strongly influence any repeated measures design.

The participants played either the physical game or a non-exertion version of the game using a traditional mouse and keyboard interface. The two players who were playing together always used the same interface.

4.3 Measures

4.3.1 Questionnaire

After the participants played the game, they were presented with a questionnaire (8.2 Appendix). It contained 60 items and included instructions. A questionnaire format was chosen because it proved to be informative in other studies of computer-mediated communication [49] [54]. It was designed to gain insights into how well the participants got to know one other, and how the system could be improved. However, the limitations of questionnaire data [73] were acknowledged and supplemental measures were also used in the experiment.

Several questions were adapted from questionnaires based on similar work to provide consistency and allow for comparisons [74] [54] [75] [76]. Demographic questions were also asked to gain a brief profile of the volunteers.

A general question on the participant's attitude towards technology was derived from a related questionnaire [77], and adapted to a video-conferencing scenario, asking the participants if they have used such a system before and how willing they were to try it out. This was used to measure if the frequent use of new technology by the volunteers would have an impact on the results of the study.

Krampen [75] developed a questionnaire regarding the participant's general attitude towards trust, based on the work of Rotter [76]. From the original 18 items presented there, a subset out of the categories "social mistrust and social fear", "media mistrust" and "trust in the reliability of others" [translations by the author] was incorporated into the questionnaire. This approach is similar to the one described by Hirsig [78], and was adapted because a person's general attitude towards trust probably influences how she/he approaches strangers and characterizes any first encounter. It therefore makes sense to compare this to the way she/he acts in the experiment.

Additionally, the questionnaire also asked the participants to rate themselves on how trusting they are on a five-point scale from 1 "much more trustful than the average person" to 5 "much less than the average person", based on the suggestion from Rotter [76].

The questions were presented in a random order to minimize a sequence effect. They were also partially negatively formulated, in order to avoid repetitive response patterns [76].

To avoid the Halo effect [73], elaborative instructions were given asking each participant to pay special attention to the different contexts posed by each question, as indicated in Rotter [76]. Confidentiality was assured.

The questions, except those of a demographic nature, were to be answered on a scale from 1 to 5, ranging from "strongly agree" to "strongly disagree". A Likert [73] scale was used to provide consistency along similar questionnaires [74] [75] and to allow for comparisons.

4.3.2 Prisoner's Dilemma

A variation of the Prisoner's Dilemma [51] was used to examine how much the players would cooperate in both conditions after having played the game. The task description that the players received can be seen in the Appendix (8.1 Appendix). The participants had to choose if they wanted to put a big X on the back of a sheet of paper or not. If both of the players chose not to put anything down, they would both win and receive an additional 5 € as incentive to ponder their choice seriously. If only one of them would mark an X, this person would receive an additional 10 €, but if both of them would draw an X, they would receive nothing extra. In any case, they would at least receive their initially promised 10 €. This is illustrated in Figure 29.

Figure 29 Outcome of the Prisoner's Dilemma

Action of A / Action of B	Cooperate (blank)	Defect (X)
Cooperate (blank)	both get 5 €	Player A gets 10 €
Defect (X)	Player B gets 10 €	both get 0 €

Both players were not able to see each other or talk to each other during this decision.

This test was chosen because it is a commonly-used measure of cooperation, and multi-round Prisoner's Dilemmas have been successfully used to assess levels of trust established between participants in remote locations [55] [54] [57]. However, this task should only be regarded as a rudimentary attempt to measure how one complex aspect of a social relationship (in this case trust) can be established through an Exertion Interface. It cannot, and is not intended to, represent the whole process involved in two people meeting for the very first time.

4.3.3 Interview

Following the questionnaire, both players were taken to a separate space in the building which had a canteen, water and couches where they would meet in person. This social atmosphere was chosen to make the players feel as comfortable as possible while they were being interviewed and videotaped. They had some time to introduce themselves before they were both given a sheet with open-ended questions (8.3 Appendix). They were asked to answer them in an informal style and freely discuss them with the observer. This way, the participants had the chance to express their opinion without the constraints of a questionnaire. The participants were informed that they were videotaped, and both players were recorded in a static shot.

4.3.4 Ranking of the Interviews

It would be interesting to see if the increased bonding between participants, which was self-assessed, is also visible to outside viewers. When people communicate, they not only use words, but also body language and facial expressions to convey their relationship [79]. This display of affection should be visible in the interviews conducted with the participants after they played the game. They were interviewed in pairs of two, and I informally observed differences in the way they talked to each other and answered the questions. These observations were of increased levels of bonding and seemed to take place only within the exertion group.

To verify the objectivity of this finding, 7 volunteers were asked to watch the interviews on videotape and rank them in order of how well the interviewees seemed to know each other. These volunteers did not participate in the previous experiment, nor did they have any knowledge about it or its scope. It is expected that the pairs who played the exertion game would show a closer bond throughout the interview than those who participated in the non-exertion game.

11 videos were randomly selected from the pool of interviews, 6 from the exertion, and 5 from the non-exertion group. These videos were roughly edited to an average length of 4 minutes. Editing was necessary to spare the observers from watching 10 hours of interviews. Obvious comments of the interviewees that could

determine their relationships were eliminated, such as "…because I don't know you…", or "…if we had met before…". I did this editing as objectively as possible. However, it is conceivable that biases crept into this process.

The videos were edited from MiniDV, and then saved in broadcast quality. The participants watched them on a computer in digital format with a standard software video player, with which all of them were familiar.

4.4 Task

4.4.1 Exertion Game

Figure 30
The players in the exertion condition played Breakout for Two 2

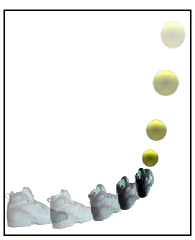
The participants in the exertion group were introduced to the Breakout for Two 2 game (Figure 30). The players were encouraged to play one practice round to become familiar with the system, and then play at least "a couple of" games. If they did not finish playing after 30 minutes, they were asked if they wanted to play longer. If both of them wanted to continue, they were allowed to play for another 10 minutes, before they were asked to stop in order to follow the time-schedule. They were always given the chance to play one last game.

4.4.2 Non-Exertion Game

The aim in building the non-exertion game was to recreate the same game experience as with the exertion game, but without the physical component. The design of the game closely mimicked the exertion game, trying to replicate the main elements as accurately as possible, separating the exertion from the rest of the game. The inclusion or lack of the exertion element should be the only difference between the gaming experiences.

In order to achieve this, ideas were drawn from computer sports games. Usually, these games try to map the physical activity onto a joystick or gamepad. A similar approach was deployed for the non-exertion game.

The same game that was developed for the Exertion Interface was used, except the input method was modified so it could be played with a keyboard interface.



The shoe is controlled with the keyboard

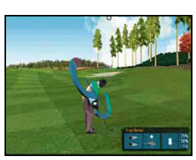
The players hit a ball against a wall; however, in this version, they hit a virtual ball with a virtual foot. The player controls the intensity, the direction and spin with a keyboard interface, and the ball follows simulated physics in a virtual environment to recreate a realistic experience. In this game, the ball is in a 3D environment which can be seen as the room where the player is on one end, the wall with the blocks on the other. The ball is kicked in this virtual space, having simulated physical characteristics. The 3D space serves as a replacement for the room in which the ball is kicked around in the exertion game.

The aim is to hit the ball with the virtual foot not too softly, so it will reach the wall containing the blocks, but also not too hard, so it will not fly above it. In order to hit certain blocks, the player has to give the ball direction.

Figure 31
The virtual shoe and ball are both animated

The game starts with a virtual ball bouncing in front of a picture of a shoe, representing the foot of the player (Figure 31). If the player hits the space bar, the shoe moves left and right in front of the ball. Another key locks this position, indicating where the shoe will hit the ball and giving it a direction once it is hit. Then the shoe moves forward and backward, waiting for another user input. This striking movement determines how intense the shot will be. If the user presses the space bar when the foot is at its maximum angle away from the shoe, the kick will go very far, missing the blocks. If the shot is too short, the ball drops before it reaches the wall, resulting in an unsuccessful shot.

The bouncing animated ball does not only fulfill entertainment purposes and indicate to the user that this object can be moved, it is also used to determine the intensity of the kick, along with the swing. As in real soccer, the characteristics of the kick depend on where the foot hits the ball. If the user kicks the ball so that the shoe hits the ball in the middle, the greatest force is applied to the ball. This results in a high-impact kick. The intensity decreases the further away from the optimal point in the middle the ball is kicked.



Pro 18 World Tour from Psygnosis

The input method used to apply force and direction to a virtual ball with a mouse and keyboard interface is similar to the one used in many golf and other sports simulations. The intensity of the swing is controlled by a key hit at a specific time during a continuous movement of the virtual golf player swinging his club.

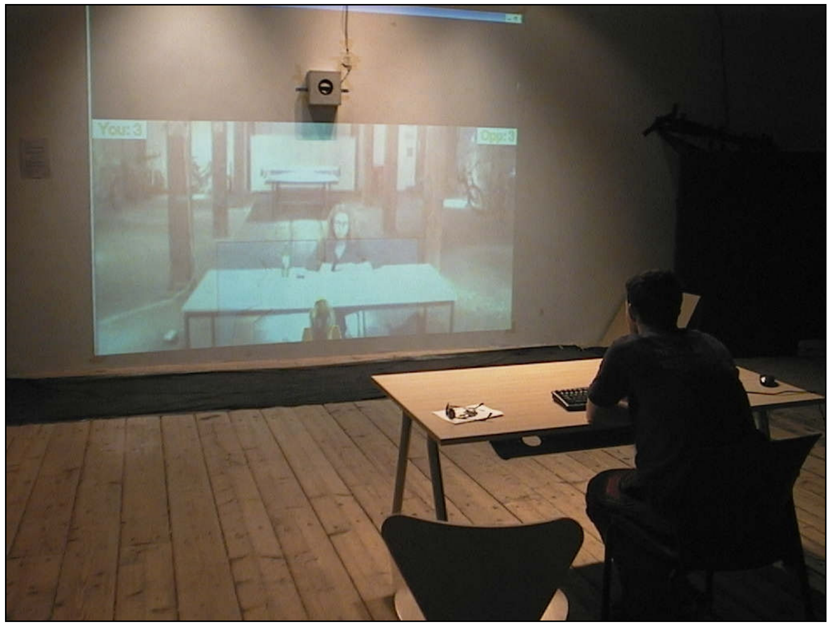


Figure 32
The non-exertion group playing using a keyboard

The exertion and non-exertion conditions both took place in the same rooms and the testing environment was consistent. The players communicated with each other through the same big screen video-conference and used the same audio setup. The non-exertion group was provided with a chair and a desk, on which they operated the keyboard. This admittedly comical arrangement of a single desk in the middle of a big room in front of a large projection created comments from the participants describing it as rather "schoolish" (Figure 32). This setup was necessary however, because the large projection had been valued highly by many users in the exertion group, and should therefore not be altered for the control group.

4.5 Procedure

The procedure for the study can be seen in Figure 33.

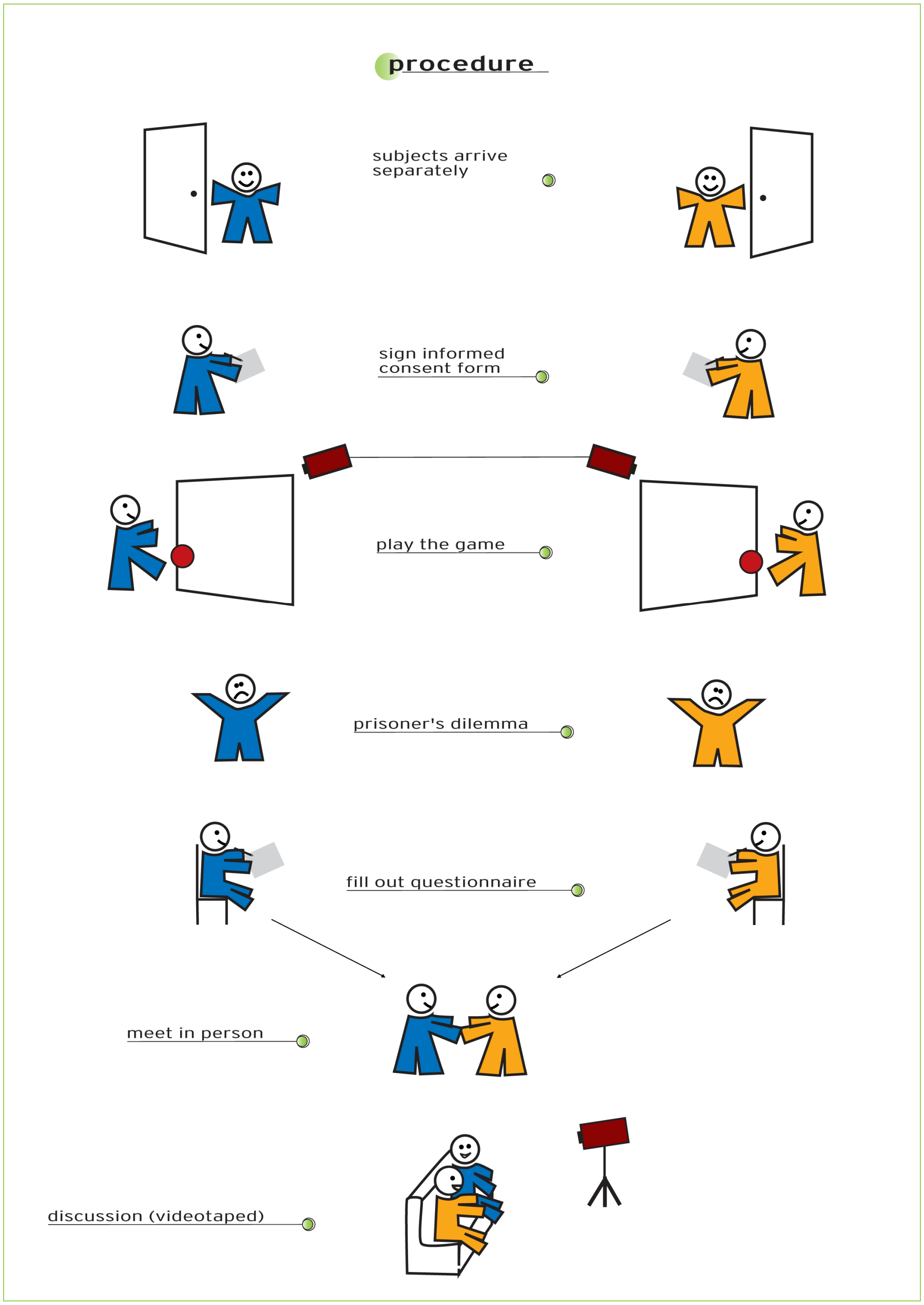


Figure 33
The individual steps of the experiment

4.5.1 Pre-Game

On the test day, the volunteers were asked to show up at the site for the full hour to be grouped in pairs. As soon as a participant arrived, she/he was escorted to one of two waiting areas. This was to prevent the players meeting each other in the lobby and having prior contact before the experiment.

The volunteers were given enough time to sign an informed consent form before they were taken to two opposite ends of the building, where they were not able to see or hear each other except through the provided video-conferencing setup.

Each room was large enough to provide space for a sports activity: one is normally used as an auditorium, and the other one usually serves as a social space. These two rooms had an identical setup to the Breakout for Two 2 system. The systems were connected through the LAN, but to simulate a larger-distance Internet connection, the bandwidth usage was artificially limited.

4.5.2 The Game

Both players were accompanied by an investigator, who could help if any questions arose, but the volunteers usually acted very independently. They were introduced to the game and the two investigators explained the rules. The volunteers were also told that their performance was not being measured, but that the goal of the experiment was to hear about their thoughts on the system and to see how much they enjoyed it. The players were encouraged to take control over the game and were told that the given rules were suggestions, not necessarily requirements for the experiment. The investigators helped the players with positioning the microphones and double-checking the audio connection to make sure they would be able to hear each other at all times. Then, they started the game, and the observers stepped into the background. The volunteers were informed that some parts of their activity would be videotaped. This was done as discreetly as possible by shooting the video from the far end of the room. Some players seemed to be uncomfortable with being recorded, so this was kept to a minimum, which usually resulted in videotaping only the first minute of the game.

4.5.3 Post-Game

4.5.3.1 Prisoner's Dilemma

After the game, the microphones were taken off the players and they were escorted to a different area, where they could not see each other or hear each other. The Prisoner's Dilemma sheet was independent from the questionnaire, printed on a separate piece of paper and presented to the volunteers after the game. They were asked to read it and to follow the instructions.

There was no time-limit, and the participants could think about it as long as they wished. They gave the sheet with the top side up to the observer and were given the questionnaire in return. Neither measure asked for the participants' name.

4.5.3.2 Questionnaire

Again, there was no time-limit, and most participants finished it within 10 minutes. None of them had any questions about the questionnaire, although they were asked if everything was clear to them.

4.5.3.3 Video Interview

After the questionnaire, the participants were escorted to a separate area, where they met for the first time in person. They were given a set of open-ended questions and were asked to discuss the answers informally. Nothing was written down, as the interview was videotaped with the consent of the participants.

4.5.3.4 Post-Experiment

After the interview, I thanked each player personally again for their participation and handed them an envelope with their payment. Only three pairs of players decided to open the envelopes together, everybody else left them closed and did not open them until they were escorted out of the building.

4.6 Summary

The experiment followed a between groups design: one group played the game using an exertion interface, while the other group played the same game using a traditional keyboard interface. Four different measures were taken: the 56 participants completed a Prisoner's Dilemma task, filled out a questionnaire and were interviewed. The interviews were later ranked by independent observers in terms of how well the players seemed to know one another.

Results

»*Friendship is the hardest thing in the world to explain. It's not something you learn in school. But if you haven't learned the meaning of friendship, you really haven't learned anything.*

Muhammed Ali

5 Results

If an Exertion Interface supports social bonds between two players, is it detectable to one of them individually, or do they experience it together? How much do they value it?

5.1 Introduction

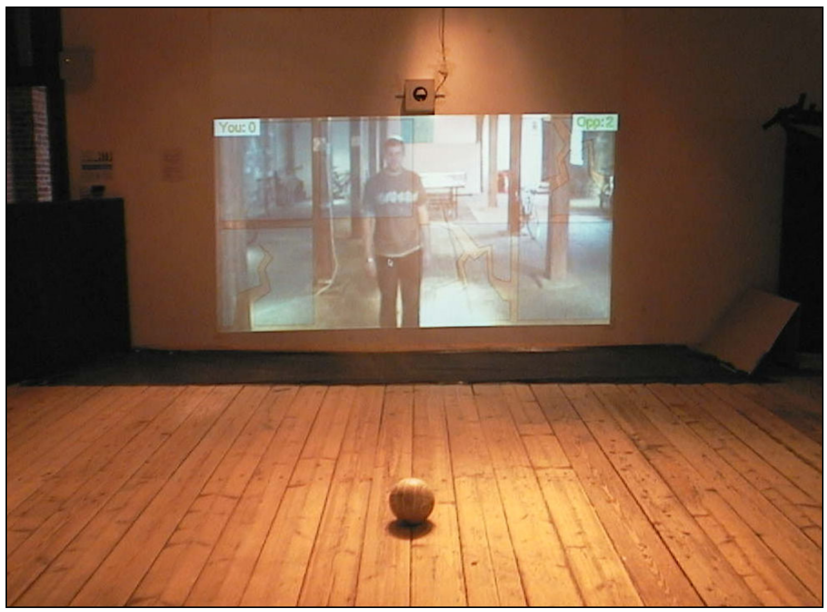


Figure 34
Ready to play?

After the participants played the exertion or non-exertion game, they were asked to perform a Prisoner's Dilemma task, which would influence their payment for the experiment. Then they filled out a paper-based questionnaire. Subsequently, both participants were brought into the same room where they were interviewed together. These interviews were videotaped and later on, they were ranked by outside viewers on how well the player peers seem to know each other. The findings of these four evaluations: the questionnaire, the Prisoner's Dilemma and its correlation with the questionnaire, the inquiry into familiarity ranking and the player interviews, are presented in that order.

5.2 Statistical Analyses

The questions were evaluated using standard statistical methods. Some of the questions were phrased negatively, to avoid the Halo effect [73], but were inverted again for the analysis (marked with an 'n'). All t-tests are two-sample, one tailed and assume equal variances. They usually compare the exertion and non-exertion group, expecting the exertion group to perform better, unless stated otherwise. It is also noted where a two-tailed test provides significant results.

The correlations are bivariate, two tailed and use Pearson's correlation coefficients. They are typically compared across questions; if not, it is stated explicitly. All significant results, measured at the level of $p \leq 0.05$, are presented.

The answers in the questionnaire are ranked, according to the five Likert categories [80], and converted to a 1 to 5 scale:

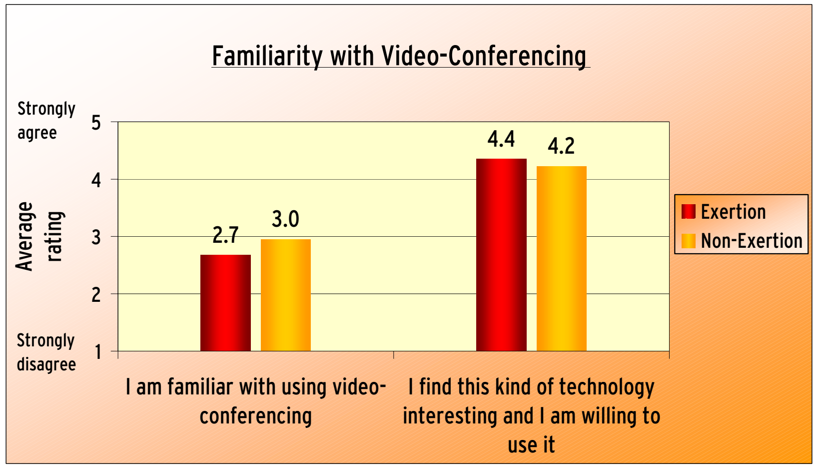
1 = Strongly disagree
2 = Disagree
3 = Neither agree or disagree
4 = Agree
5 = Strongly agree

5.3 Results from the Questionnaire

5.3.1 Demographic Distribution

The 53 participants were asked for some basic demographic information in order to check for an even distribution between the two groups. For instance, the average educational level of the players in both groups is equivalent to a university education.

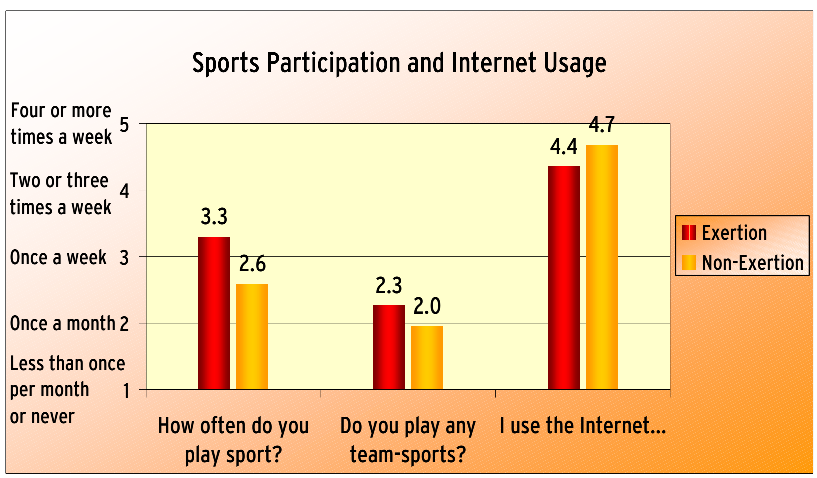
Figure 35
Participants' familiarity with technology



Internet usage and video-conferencing experience is not significant between groups ($t=0.21$, $p>0.1$)

In order to gain an understanding of the participants' technical understanding and attitude towards technology in general, the questionnaire asked them about their average Internet use and their experience with video-conferencing as well as how interested they are in it (Figure 35 and Figure 36). Comparing the answers between the group that played the exertion game and the group that played the computer game revealed no statistical significance.

Figure 36
Sport participation (average of sports questions: $t=-0.84$, $p>0.1$) and Internet usage ($t=1.32$, $p>0.05$) is not significant between groups

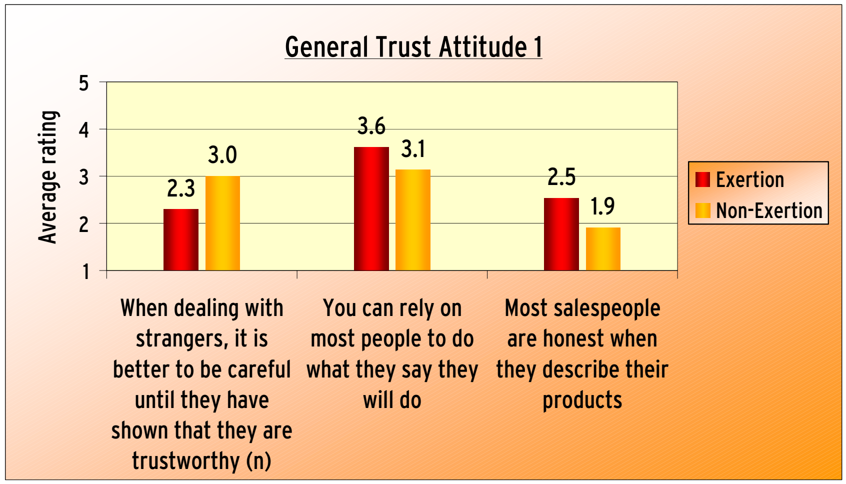


The exertion game might be more appealing for players who have previous sport experience, therefore it is important that the level of involvement in physical activity is equal among both groups (Figure

36). The exertion and non-exertion group both consist of participants who play sport every day as well as people who do not do any sport, and there is no significant difference between the two.

5.3.2 General Trust Attitude

Figure 37
No significance of general trust attitude, individually and averaged (average: t=-0.26, p>0.1)



It is important to consider the possibility that the participants in the two groups have a different attitude towards strangers and a different level of trust in general (Figure 37).

Figure 38
General Trust Attitude continued

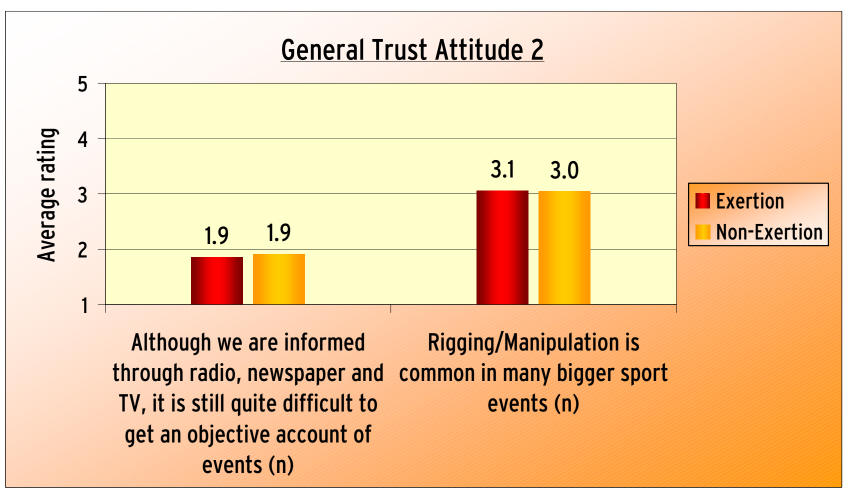
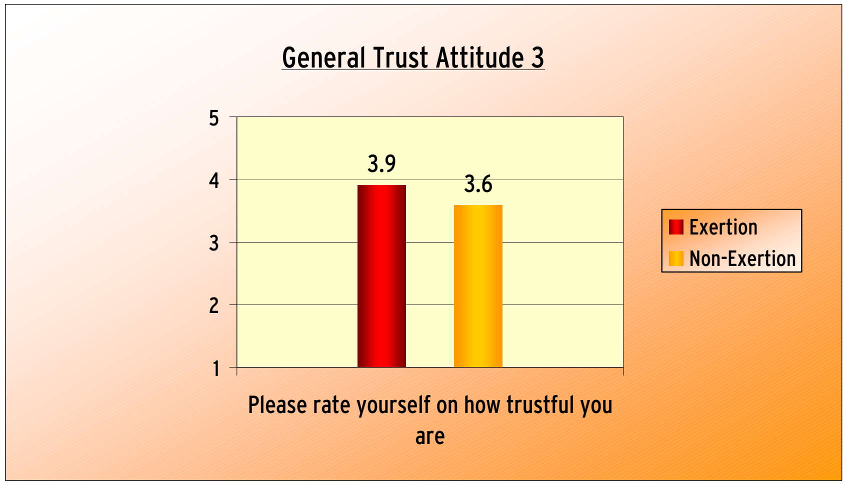


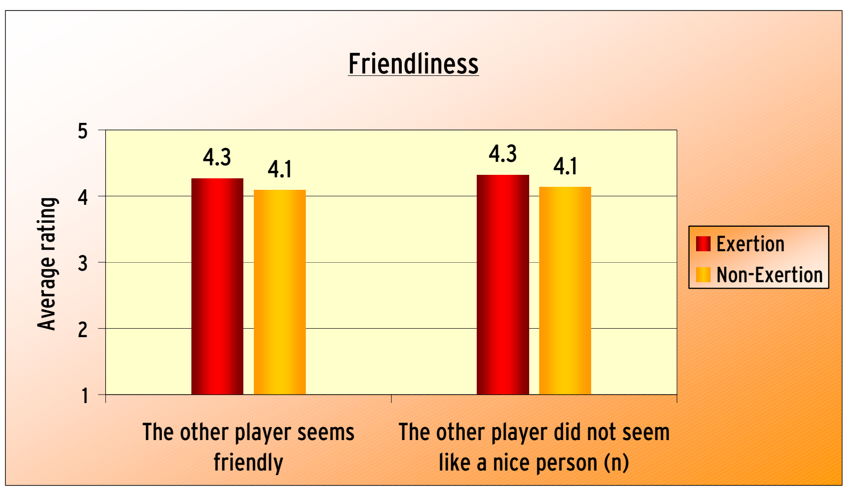
Figure 39
General Trust Attitude continued



The questionnaire therefore contained five questions from Krampen [75] (Figure 37, Figure 38) as well as a self-rating on trust [76] (Figure 39). The responses showed no statistical significance between the exertion and non-exertion group, which is an indicator that the following findings are directly attributable to the experimental manipulation.

5.3.3 Perception of the Other Player

Figure 40
The exertion group rated the other player to be friendlier and nicer, however, there is no statistical significance ($t=-1.15$, $p>0.1$ and $t=-0.86$, $p>0.1$)

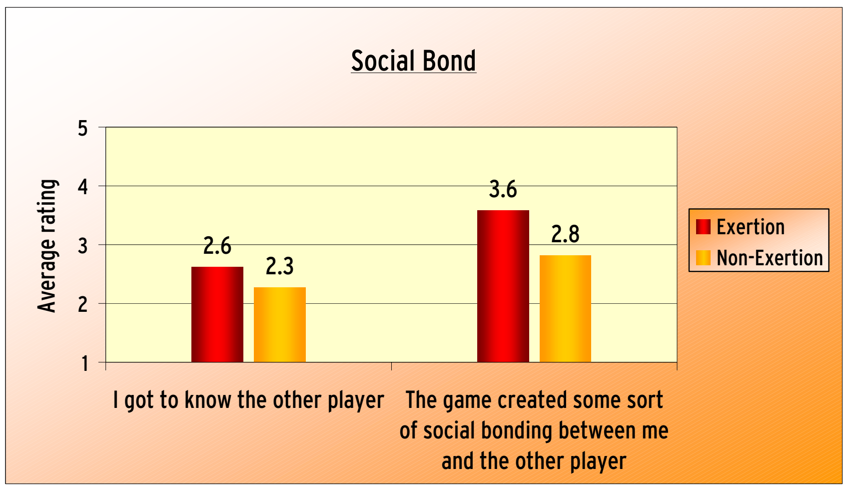


Evaluating the answers about how the players perceived their partners at the other end showed that most participants thought their partners were friendly (Figure 40).

Not only did most of the players agree that the other player was very friendly, they also described the partner as "a nice person". The game seemed to be an important factor in how players saw their opponent, which was also reflected in the interviews afterwards. They all seemed very relaxed with each other, and although they had never met before, acted very comfortably together.

5.3.4 Social Bond

Figure 41 Statistically significant differences in terms of social bonding



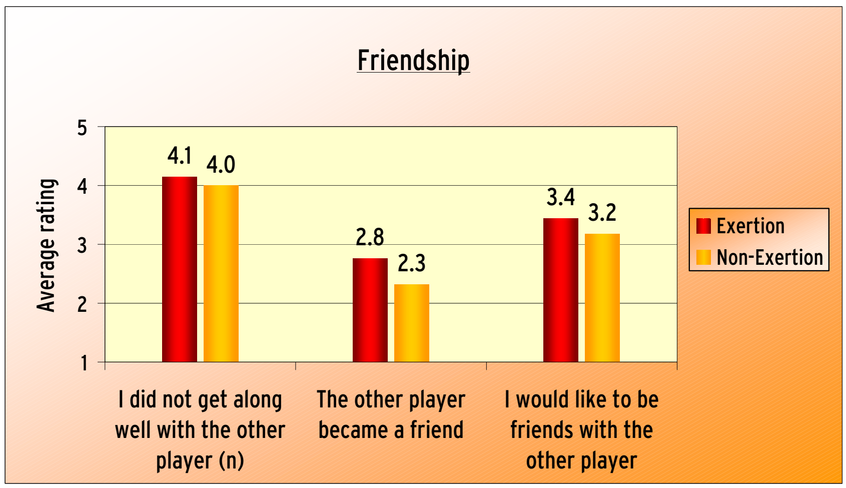
"I got to know the other player" (t=-1.94, p<0.05)

"The game created some sort of social bonding between me and the other player" (t=-2.73, p<0.01, unequal variances, two tail: p<0.05)

The exertion group answered the question "I got to know the other player" with a significantly higher rating than the non-exertion group (Figure 41). Additionally, the players of the exertion group believed that the game created a much stronger social bond between them than the computer-game players. The difference is one of the highest differences between the two groups and highly significant. This finding was reinforced by the interviews, where the players who rated the question higher showed much more knowledge about their partner. This was not necessarily on facts, but on characteristics. For instance, when answering the question of whether they played competitively, one player said that the other played very competitively, to which his partner replied that the first player was much more competitive, starting a playful argument. In the non-exertion group, however, the interviewees often confirmed their answers politely with each other: "I did not play competitively, did you?" It is possible that the Exertion Interface brought out more competitiveness in the game, however with a friendly spirit.

5.3.5 Friendship

Figure 42 Friendship developed more in the exertion group



"I did not get along well with the other player (n)" ($t=-0.80$, $p>0.1$)

The pairs in the exertion group seemed to get along better than those in the non-exertion group, and although they confirmed the corresponding statement more strongly, the difference was not significant (Figure 42).

"The other player became a friend" ($t=2.50$, $p<0.01$)

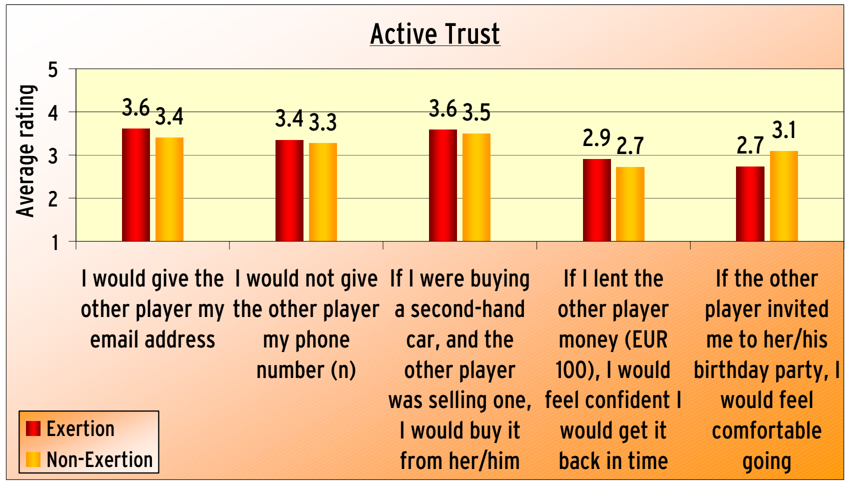
"I would like to be friends with the other player" ($t=-1.57$, $p=0.061$, trend)

The exertion players became much better friends than the non-exertion players, a finding that is highly significant. There was also a trend that they wanted to become friends more strongly (if they were not already). A correlation between how well the participants got along and if they wanted to be friends confirms this relationship.

Correlation between how well the participants get along and if they want to become friends ($r=0.33$, $p<0.05$)

To validate these results, it was checked whether the participants would go one step further and create the possibility of a future encounter, by asking them if they would give the other player their email address.

Figure 43
The depth of the established bond



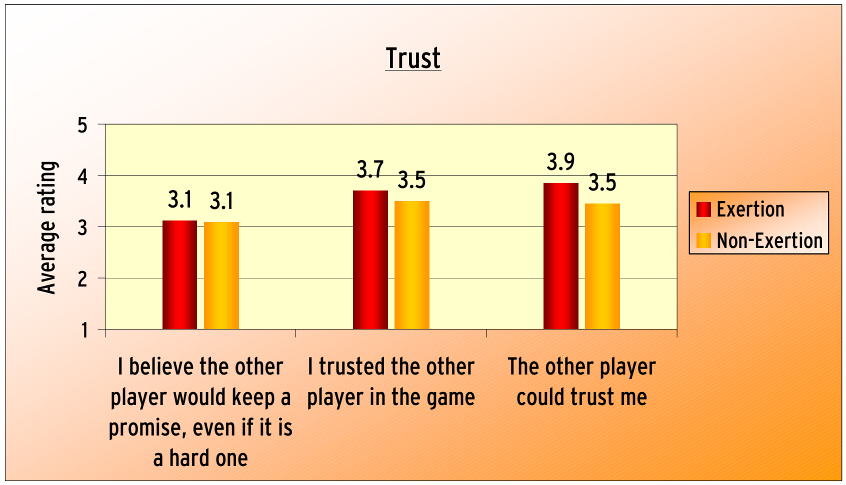
Correlation future friendship – give out email address (r=0.31, p<0.05)

"I would give the other player my email address" (t=-1.00, p=0.16)

Although the exertion group responded higher to this, and there is a correlation with the question about future friendship, a strong trend could not be observed. The players were also asked if they would consider giving out their phone number to the other player, which showed a non-significant difference between the two groups. Along the same lines was the question of whether the player would buy a second hand car from the other person if she/he had one for sale. Again, there was no significant difference in the answers. The same result applies to the question of whether the player would feel comfortable lending the other person money. The question of whether a participant would feel comfortable going to his/her playing partner's birthday party if invited also showed no significant difference. One participant commented that he only answered this question with a "no" because he has a girl-friend and she would not like it if he went to another girl's party.

5.3.6 Trust

Figure 44
How much the players trust each other



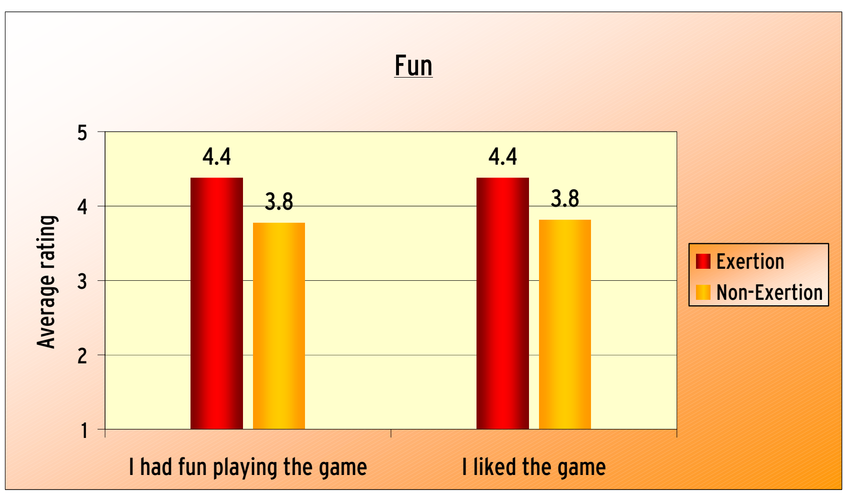
"I trusted the other player in the game"
(t=-1.16, p=0.12, trend)

"The other player could trust me"
(t=1.93, p<0.05, unequal variances)
correlates with the average trust rating
(r=0.32, p<0.05)

Both groups believed equally well that the other person would keep a promise, but there was a small trend that the exertion group trusted the other player more (Figure 44). However, it is highly significant in comparison to the proportion of the non-exertion group that they said the other player could trust them. This correlates with the average trust rating attitudes mentioned earlier (5.3.2 General Trust Attitude), confirming the validity of the answer. One's self-assessment of trustworthiness seems to increase with playing an exertion game.

5.3.7 Fun

Figure 45
Exertion players have more fun



"I had fun playing the game" (t=-4.11, p<0.0001, two-tail: p<0.0005)

"I liked the game" (t=3.45, p<0.001,two-tail: p<0.005)

The exertion group had much more fun, which is highly significant (Figure 45). This is no surprise if one looks at the comments during the interviews: almost all sports players confirmed how much fun they had without being asked, and some of them wanted to know when the system becomes commercially available and if they can show it to their friends. They also liked the game more, a highly significant result.

Some players were getting so involved that they were seriously out of breath and their shirts heavily sweaty. I had to put a water-cooler close by, because I got concerned that some participants might become dehydrated.

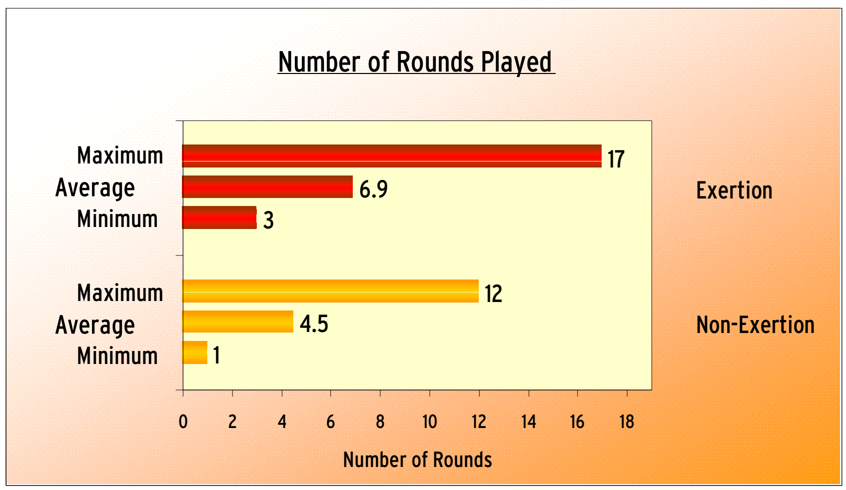


Figure 46 On average, the exertion group played more rounds

The last question asked the players to recall the number of rounds they played (Figure 46). A lot of them mentioned that they were not sure about this number, because they simply did not pay attention while playing, and therefore estimated this number. Based on their approximations, the exertion group played an average of 6.9 rounds, the non-exertion group 4.5.

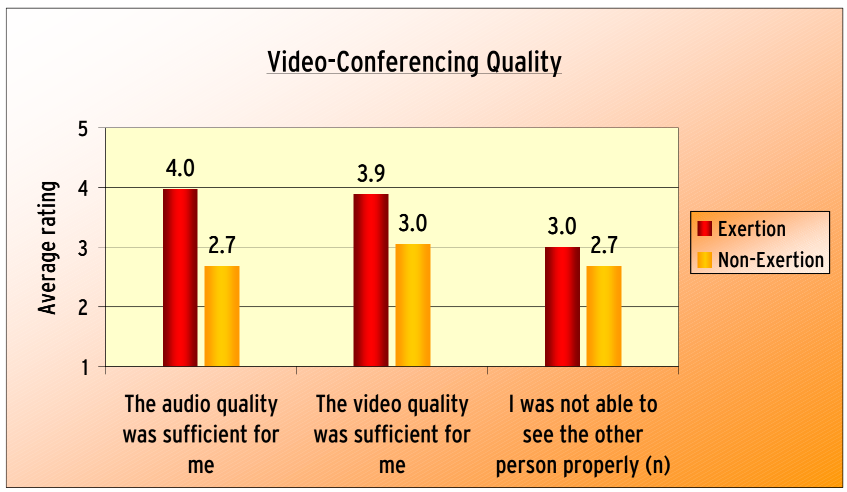
Number of rounds played (t=3.16, p<0.005, two-tail: p<0.005)

It has to be noted that although the interface for the two games was different between the groups, playing each game took them equally long. Both games included the same amount of targets to hit, and the average time to complete one round was also approximately the same. As an observer, I would say the number of games the exertion group reported was estimated too low for many pairs, and a lot of them seemed to have played more than 7 rounds. One team played 17 rounds and wanted to play even more.

Both systems are very new and exciting for the players because of the large projection, which might be one of the reasons the participants played so long. Although the exertion game probably has a more original character, the differences in the amount of time the participants spent playing the game are too large to be simply attributable to the novelty factor.

5.3.8 Video-Conferencing Quality

Figure 47
The exertion group perceived the video-conferencing quality to be higher



During the interview, the differences in the remarks about the video and audio quality of the video-conference were very notable. It is true that, due to the limited resolution and the compression, “facial expressions and especially the eyes”, as one participant noted, were very hard to distinguish. Some of them also remarked that they had some trouble understanding each other.

“The audio quality was sufficient for me” ($t=-5.36$, $p<0.000001$, two-tail: $p<0.000005$)

Having these comments, it would be interesting to find out if there is a difference in perceived quality between the exertion and non-exertion group. Indeed, the exertion group answered, with high significance, much more often that the audio quality was sufficient for them (Figure 47). The difference between the given answers was

"The video quality was sufficient for me"
(t=-3.37, p<0.001, two-tail: p<0.005)

"I was not able to see the other person properly (n)"
(t=1.2, p=0.12, trend)

the highest of all questions. Similar results were obtained about the video quality: again, the exertion group was much happier with it, at a high level of significance. The fact that there was a trend that the computer game group complained more of not seeing the other person properly confirms these findings. Averaging these answers also leads to a statistically significant result.

A
perceived quality
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It is important to consider the influence of previous exposure to ncing across the subjects. The question "I am familiar eo-conferencing" was not significant between groups orrelate with the query about the sufficiency of the audio and video quality, indicating that the interface influenced the perception of the video-conferencing quality.

"I am familiar with using video-conferencing" does not correlate with sufficiency of audio and video quality
(t=0.16, p=0.24)

These results are surprising, because both groups used the same video-conferencing setup, with the same microphones and the same speakers. The tests took place on the weekend, to ensure that network traffic was at the same level. The network logs also showed no particular additional traffic. I was present at all experiments, able to compare the video-conferencing quality, and I perceived the video and audio quality for both groups as exactly the same, which was confirmed by a second observer.

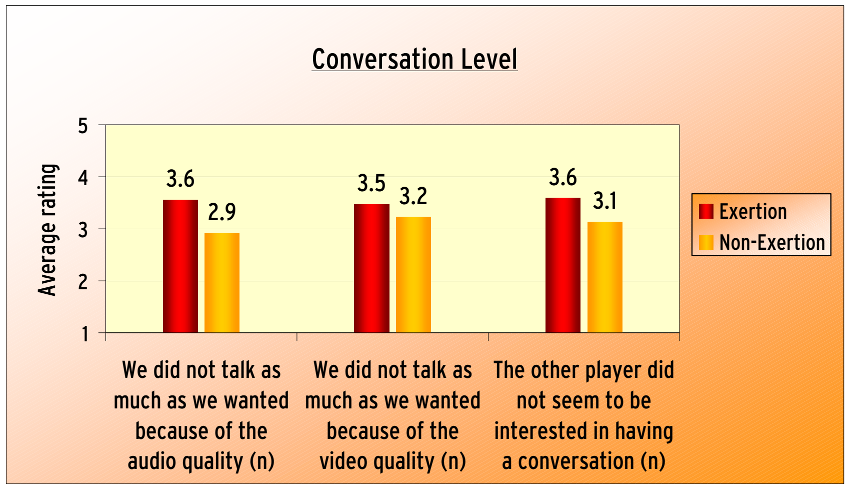
Considering that the audio and video quality was the same for both groups, it seems reasonable to conclude that an Exertion Interface does not require a high video-conferencing quality to the same extent that a keyboard interface does. Its users are more willing to accept limited quality of the audio and the video than the users of a keyboard interface are.

My assumption is that because the sports game allowed the other person's full body to be viewed from various positions, it permitted the players to "read" much more through body language and posture, and also to express themselves better with non-verbal language. This compensated for deficits in the video-conference quality.

These findings were emphasized by comments during the interview, where the exertion group praised the full-body size projection much more often than the non-exertion group.

5.3.9 Conversation Level and Video-Conferencing Quality

Figure 48
The interaction in the exertion group were less hampered by technological limitations



"We did not talk as much as we wanted because of the audio quality (n)" ($t=-2.42$, $p<0.01$, two-tail: $p<0.05$)

Correlation between participants talking as much as they want and sufficiency of audio quality ($r=0.66$, $p<0.05$)

Correlation between participants who talked as much as they wanted and who saw the other person properly ($r=0.32$, $p<0.05$)

A logical consequence is to investigate whether the audio quality was perceived differently between groups, as the exertion group did not talk as much or not at all (Figure 48). This can be disputed, because the exertion group said that they talked as much as they wanted despite the limited audio quality, with a high significance contrasting the non-exertion group. This strengthens the previous finding, and is confirmed by a correlation with the sufficiency of the audio quality.

The participants who said that they did not talk as much as they wanted because of the video quality were the same who said that they did not see the other person properly, meaning that these questions were answered thoughtfully and it was indeed a problem for them. The exertion group however, did not seem to have these difficulties in the interaction.

5.3.10 Conversational

"The other player did not seem to be interested in having a conversation (n)" (t=1.95, p<0.05)

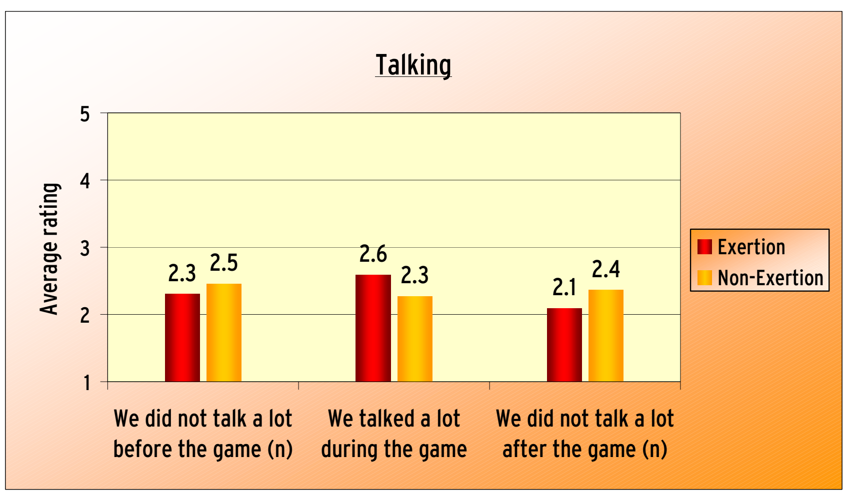
The participants who played the exertion game answered the question "The other player did not seem to be interested in having a conversation (n)" with a much higher ranking than the non-exertion players (Figure 48). This statistically significant result is remarkable, suggesting that an Exertion Interface not only helps the players to forget about limited video-conferencing quality, but also makes the other player seem more talkative.

Correlation between participants who believed the partner was more talkative and satisfaction with audio quality (r=0.36, p<0.01), also correlates with the ability to see the other player properly (r=0.35, p<0.01),

To confirm this statement, these answers were correlated with "the audio quality was sufficient for me". Indeed, these two questions strongly correlate. Additionally, the question of whether the players could see their partner properly also showed a strong relationship. If the audio quality seems adequate for the users, they attribute a higher motivation for conversation to their partner. Exertion Interfaces increase the seeming quality of the video-conference and consequently make the players perceive their partners to be more conversational.

5.3.11 Interaction

Figure 49
The exertion group talked more during the game



"We talked a lot during the game" ($t=1.33$, $p<0.1$, trend)

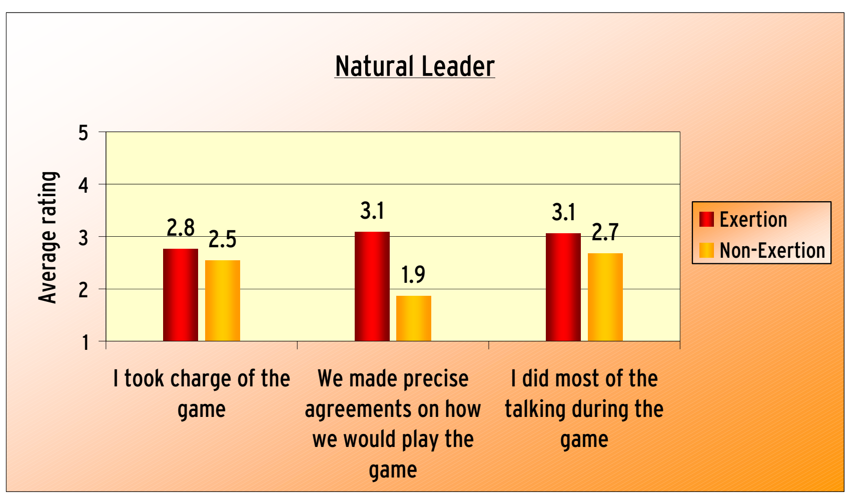
There is a trend that the exertion group talked more during the game than the non-exertion group (Figure 49). There was no difference in how much they talked before the game, as is to be expected.

"I can't breathe anymore"
"I need a break"
"Look how sweaty I am"
Comments from the participants of the exertion group

It is easy to explain why the exertion group did not talk as much after the game: they played significantly longer than the non-exertion group (Figure 46). In fact, they played so long, that I had to interrupt them so they would have enough time for the questionnaire before the next participants arrived. I had to take their microphones off and tell them that they had to proceed with the experiment in order to stay within a one-hour time slot. The non-exertion group usually finished well within this timeframe. The exertion group simply did not have any opportunity to talk after the game, because they had to proceed with the experiment. I assume if I had also given the players more breaks, they would have talked even more. Breaks were a very fruitful starting point for interaction, and some interesting conversations evolved from them. Unfortunately, the limited time did not allow for too many of these breaks; but a less restricted schedule would probably have facilitated more of these informal interactions.

5.3.12 Natural Leader

Figure 50
The exertion game seemed to bring out the natural leader

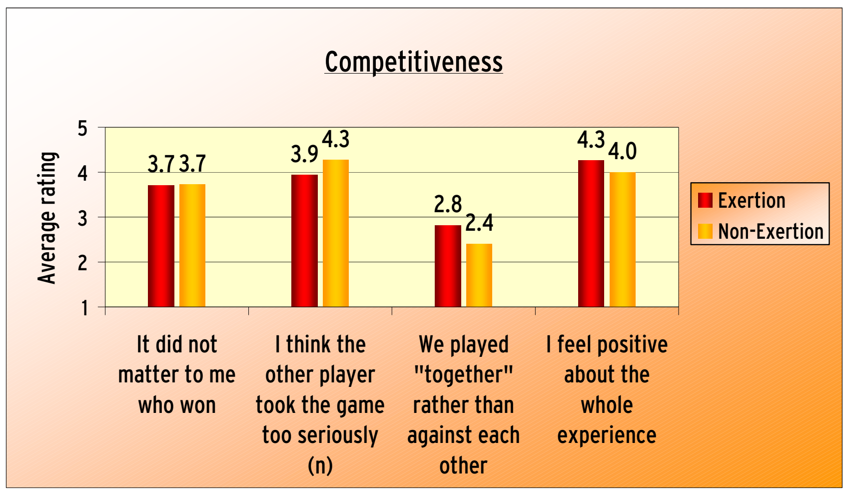


"We made precise agreements on how we would play the game" ($t=-4.99$, $p<0.000005$, unequal variances, two-tail: $p<0.00001$)

"I did most of the talking during the game" ($t=1.70$, $p<0.05$) correlates with "I took charge of the game" ($r=0.36$, $p<0.01$)

The exertion group answered the question "I took charge of the game" more strongly than the non-exertion group, however, the difference is not statistically significant (Figure 50). This group also made more precise agreements on how to play the game, and they said more often that they did most of the talking in the conversations they had, which is statistically significant. This in turn correlates strongly with the question asking who was in charge during the game, resulting in the suggestion that the Exertion Interface brought out the dominance or natural leader characteristic in the players' personalities.

Figure 51 Attitude to game and overall experience



"I think the other player took the game too seriously (n)" ($t=1.82$, $p<0.05$)

"We played together rather than against each other" ($t=1.53$, $p=0.066$, trend)

It did not really matter to the players who won the games, both groups showed almost no difference in answering this question (Figure 51). The exertion group believed that the other person took the game too seriously more often. There was a trend that the exertion group "played together rather than against each other" more strongly than the non-exertion group.

5.3.13 Overall Experience

"I feel positive about the whole experience" ($t=1.74$, $p<0.05$)

In addition to these findings, the exertion group also ranked the whole experiment higher (Figure 51) and felt significantly more positive about the experience. Physiologically, physical activity is known to release endorphins which might have put the players in an affective state of arousal, resulting in a more optimistic view of their surroundings. Hence, the overall heightened positive experience of the exertion group is to be expected.

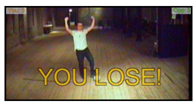
5.4 Prisoner's Dilemma

All participants were given a Prisoner's Dilemma task after playing the game, but before answering the questionnaire. This order was chosen because the results of the Prisoner's Dilemma should be based on the game, and not on the questions. However, this might have created some confusion, because the players had to switch from playing a competitive game to participating in a collaborative activity. One player confirmed this by mentioning that he treated the game and the task completely separately. He said "I did not consider that they had anything to do with each other."

In the exertion group, 15 players put an X on the back of their sheet (44%). This comprises 11 pairs where only one person put an X down (resulting in this person receiving an extra 10 €), 2 teams where both participants wrote an X (resulting in no extra payment), and 4 teams where both players left the page blank (resulting in an extra 5 € for each of them).

In the non-exertion group, only 5 players put down an X (23%). In each case, their partner left the page blank, resulting in an extra 10 € payment for the first player. Six pairs put nothing down, receiving an additional 5 € each and no team had an X on both sheets.

Although more players in the non-exertion game cooperated in this task and did not put an X down, it does not necessarily mean that they felt as if they knew the other person better. For many participants, it seemed to be like another game, where they had to "read" the other player, encouraging a situation similar to playing poker, where they tactically tried to decide whether they should put down an X or not. They saw it more like a game with a competitive component, rather than an indicator for their trustworthiness, reinforced by the competitiveness of the sport. After the interview, some players from the exertion-group commented that they "knew" the other player would put down an X, and that they did not want the other player to get "all the money", so they put an X down themselves. It was not a matter of how to gain more money, but how to make the other player not get more than oneself.



The participants played a competitive game before performing the Prisoner's Dilemma task

In particular, players in the exertion group made comments such as "the other player was so nice, I knew she would not put an X down", putting down an X themselves, just because they were so sure about it. This is an indicator that this group was able to assess the other person and was more confident in predicting her/his future actions. These kinds of statements require increased judgment and insight, however, they are not indicative of collaborative behavior. Having the players play a competitive game (where the winner is the one who gains more points) and subsequently having them perform a cooperative task when they have not had a chance to try cooperating until then, could have influenced these results.

5.4.1 Correlation with the Questionnaire

The results from the questionnaire were analyzed in order to explain this behavior. One would think that participants who play team-sports are more likely to cooperate in the Prisoner's Dilemma game, based on their team experience. After all, the correlation between sport and trust is plausible, and has been previously studied [7]. However, the data does not correlate between the outcome of the Prisoner's Dilemma and the participants who played team-sports.

The participants were asked about their general trustworthiness and how much they trust others, again, the Prisoner's Dilemma outcome did not correlate with the average of these questions (Figure 37), meaning that the more trusting players did not necessarily exhibit more trust in this task. Putting down an X aiming for an additional compensation did also not correlate with the question "I trusted the other player in the game", nor with "The other player could trust me". However, looking only at the non-exertion group, there is a

Correlation in the non-exertion group between Prisoner's Dilemma and "The other player could trust me" ($r=0.55$, $p<0.01$), no significance in the exertion group ($r=-0.02$, $p=0.90$)

significant positive correlation between the Prisoner's Dilemma outcome and this later statement "The other player could trust me". The exertion group shows no significance in this.

These findings may explain the unexpected behavior observed in the Prisoner's Dilemma task. The non-exertion group cooperated in this task according to how much they said the other player could trust them. In the exertion condition however, the player's general attitude towards trust, their own trustworthiness and the trust they bring towards the other player had no relationship to the outcome of the Prisoner's Dilemma task.

Jonas Smith in "The Architectures of Trust" comments quite frankly: "To certain theorists, if people chose to co-operate in a Prisoner's Dilemma, they were not playing the game right" [49].

Only three teams decided to open the envelope while still being in the building. The players were perhaps embarrassed about the outcome, and wanted to keep it separate from their relationship with the other player. This might be another indicator that the participants did not see or did not want to see any connection between the task and the relationship with their partner.

5.5 Ranking of the Interviews

7 independent observers were asked to rank 11 videotapes in terms of how much they think the people in the video know each other or are familiar with each other.

The videos are numbered 1 to 11, and how the observers ranked them can be seen in Figure 52.

Figure 52
Ranking of the interviews

Observer	← know each other more						know each other less →				
1	5	2	6	1	9	4	7	11	10	3	8
2	5	9	4	6	3	1	2	11	7	8	10
3	9	5	1	6	11	7	4	8	10	2	3
4	5	2	11	1	7	6	4	9	3	8	10
5	5	1	2	11	6	9	4	7	8	3	10
6	5	10	2	11	1	3	8	4	7	9	6
7	5	4	6	9	11	7	2	10	1	3	8

Exertion group   Non-exertion group

Almost all observers ranked pair 5 as the most familiar

The observers were not able to rank them consistently, and the interviewee pairs from both groups are equally spread across the whole scale. However, the observers' first choice on the team that seems to know each other best was always a pair from the exertion group. 6 out of the 7 observers chose the same team, and the 7th observer put that particular team in second place. They all agreed that these two players knew each other very well. When being asked how they came to this conclusion, they explained that this team laughed together a lot, seemed to have the same humor, showed a lot of eye-contact, and were generally demonstrating how much they liked each other through body-language.

All observers were surprised when I told them that this pair had met for the first time half an hour before the interview. The Exertion Interface seemed to have had an influence on this team's behavior, facilitating the development of a strong bond between them so quickly that it was obvious even to an outside observer. However, the remainder of the data seems to indicate that the task of ranking the interviews was not feasible, at least for independent viewers. This is not too surprising, considering the players had only met for a short time, and the interviews excerpts were only 4 minutes long, as well as having been subjectively edited, which all could have influenced the outcome.

5.6 Interviews

In addition to the questions asked through the questionnaire, the participants were interviewed to give them a more open format to express their opinion and thoughts. Most of the answers were related to issues that arose in the questionnaire, the comments reported here are additional thoughts and ideas from the participants that have not already been discussed above.

The interviews with the people who played the exertion game lasted much longer than the interviews with the non-exertion players. They seem to be more comfortable chatting freely and interacted longer, showing a deeper involvement.

Many participants reported that they play online computer games, but made a clear distinction between these games and the exertion system. They preferred the ability to see and hear the other person while playing a game to simple text chatting or voice-over-IP technology. They commented that with most computer games, they are so immersed in the virtual environment that they do not want to have a conversation because it might distract them. The ability to see the other person while simultaneously following the game would be preferred by them.

Both groups praised the big screen projection and attributed the success of the game to it. As one participant commented: “The exertion would not work if you would play it on a regular screen.”

There were quite a few people who said that they do not like computer games, because “they are just not my cup of tea”, but that if these games had an exertion component, as demonstrated with the Exertion Interface, it would be a different experience: “For a game like that, that has a competitive edge, I’d say a ball there and you actually running around doing something, you’d feel like more competing than just pressing a button because it seems very remote and clicking, but if you are running about and doing something it will immediate spark much better than, for me anyway because I am used to playing sports." This confirmed the heightened feeling of competitiveness in the exertion group. A player of the non-exertion group suggested the following: "If you were running about, it would imitate sport much better".

One participant commented that a system like the exertion game could be used to introduce technology like video-conferencing to underdeveloped communities. She mentioned her home country, Mexico, where people might be hesitant towards technology and uncomfortable using it; however if they could play soccer with a famous soccer player using such a system, they would all line up to do so.

Another player commented that the exertion game also gave a good opportunity to level out players in terms of their skills. If one person cannot kick the ball, she or he can just throw it. This way sports enthusiasts who would normally be too different in their abilities could play together.

Most players, especially in the exertion group, said that the limited video quality did not bother them; one participant actually said that she liked it this way. Not being able to see the other person perfectly prevents one from getting too exposed and can hide embarrassing moments that might occur during the game. She liked this because she was able to "hide" behind the compression artifacts. Another player commented about the fact that the smell of sweat luckily does not get transmitted.

One participant mentioned that he would like to see such a game in a bar, allowing him to play with friends who could not be there.

Another participant, who played the computer game, wanted to add a physical component: "Make it more interactive, if you could move your hands, for example." The non-exertion group commented several times how beneficial a prior meeting would be: “It would be very good if the people playing would know each other beforehand.”, or “If you’d meet the other person beforehand, it would be more competitive.” The exertion group, however, did not make such comments as much, showing that they were able to emulate such an encounter through the game.

Almost all of the players in the exertion group were very exhausted after the game. Most of them told me that it was much more exhausting than they thought it would be in the beginning. Indeed, the game can be very demanding and fatiguing. The reason for this is because there are no opponents or teammates to wait for and there are no scheduled time-outs. Only when both players agree on a break, they can have one. Some of the participants commented on this and said the reason why they did not talk more was because they were simply out of breath.

5.6.1 Ideas from the Participants

One of the most common questions participants of the exertion condition raised during the study was whether the ball had to be kicked or thrown. We left this decision to the player, as it seemed likely that some people would be more comfortable with throwing a ball rather than kicking it. This sparked many ideas from participants: they came up with highly entertaining and creative ways to strike the ball against the wall. Most people threw or kicked it, using both or only their weaker/stronger arm or foot. This method was often employed to level out players with different skills. Some players also came up with rather unconventional ways to throw the ball. Several players decided just to head it against the wall, others used bump, set and spike from volleyball. Some players used a line on the floor to mark a minimum range from which the ball could be kicked. Others hit the ball with their fist only, and another team tried throwing the ball while sitting on the floor, which appeared to afford them a great deal of amusement. Yet more entertainment was generated when they threw the ball through their legs, facing the opposite site of the wall.

Volleyball over a Distance

Figure 53
Breakout for Two 2 played with 4 players

The other team

Some participants wanted to play two on two, which turned out to be very engaging (Figure 53). Playing in a team of two seemed to encourage the interaction with the remote end even more, because the game had to be coordinated among four players. Playing with two balls on each side was even more entertaining and created a very fast paced game, which was favored by the very athletic participants. Nevertheless, all of the participants sweated a lot and exerted themselves greatly as they confirmed while standing next to the water-cooler after the experimental session ended.

5.7 Recommendations for Future Exertion Interfaces

The study revealed some particularly interesting results, some of them were rather unexpected. These outcomes, combined with the comments from the interviews, laid out the basis for the following practical recommendations that seem essential for the design of any future Exertion Interfaces.

Guidelines for future Exertion Interfaces

Allow for body language and non-verbal expression by using a large screen.

Give the players enough time during and after the game to interact.

Protect everything. If equipment is not protected, the players will break it.

Allow for serendipitous games by making it very easy to start playing.

Add sound effects.

If one designs an Exertion Interface, the audio and video quality will not be of uppermost importance for the users.

However, the audio quality needs to be sufficient for conversational speech.

Consider the various positions of the players in the design of the audio setup.

Provide water.

5.8 Summary

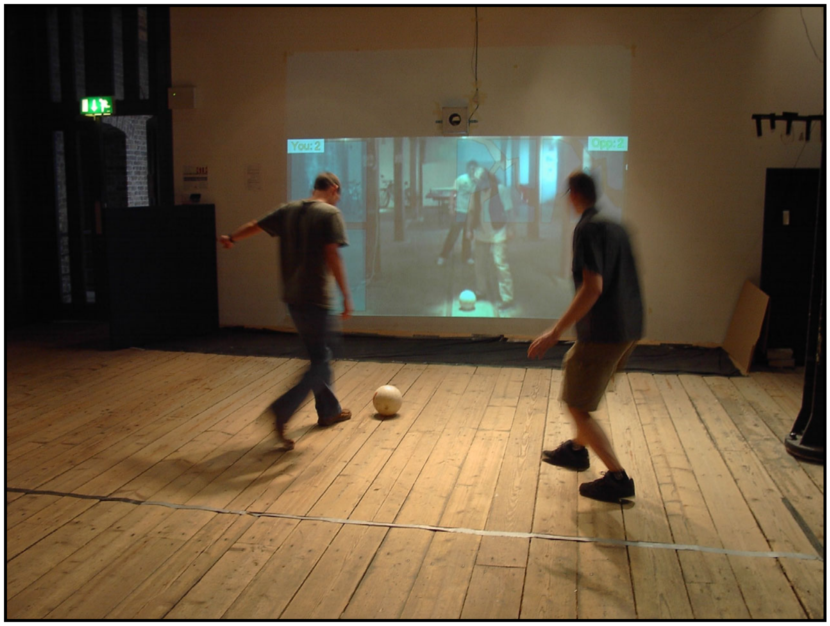


Figure 54
Playing two on two

This chapter presented the results from the experiment. It reported the numerous significant results from the questionnaire showing improved bonding between the participants in the exertion group. The Prisoner's Dilemma task did not prove to be a valuable indicator for increased trust or cooperation. There were no significant results in the ranking of the video assignment. On the other hand, the interviews revealed valuable insights into the potential of Exertion Interfaces. The experiment also suggested new ways the game could be played, such as two on two.

Discussion and Conclusion

»In a few years, men will be able to communicate more effectively through a machine than face to face.

Licklider & Taylor, 1968

6 Discussion and Conclusion

What can an Exertion Interface teach us? How does it fit into the bigger picture of computer mediated communication? What does Sport over a Distance lead us to?

6.1 Discussion

Figure 55 Sport over a Distance

The aim of this thesis was to determine if a sports environment could be a valuable augmentation of what current collaborative tools try to accomplish in terms of social interaction. I postulated that if a game or interaction requires some physical activity, it would be better at supporting people getting to know one another and fostering bonding between them than an interaction that lacks it. If a game like this augments the interaction with an engaging activity involving both participants, it will support this communication.

A questionnaire about social games in the workplace confirmed that games have an impact in bringing people together, and gave initial insights about their potential.

However, these games typically require the players to be in the same location, and fall short in connecting people over a distance. Telecommunication technologies, on the other hand, are very good at bridging large distances, but are mainly designed with the practicalities of creating the technology in mind, rather than the quality of the resulting interaction. Combining the strengths of both, the ability of sports to connect people socially, and the ability of telecommunications to connect people over a distance, leads to the idea of Sports over a Distance.

However, this does not imply that social interaction in local sports clubs needs to be replaced. Rather it is envisaged that Sports over a Distance steps into the areas where current social games are lacking. It could maintain bonds between people which might otherwise fade as they geographically moved apart, and in turn, these social interactions might lead to introductions to new people.

Sports over a Distance is not meant to replace or necessarily be as good as local games either. For example, a parent might desire to play with her/his children in person, but if business requires the parent to travel, a set-up room in a hotel enabling the parent and child to kick a ball together would be the second-best thing to the parent being present.

6.1.1 Exertion Interfaces

Combining sports and telecommunication requires the creation of a new interface, which I define as an Exertion Interface. Such an auxiliary interaction interface facilitates social interaction through intense physical effort, and is expected to be exhausting if used for a sustained period of time, encouraging the improvement of specific athletic skills.

6.1.2 Lessons Learned from a Technical Viewpoint

In order to test the hypothesis, I built an example of an Exertion Interface. The system allows two players to play a ball game over a distance, and requires physical effort. The design of the system leaves the two players with the impression of being on two halves of a field, separated by an oversized glass window. They are able to see and talk to each other, but cannot be in physical contact. This setup allows for a clever alternative to expensive but imperfect force-feedback and virtual reality hardware.

As part of the system, a new detection technology was developed that measures the impact of a ball on a wall and determines its location and intensity. The ball itself is not altered in any way, and is independent from the detection technology, resulting in a universal design for many ball sports, such as soccer or tennis. Two alternative detection systems were developed, one audio- and the other video-based. The audio solution uses the speed of the sound travelling through the wall as a measurement of the impact, the video solution deploys image analysis to determine the location of the ball. The audio solution extends the work of the Tapping Window [62], which determines soft knocks, by detecting the very loud bangs created by a ball hitting a wall. The video-solution showed that an image-processing approach is scalable to the use of very large walls as playing areas. It proved useful to have two different setups to compare: the audio solution showed better detection rates, especially in regard to the intensity measure, but the vision detection solution demonstrated greater flexibility, although it required more sophisticated and expensive equipment. Both technologies provided more than sufficient detection rates for a sports game and were very robust and reliable.

Alternative technologies to detect an impact of a ball would be possible, for example through touch sensors on the wall, but most of them would not be robust enough to withstand the enormous strength of the impact of the ball against the wall.

The video-conferencing software adjusts to various bandwidth conditions and is designed to be independent from the detection technology. The video cameras capture the entire playing field, allowing for body-language in the interaction, and the result looks quite remarkable when projected onto the wall. The audio setup initially created some difficulties, with feedback being a constant problem. Players running around chasing a ball in a big room, varying their distance to any fixed microphone constantly, presents a challenge for recording audio. An additional problem is the background noise of the players' footsteps and the noise of the bouncing ball. Clip-on microphones overcame these issues, but limited the chance of serendipitous encounters, because both players had to put them on before they can play.

The game engine works independently from the detection system and connects over a common protocol. This makes it easy to change between different games that deploy over the Exertion Interface. The system demonstrates how it supports competitive and collaborative play via several games. They have been tested informally, but not all have been tested under experimental conditions. The separation of the game engine from the detection technology makes the system a universal platform for experiments with Exertion Interfaces.

6.1.3 Lessons Learned from the Experiment

6.1.3.1 Questionnaire

The questionnaire revealed many statistically significant findings between the exertion and non-exertion group. The main conclusions regarding social interaction were that the exertion group indicated:

- they got to know the other player better (5.3.4 Social Bond)
- they believed that the game created a stronger social bond between them (5.3.4 Social Bond)
- the other player seemed to become a better friend (5.3.5 Friendship)
- the other player could trust them more (5.3.6 Trust)
- they were happier with the quality of the video-conference (5.3.8 Video-Conferencing Quality)
- they perceived the other player more conversational in comparison to the non-exertion group (5.3.10 Conversational)

The players who played the exertion game also stated that they

- had more fun with the game (5.3.7 Fun)
- liked the game more (5.3.7 Fun)
- played longer (5.3.7 Fun)
- and felt more positive about the experience (5.3.13 Overall Experience).

The exertion group mentioned that they had more fun playing the game; the simplistic nature of the game was made more interesting by the skill of kicking a ball. The non-exertion group played the same game; however, the keyboard-based interaction might require a different kind of game for the players to enjoy. Having the non-exertion group play a commercial computer game could be an alternative, but the interaction modalities would be different, making them a non-viable control group. The exertion players showed their increased enjoyment by playing longer than the non-exertion players, and they also stayed longer during the interviews.

In addition, the exertion group did not feel as limited by the technology as the non-exertion group; they were less worried about the limited video and audio being transmitted. This is reasonable, because they had a better opportunity to read the other participants' non-verbal expressions. For instance, the ability to express body language and physical fitness through an interface seemed to have created a stronger impression regarding the user than a simple keyboard interface does. "The less precision there is to a message, the more information it may convey about the transmitter." [49] An additional reason why the exertion group perceived the video-conferencing quality as being better than the non-exertion group could be the increased connection between the exertion players.

However, it should be noted that although both groups were using the wall-sized video-conference, the non-exertion players were sitting behind a desk, limiting their view of the other player. In the exertion game, the players were moving around, and could be viewed from different angles by the camera. They were also more occupied with chasing a ball, and not constantly looking at the screen.

Participants in the exertion group explained during the interviews that they would have talked more during the game if the game had been less intense. The game required a lot of physical exertion, and it appeared that some of the participants were simply too exhausted to have a more in-depth conversation. Moreover, they also said more often that their partner seemed willing to have a conversation, than the players in the non-exertion group did.

These findings probably relate to the increased arousal state, which corresponds to stronger emotions of enjoyment, frustration or anger, causing the players to speak louder. The bouncing ball also added to the background noise, forcing the players to speak up. This may provide a further explanation of the difference in perceived video-conferencing quality.

The competitive nature of a physical game seemed to bring out the natural leader in the participants more, for example they thought that they were the dominant talker more often than the non-exertion group did. Although the game featured competitive activity, the players agreed that they played together, rather than against each other, with a significantly higher agreement from the exertion-group.

6.1.3.2 Prisoner's Dilemma

The Prisoner's Dilemma task did not turn out to be a valid measurement for interpersonal trust between the participants. Although the questionnaire data revealed participants in the exertion condition were more certain that their game partner could trust them, the Prisoner's Dilemma showed the opposite. Three reasons might explain this. Firstly, the participants had to change from a competitive game to a collaborative task. Secondly, they regarded it as a completely separate issue, which they did not associate with the physical game. Some participants confirmed this during the interviews. Thirdly, the participants were "hyped up" by the physical competition, eager to compete, and played a poker-like game with each other, where they were trying to predict the other person's future actions in order to win more money. Rotter labeled this behavior "special reactions to these laboratory situations which are highly competitive in nature and are specific to these situations, or at least have limited generality". He concludes that the "…situation is reacted to by many if not all subjects as a competitive game…" [76].

It might also be possible that a game which was played for about half an hour is not enough to create an interaction history. As Smith points out based on Axelrod's analysis, "Bob must know how Alice acted in earlier interactions in order to assess the situation and plan his strategy" in order to create a situation in which it is rational to cooperate [49]. The players also knew they would probably never see each other again, hence a multi-round Prisoner's Dilemma might have been more appropriate.

6.1.3.3 Interviews

The interviews strengthened these findings. It was valuable to see confirming statements in a more open format than that allowed by the questionnaire. The players confirmed the proposal that the exertion game helped them to get to know each other better. Players in the non-exertion group (ignorant of the exertion condition) even mentioned that some physical activity would have helped them create a closer bond with the other person.

Physical exercise alone might influence the outcome of experiments, and could be independent from the interaction. The results from the questionnaire and especially the interviews however, showed that the exertion players had a much higher involvement in the interaction during the game, as well as a greater awareness of the other player.

Participants also reported their experiences with playing online games, and drew comparisons. While the non-exertion game could not compete with current state-of-the-art computer games, participants said they would like to see a similar video-conferencing system being deployed in these games. They suggested that being able to see the other player, and playing a game in a layer on top of this, would make the interaction more appealing.

Whether people prefer computer games or physical games depends on the situation and the personality of the player. Not everybody will like participating in a physical game, regardless of whether that game is played over a distance or on the same court. An Exertion Interface, however, gives these different characters the option to play with somebody remotely. One participant stated: “Computer games are not for everybody, they are certainly not my cup of tea, I prefer sports”.

6.2 Results Overview

The experiment confirms that an Exertion Interface can work more effectively at connecting people socially over a distance than a traditional interface. The study shows that the players in the exertion-group got to know each other better and created a stronger bond with each other than the non-exertion group.

The design was based on the concept of a game, and compared two different interfaces for this game. There are many more alternative ways to try to connect people over a distance, which would also be interesting to see deployed with an Exertion Interface.

The increased social bonding and perceived connectedness can provide valuable augmentations for experiments such as those done by Rocco [81]. Instead of comparing text-chat with audio- and video-conferencing, a system like Breakout for Two could offer an additional experimental condition. The findings show that we came a step closer to solving the problem of “short of sight, out of trust” [81].

Social relationships are hard to quantify, which makes evaluating systems that support these interpersonal connections very challenging. However, the measures performed here revealed valuable insights and shed some light on how first encounters can be influenced by an Exertion Interface. These measures could be easily performed on several other connected physical interfaces, such as the Tug-of-War [40] or Snowwars [47].

Also, the experiences of connecting physical interfaces, as demonstrated with Breakout for Two, could be used to link currently single-user interfaces, like the robotic foosball table [34].

Social games could also be a valuable add-on to the concept of media spaces, augmenting them with a physical component. A system like iCom [5] would not only support serendipitous conversations, but also provide a reason to communicate in the first place. After people met through playing the game, they could use the same system later on to discuss work-related issues, for example.

Either adding an Exertion Interface to a networked game, or a network to a physical interaction, would release a potential for social interactions between the participants. More studies are needed to investigate the social impact of these different approaches. Results from this could lead to further insights into the design of future Exertion Interfaces.

6.3 Suggestions for Future Research

6.3.1 Multiple Game Stations

An obvious extension to the current research is to support team sports, extending the current approach where you can play two on two. Additional game stations could be easily added, especially because the software architecture is already scalable in this regard (Figure 56). The separation of the game engine from the detection system makes this augmentation effortless, and having the same game software running on all stations allows for easy controlling and updating of any new game.

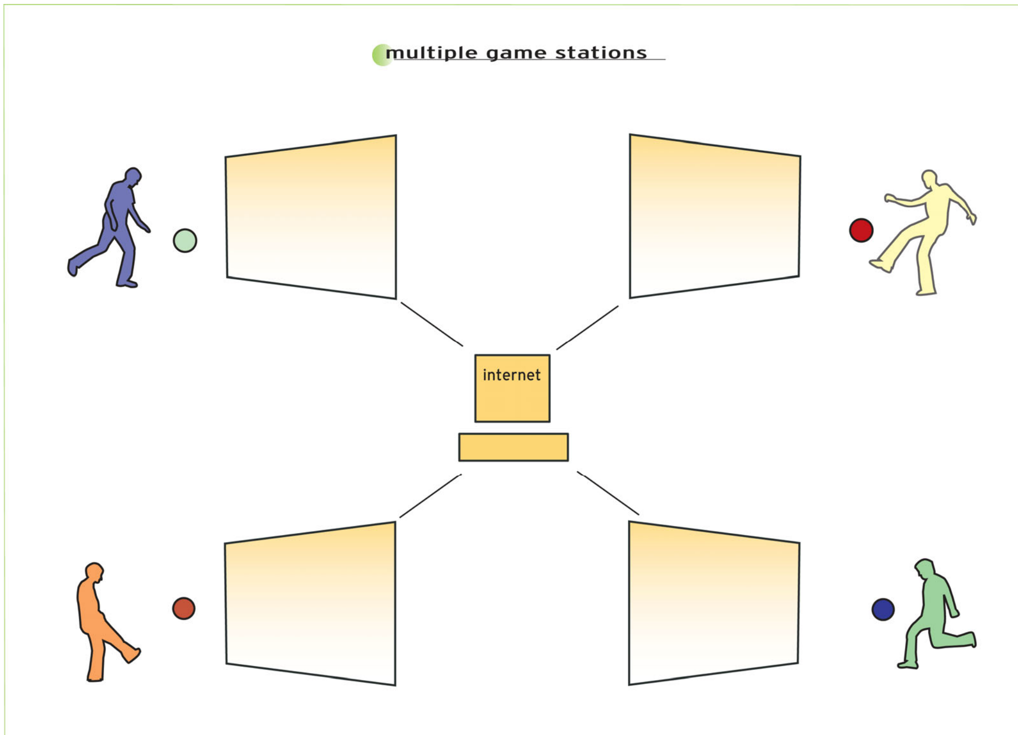


Figure 56
Adding additional game stations

A more challenging task would be to integrate multiple game stations into the video-conference. The use of multiple windows would probably be too "computer-like" and would not really support the idea of being together. Adjustable window sizes such as those in the iCom system [5] could address this issue, but extracting the players from the background, followed by overlaying multiple players together as in Reflexion [82], may be more promising because it would allow for a more natural representation of the participants. The ball would also need to be extracted, and probably colored to be identifiable to a certain gaming station, because as participants noted, it is important to "see what the other player is doing".

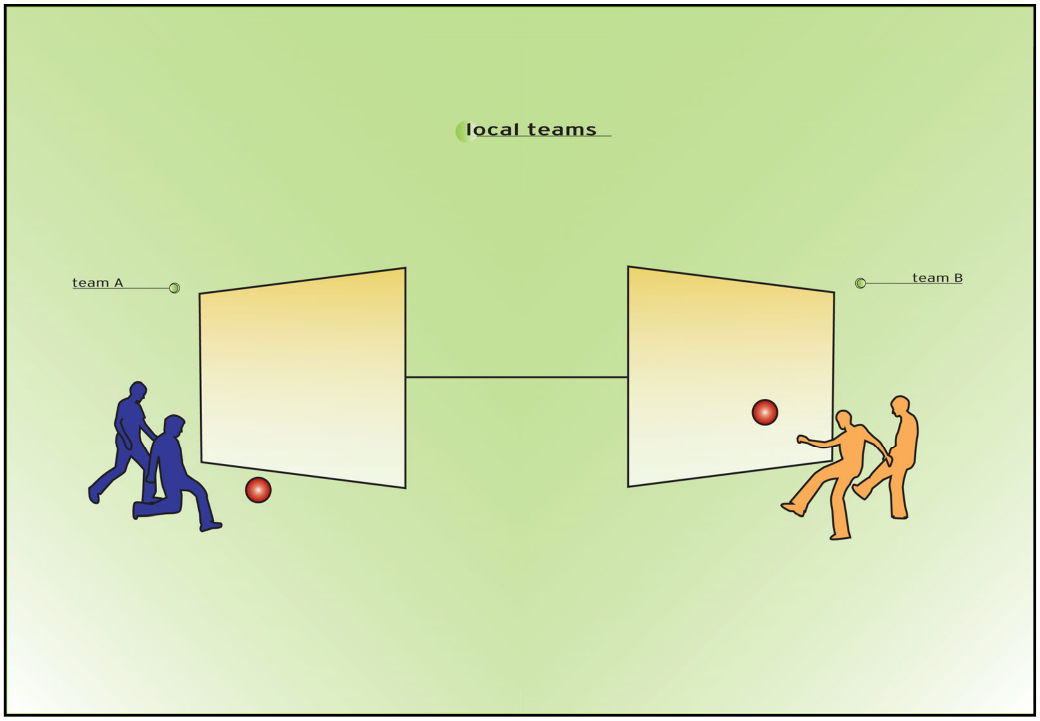


Figure 57
Two on two with local teams

6.3.2 Your Teammate is in a Different Country, but Your Opponent is Next to You

An interesting avenue for research would be to investigate how supporting remote teams in an exertion setting would differ from supporting local teams, playing simultaneously (Figure 57). One possible mechanism for supporting remote teams is shown in Figure 58.

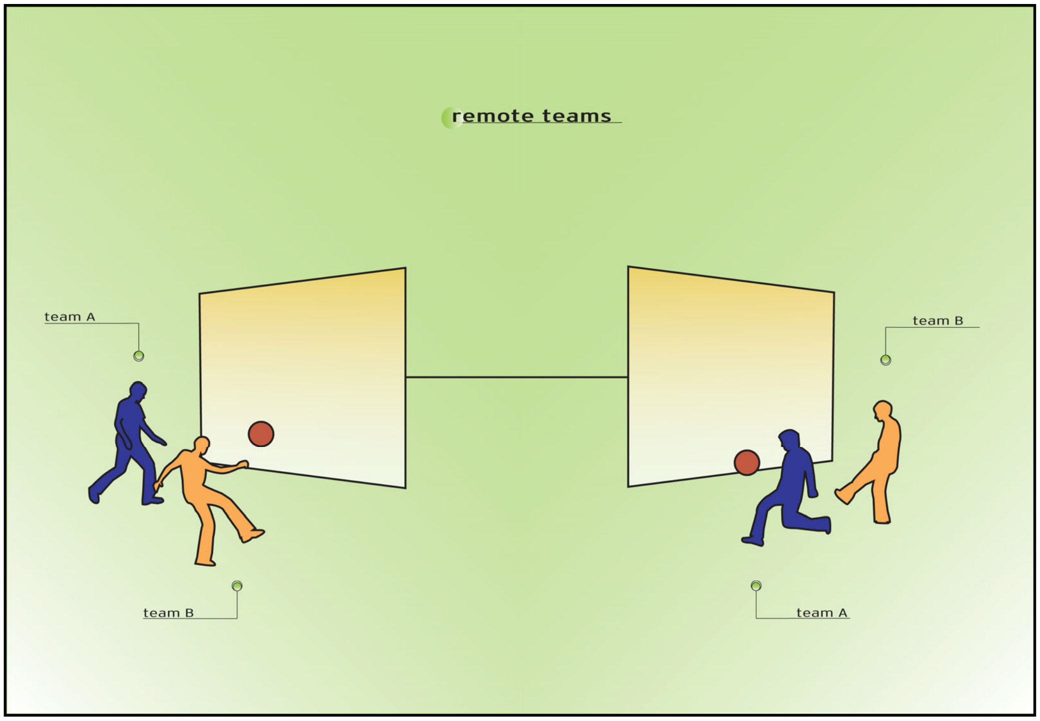


Figure 58
Two on two with remote teams

Four players would play a two-on-two game. In the current implementation, the two players in one location would have to be on the same team. What if this did not have to be the case anymore? Imagine playing a game with your teammate situated far away, perhaps in a different country, but your opponent playing right next to you. How would the interaction differ, and how would bonding change if you introduce teams in this way? How would distance relationships evolve differently if they were created by playing against each other versus together?

6.3.3 Long-Term Effects

Another aspect would be the investigation of long-term effects on the players. Many factors are critical before a complex connection like friendship can be established between individuals, and a large dataset would be necessary to reliably trace such an occurrence. Based on the presented results, however, there is reason to believe that an exertion interface could be a supportive framework for this. It would be interesting to see if the volunteers, who have never met before, and were not asked to meet again, have indeed met up subsequently, whether by chance or on purpose. These post-game interactions could be studied and easily compared to the non-exertion control group. Another interesting approach would be the study of existing relationships. How could an Exertion Interface maintain or improve friendships between two people? For example, the relationship between friends who had just moved apart geographically could be observed. One group could play an exertion game on a regular basis, while the control group would communicate via video-conferencing alone. Do these relationships change differently over time?

6.3.4 Zoomed Attention

In addition to the obvious improvements that are inherent in any video-conferencing system - better audio and video quality - more sophisticated video presentation might be worth investigating. Many participants in the study commented that it was very hard to see their opponent’s facial expressions. Establishing eye-contact could be troublesome due to the limited video resolution. One way to address this issue would be to zoom in on the player. However, the player is not stationary, but moves around. Intelligent tracking of the player’s head, however, might allow a movable camera to follow an individual player and capture a high-resolution image of her/his face with all its details. This image could then be superimposed over the low resolution head, taken from the wide angle camera. Alternatively, the head could be magnified and projected onto the wall, disregarding the rest of the image. This would allow investigations into how important other aspects of body language are in the case of sports. However, the other player’s actions and the ball would still need to be displayed. An intelligent compromise would be needed that takes both requirements into account.

6.3.5 Separating Sports into its Pieces

The possibility of controlling the visual and audio space between the players creates great opportunities for future research on the individual components of sport. For instance, how important is the ability to hear your opponent, compared to being able to see him?

The current implementation allows adjusting compression parameters to allow for bandwidth limitations, but this could also be used to vary the proportion of each component transmitted. How does the interaction change if clear video is transmitted, but the audio is distorted to feature only barely-distinguishable sounds? A suggestion was given by the participants of preliminary tests. They agreed that the sound quality was essential for their interaction, and demanded high quality. Transmitting exceptionally good sound, yet poor image quality, might not be a hindrance, but a desired effect. One participant commented that it was good not being able to see the other person properly, because it can prevent embarrassment for failed actions during the game. This particular player was relieved that not every detail was visible and felt more secure and confident in playing a new sport because of that.

6.3.6 Modifying Transmitted Components in Real-Time

Separating two players of a sports game in autonomous locations connected only through a network does not only serve the obvious goal of being able to play together over large distances. The interaction's audio, video, and physical component are all in digital form, and therefore capable of being modified by a computer in real-time. If played outdoors, for example, fog on one side could severely handicap one particular player (see golf) but not affect the other. The transmitted video data at the other side could be digitally modified with a "fog add-in", which would overlay rendered fog to equalize the limited visibility for both players.

6.3.7 Adjusting Players' Skills

More sophisticated manipulation of the transmitted data makes it possible to adjust the players' skills in order to find a common level for both players. In traditional sports, better players can be handicapped to allow for a more enjoyable activity for both players as well as the spectators. The better player accepts a handicap, as in golf, where the concept of a handicap is an essential part of the game. In other sports, such as running or horse riding, carrying extra weight limits the better player in terms of strength and flexibility, making it easier for the opponent.

These limitations, however, are cumbersome, have to be determined before the game, are non-adjustable after the game started, and constrain the better player. This player's abilities to participate in the game appropriately are restricted, and so she/he might not be very satisfied. Having the interaction in digital form allows for the reverse action: instead of making the stronger player weaker, it is possible to make the weaker player stronger. For example, the strength of the impact of the ball could be slightly increased during the transmission process, giving the weaker player the ability to hit "as hard" as their opponent. Another option would be to extend the tolerance area on which the targets need to be hit for only one player. This would give this player a slight advantage to compensate for deficits in other areas. Unlike real handicaps such as weights, heavier balls or modified rackets, these digital modifiers are adjustable in real-time. This would allow adjustment to the players' strength, helping the game to always be challenging for both participants.

This, of course, raises many issues on the nature of competition itself. Is it still a sport if the players' capabilities can be modified by a machine? Technology is commonly used to enhance a professional player's capabilities. How would its application differ if used in a social setting? Would it be welcomed by the players, or would they feel manipulated by a computer? Can these adjustments be made so gently that they will not be noticed? What if they are detectable?

A participant of the exertion experiment commented that he thought the game was modified, and that he was being tested on his ability to play a rigged game. The reason for this could be the experimenter effect; although the observer tells the participants that their score does not matter, they often believe they are being assessed. Alternatively, this could indicate that people are very suspicious of their own performance, especially if judged by a machine. This is not surprising, if one recalls the many discussions tennis players have with referees about the decisions of the "electronic eye", a technology that detects whether a serve was legal or a fault [83].

Thorough investigation will be necessary to see how spontaneous modification of a player's skill changes the nature of the sport. It is easy to believe that the results would vary for different sports, for individual and team sports, and for social, collaborative and competitive play.

A system like Breakout for Two can serve as an initial starting point for further investigation in this field and the variety of sports available will demand many more creative ideas in order to get to the core of social play and sports.

6.3.8 Further Studies

Further studies could reveal more insights into the effects of an Exertion Interface on social interaction, especially if compared with people meeting face-to-face. Participants meeting locally could be given a fun physical game, which they play together, right next to each other. These players would probably bond more quickly and to a greater extent than they would if they have met over a distance. Finding out a quantifiable difference in how these interactions progress could be very valuable to the improvement of Exertion Interfaces. However, this would be very difficult to measure, simply because relationships are hard to quantify and evolve over long periods of time.

6.4 Conclusion

This thesis has defined an Exertion Interface, and shown that it can provide a valuable augmentation to what current interfaces try to accomplish in terms of social interaction. I demonstrated that distance communication could be improved through the addition of information in another modality, by developing a system that allows Sports over a Distance. This system supports two players playing a game by throwing or kicking a ball against a wall, although they might be miles apart. Experiments with the system demonstrated that participants who played Sports over a Distance reported a significantly greater social bond than players who used a keyboard interface. The users of the Exertion Interface also said that they had more fun and rated the overall experience higher.

The addition of an Exertion Interface to currently available interface designs opens the door to another world of social interfaces. This interface is not designed for a wide range of applications, where traditional keyboard interfaces are much more suitable (e.g. word-processing and programming), but in supporting social interactions, an Exertion Interface is advantageous. This approach moves in the opposite direction to most other current interface design trends, because although it is easy to learn, an Exertion Interface requires skill and strength, and is hard to master.

An Exertion Interface supports people connecting with one another, whether they are friends or have never met before. Players use the universal language of sports to come together, and they now can do this with people situated on the other side of the world.

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8 Appendix

8.1 Prisoner's Dilemma

Attention!

You have a chance to increase your payment for this experiment. Here is the deal:

You have the choice to draw a big X on the back of this sheet.

If there is an X on your sheet, and NOT the other person's sheet, you get another €10. Of course, if the other player has an X, and you don't, she/he gets the 10.

If each of you put nothing on your sheets, each of you gets another €5.

BUT if there is an X on your sheet AND on the other player's sheet, you will both receive nothing extra.

We will look at your decision later. We will not tell the other player what you did, nor will we tell her/him how much we paid you.

8.2 Questionnaire

Questionnaire

Thank you for participating in this study. Please take a few minutes to complete this questionnaire. We are interested in your thoughts and opinions, there is no right or wrong answer (except the year you were born). Please answer all questions as thoughtfully as possible, paying special attention to the different characteristics called for in each description. You may find the task difficult but we hope you will take it seriously and do the best you can. Please feel free to use the full range of responses. Your answers are completely confidential, so please answer honestly.

You are

☐ female ☐ male

In which year were you born?

19 ☐

What is your highest education level?

☐ primary school ☐ secondary school (High school) ☐ University (Undergraduate) ☐ postgraduate education

How often do you play sport?

Four or more times a week	Two or three times a week	Once a week	Once per month	Less than once per month or never
☐	☐	☐	☐	☐

I use the Internet...

everyday	every other day	about once a week	about once a month	less than once a month or never
☐	☐	☐	☐	☐

Me and the other player exchanged contact details.

Yes	No
☐	☐

1

Please rate yourself on how trustful you are.

Much more than the average person	More than the average person	Like the average person	Less than the average person	Much less than the average person
☐	☐	☐	☐	☐

I had fun playing the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

You can rely on most people to do what they say they will do.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I did not get along well with the other player.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

Me and the other player made plans to meet each other again.

Yes	No
☐	☐

Do you play any team-sports?

Four or more times a week	Two or three times a week	Once a week	Once per month	Less than once per month or never
☐	☐	☐	☐	☐

I did not play the best I could in the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

The other player did not seem to be interested in having a conversation.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

2

The other player seems friendly.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

Most salespeople are honest when they describe their products.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I am familiar with using video-conferencing.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I find this kind of technology interesting and I am willing to use it.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I got to know the other player.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

When dealing with strangers, it is better to be careful until they have shown that they are trustworthy.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

Although we are informed through radio, newspaper and TV, it is still quite difficult to get an objective account of events.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I would not give the other player my phone number.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

3

I trusted the other player in the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

The audio quality was sufficient for me.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

The video quality was sufficient for me.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I would give the other player my email address.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

We did not talk as much as we wanted because of the video quality.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

If the other player invited me to her/his birthday party, I would feel comfortable going.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

Rigging/Manipulation is common in many bigger sport events.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

Based on what I know about the other player, I believe
the other player would keep a promise, even if it is a hard one.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

4

I was not able to see the other person properly.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

If I were buying a second-hand car, and the other player was selling one that matched my requirements, I would buy it from her/him.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

During the game, I kept the strategy I started off with.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I remember who won most of the games.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I wanted to play longer.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

It was not always clear how to play the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I think the other player took the game too seriously.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

The other player became a friend.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

5

I experienced some delay in the video-conference.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

If yes: This delay was disturbing.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I experienced some delay when I hit the blocks.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

If yes: This delay was disturbing.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I feel positive about the whole experience.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

We made precise agreements on how we would play the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

It did not matter to me who won.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

The other player did not seem like a nice person.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

6

I would like to be friends with the other player.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

It was more a social game than a sport.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

We talked a lot during the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

The other player could trust me.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I liked the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

The game created some sort of social bonding between me and the other player.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

We did not talk as much as we wanted because of the audio quality.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I took charge of the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

7

We did not talk a lot after the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

We did not talk a lot before the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

If I lent the other player money (EUR 100), I would not feel confident I would get it back in time.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

We played “together” rather than against each other.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

I did most of the talking during the game.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

How many rounds did you play (excluding practice rounds) ?

☐

8

8.3 Open-ended Questions

Please answer the following questions together. Feel free to discuss and express your opinion. We will videotape your answers, so we can review your comments. Please feel free to ask questions, tell us what you think, what we can do better ...
Again, thank you very much for your cooperation!

Would the interaction you had with the other player be different if you were playing in the same location?

Would you have played the game differently if you were in the same location?

Did you develop any strategies for playing the game? What were they?

Do you think exertion interfaces like this would be better for getting to know people than mouse-keyboard interfaces?

Did you want to play longer? If so, why?

Did you like the game?
Did you like the idea? The setup?

What could we improve?