Chapter VIII
Computer Supported Collaborative Sports:
An Emerging Paradigm

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ABSTRACT

Augmenting existing sports experiences with computing technology is increasingly gaining attention due to its potential for performance enhancement. However, most of these approaches focus on existing single-user activities. The authors are presenting the newly emerging field of Computer Supported Collaborative Sports (CSCS) to draw attention to the social aspect of sport and its potential to support novel experiences for players that are not available in traditional sports environments. They discuss important dimensions in the design space of CSCS by detailing two example applications and lay out further research directions for the design of collaborative technologies in computer augmented sports.

INTRODUCTION

Computer games have turned into a popular form of entertainment. An increasing number of people are playing computer games, making it one of the most rapidly growing leisure activities. When asked for the most fun entertainment activities, 35% of Americans mentioned computer and video games outranking alternatives such as watching television, surfing the World Wide Web, reading books, or going to the cinema (IDSA). Since their introduction, computer games have fascinated its users and drew people's attention. However, the success of computer games has been watched critically. Controversial game content, social isolation of players and the promotion of sedentary lifestyles are major concerns with regards to computer games.

Quite a number of computer games deal with shooting or killing activities. An often expressed criticism in regard to this type of games is based on the assumption that killing activities within games will lead to an increased aggressive behavior in daily life (Rauterberg, 2003). While empirical investigations with regard to this hypothesis show heterogeneous results (Fritz & Fehr, 1997), the design of ethically less questionable, but equally fascinating game content can be a challenge.

Critics have pointed out that intense use of computer games may lead to social isolation of the players (Provenzo, 1991). However, social arrangements such as playing single user games in a group or LAN (Local Area Network) parties where multi-user games are played in physical proximity can compensate for this problem. Some computer games address this issue by allowing playing together across geographical distances.

Another problematic issue with regard to computer games is the lack of physical activity when playing – in stark contrast to the 'physical' content of many games: most game content involves muscled heroes who perform intense exerting physical activity, quite different to the player in front of the screen. The typical input devices of computer games are game pads, keyboards and mice, unsuitable for promoting physical activity. Output is typically provided to the players by auditory and graphical means (e.g. loudspeakers and screens). The research area of Ubiquitous Computing has begun to introduce new input and output technologies which are also applicable for games (Björk, Holopainen, Ljungstrand, & Mandryk, 2002). Some approaches have taken sportive activities like skateboarding and karate as a platform and augmented them with information technology. By doing so, existing sports activities can experience an additional 'game content' (Ishii, Wisneski, Orbanes, Chun, & Paradiso, 1999; Mokka, Väätänen, & Välkkynen, 2003; F. Mueller, Agamanolis, & Picard, 2003).

With our contribution, we want to get one step beyond by further integrating computer games and computer augmented sports. We postulate the approach of Computer Supported Cooperative Sports (CSCS). By leveraging innovative input and output technologies we believe we can offer users new experiences in shared computationally augmented game environments.

OVERVIEW

This article is structured as follows: First, we will present related work in computer games that use augmented sportive interfaces. Then we will outline the concept of Computer Supported Collaborative Sports. Two prototypes of this design paradigm will be presented: the FlyGuy offers flight experiences in shared 3D spaces and Table Tennis for Three offers tangible game play in a mixed-reality environment for three distributed players. We will conclude by discussing our findings in regards to future applications of the design space and the role of CSCS for emerging distributed sports activities.

Ubiquitous Games and Computer Augmented Sports

Ubiquitous computing offers a relatively new approach of interacting with computers through real world objects and spaces, which can provide novel opportunities for innovative games and physical experiences. For example, the 'STARS' environment offers a platform to implement different board games on a computer augmented table. Real world objects, such as chess figures, can be moved on the board and their positions can be tracked. Based on this input, a game engine can compute appropriate output behaviour (Magerkurth & Stenzel, 2003). Based on similar input technologies, Harvard and Lovind (Harvard & Løvind, 2002) have developed toys based on a rather different conceptual idea. They try to encourage storytelling by moving away from the computer screen and take physical objects (typically simple plastic toys) as an interface that permits the exploration of the quirks of a story. Stories can be recorded and attached to different toys and their actual position.

A different approach is taken by Sanneblad and Holmquist (Sanneblad & Holmquist, 2003). They distribute a game area onto several handheld computers in a way that the whole area can only be seen by means of all the different displays. The players have to move towards each other to perform gaming activities, e.g. controlling Pac-Man in the classic arcade game in those parts of the game area which are not represented on their personal handhelds. In this case physical activities of the players result from the need to see the entire game area.

Other approaches record human movements in order to navigate in virtual environments. Humphrey II, developed by the Futurelab in Linz, is a flight simulator where the user emerges into a 3D virtual space by means of a head mounted display. The behaviour of an avatar representing the users can be controlled by means of arm movements. In the Virtual Fitness Center (Virku) an exercise bicycle is positioned in front of a video screen. The physical movements conducted on the exercise bicycle are used as input to modify the representation of 3D virtual environments from map information. Reversely, the map information affects the pedaling efforts. In an early implementation the players move this way along a hilly landscape in Finish Lapland (Mokka et al., 2003).

Other approaches address collaborative sporting activities explicitly. They can be understood as early instances of CSCS research. AR2 is an augmented reality airhockey table with a virtual puck. The two players wear head-mounted displays to see a virtual puck on the table in front of them (Ohshima, Satoh, Yamamoto, & Tamura, 1998).

Airhockey over a Distance (F. Mueller, Cole, O'Brien, & Walmink, 2006) uses a physical instead of a virtual puck for distributed gameplay: the puck is shot out at the remote end by puck cannons whenever the player hits the local puck across the middle line.

The Wii® game console comes with a controller that contains accelerometers to support physical activities in its games, and force-feedback is provided through subtle vibration in the controller. Although such exertion games are achieving commercial success, they have been criticized for not being comparable to the sports activities they are simulating (Graves, Stratton, Ridgers, & Cable, 2007). For example, Wii Tennis does not facilitate the same energy expenditure and therefore similar physical health benefits than a traditional game of tennis. However, computationally augmenting such activities can offer novel experiences, such as supporting distributed participants.

Dance Dance Revolution (DDR) is a physical game that requires players to follow dance instructions on a screen. The players' movements are detected by sensors embedded in the 'dance platform' that forms the stage the players are performing on. This game can be very exhausting, and early investigations indicate that it can contribute to an understanding of music-based characteristics in CSCS applications (Behrenshausen, 2007).

PingPongPlus is a system which augments traditional table tennis by means of a tracking device for the ball and a video projector. Different applications have been designed which project images on the table according to the location where the ball hits the table. When a ball hits the table in the "*water ripple mode*", an image of a water ripple appears from the spot the ball landed (Ishii et al., 1999). Mueller et al. (2003) have developed a system called "*Breakout for Two*" which allows players to interact remotely through a life-size videoconference screen using a regular soccer ball as an input device. Both players kick the ball against their local wall on which an audio and video connection with the other player is displayed. By tracking the position where the ball hits the wall various games can be added on each player's side via an overlay technique.

While there are quite some interesting developments in the ubiquitous and entertainment computing fields, the sports engineering community has not captured the full potential of computer-augmented sport devices, we believe. Most research is still restrained to analyse and model traditional sport devices or aspects of the human body (for a good summary see Subic & Haake, 2000; Ujihashi & Haake, 2002). Respective contributions are often only to be found in training science, with a specific purpose to use the computing technology to achieve particular training objectives, or in rehabilitation in which the technology is used to support regaining specific physical capabilities (Powell, 2008).

COMPUTER SUPPORTED COOPERATIVE SPORTS

Computer Supported Cooperative Sports investigates the design of computer applications which require sportive input activities to gain collective game experiences (F. Mueller & Gibbs, 2007; F. Mueller, Stevens, Thorogood, O'Brian, & Wulf, 2007). It is an interdisciplinary research field where sports engineers, computer scientists, designers, sport scientists, and social scientists need to cooperate, guided by a systematic design approach (Moritz, 2004). In the following section, we elaborate on the concept and discuss important aspects of the design space for such CSCS applications.

Integrating Sports and Games

In the following section, the hermeneutic and practical core of sports and games and their implications will be identified and related to one another. Sports in a traditional understanding has been defined as "*organized play that is accompanied by physical exertion, guided by a formal structure, organized within the context of formal and explicit rules of behaviour and procedures, and observed by spectators*" (Anshel, 1991, p.143). Still widely spread, this formalizing definition coerces sports into a specific scheme and strangely strangles the scope for innovation with respect to social and individual use value. However, there are also more context-sensitive approaches, defining sports as a "*specific expression of human movement behaviour*" (Haag, 1996, p.8) that becomes "sports" only by "*a situation-specific reception and an attribution of meaning*" (Heinemann, 1998, p.34). Eventually it is the purpose an individual assigns to a movement which she/he considers being sportive (which in many cases encompasses 'physical exertion'), that defines sports. Reasons to do sports include fun, health, socializing with others, maintaining fitness, and compensating for sedentary occupation (Meyer, 1992; Moritz & Steffen, 2003).

'Doing' sports and playing games have many similarities, especially the voluntary character of the activities motivated by a perception of fun. In the domain of computer games, sport genres have already been utilized: players can simulate sport competitions, such as soccer championships, on their computer. The aim of CSCS, however, is not to simulate sports activities, but to offer the opportunity of 'doing' sports.

Input and Output Devices for Sports Activities

An important dimension in the design space of CSCS is the type of sports activity which shapes the input and output interface to the computer augmented environment. If sport is defined by the meaning individuals assign to the involved body movements, it is possible to imagine a wide scope of different activities. If we either presuppose the objective of increasing fitness levels or at least aim to minimize long-term physical harm, one of the essential requirements would be the balancing of external load distribution, for example not to require an over-utilization of the biceps while offering no stimulation to the triceps. Practical technical and bio-mechanical considerations and the wish to monitor progress suggest a reduction of movement complexity to a simple combination of translational and rotational movements – in which, however, one might have to compromise a 'natural' feeling while moving around in a virtual world.

With regard to the design of the input interface the question arises how to register sport activities appropriately. If this cannot be done by monitoring movements and forces within the device directly, e.g. the actual engine torque, then sensors would need to become an essential part of the design. These sensors can either measure the movements of the human body (e.g. stirring and pedaling an exercise bike) or of different types of sport tools (e.g. the ball in table tennis or the stick in hockey).

With regard to the design of the output interface in a distributed game environment one has to think of how to represent the activities of other actors and the physical texture of virtual space. This can either happen merely visually or also physically by means of forced feedback. For instance, in the Virku environment the physical texture of the virtual landscape translates into different levels of required pedaling efforts.

Collaboration

The concept of collaboration in CSCS environments requires some discussion. Sports, like many game genres, seem to imply competition either among individuals or among teams. However, in dancing or acrobatics it is the feeling of being together in combination with (joint) movements that people are aiming at. So, in principle, CSCS can be centred on cooperation or competition. Hence, the meaning of collaboration in CSCS can span the whole spectrum from multi-user competitive settings (e.g. computer-augmented table tennis or a bicycle race in a virtual 3D environment), to settings of mere co-presence (e.g. playing soccer individually in a shared audio and video space or riding bicycles together in a virtual space) and settings where cooperation is needed to achieve the common goals (e.g. moving in a game area distributed via different handhelds or producing output loads that are converted into a stimulating input for the partner at a remote location).

From a computer science perspective, collaborative settings can be classified along the time-space dichotomy (Johansen, 1988). With regard to the design space, players in CSCS applications can either interact in the same place ~~(e.g. computer augmented table tennis)~~ or at remote locations ~~(e.g. soccer within a shared media space)~~. With regard to time, most of the applications in the field of entertainment computing are synchronous in the sense that the players interact with each other at the same time. However, asynchronous applications such as community systems may help to shape social relationships among players. Seay, Jerome, Sang Lee, & Kraut (2003) and Friedl (2003) describe how synchronous and asynchronous computer mediated communication such as chat and email can be integrated into Massive Multiplayer Online Games. Friedl (2003) stresses the importance of asynchronous features. Web pages allow, for example, the displaying of information about player's performances in past games that is available at any time.

Another important dimension with regard to collaboration is the question of whether the players know each other beforehand or whether they form a social bond within the game environment. In the latter case specific technical features may be needed to introduce or match human actors (Al-

Zubaidi & Stevens, 2004). Friedl (2003) points out that personal information and information about players' performance can stimulate social interactions.

Objectives and Vision

CSCS emerges in an interesting intersection of sports, game and innovative technologies. It may help to tackle problems which are of imminent importance to individuals and the society as a whole:

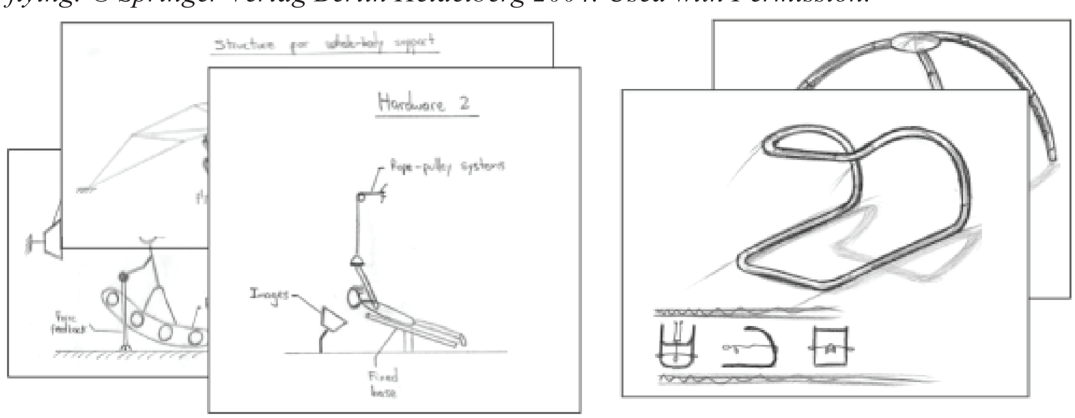
- **Animated fitness equipment:** Has the potential to enhance motivational factors to improve health and fitness, and to maintain such commitment by combining exertion with diversion (and diversity).
- **Animated fitness worlds:** Could combine play, sports, and fitness: A leisure attraction may create an opportunity to get kids away from stationary computer gaming, and thus to fight obesity and social isolation.
- **Computer controlled sports equipment:** Could allow monitoring movements and performance, adapting training and rehabilitation, and enable remote supervision.
- **Computer enhanced sports equipment:** May offer further understanding of the realms of emotions and feelings in sports, especially through combining movements and visual displays, in contrast to purely mechanical sports equipment.
- **Computer supported collaborative sports equipment:** Could link people together to engage in collaborative physical activities. This could enhance motivation and open up new social channels for friends, strangers or even distributed teams.

To arrive at these objectives, however, high demand is put on how to conduct respective research and development projects. A project team heterogeneously assembled with engineers, computer scientists and sports experts will have to combine their competencies, guided by a systematic approach to innovation in sports, and backed up by a distributed project management. Initial pilot projects in this area have been conducted and will be reported upon in the next sections.

THE FLYGUY APPROACH

We have developed a concept called FlyGuy for an innovative CSCS device which combines fitness training with playful challenges, social interaction, and versatile entertainment. The work was conducted in a multidisciplinary design team which consisted of researchers and

Figure 1. First sketches of the FlyGuy and design alternatives of the frame which holds the human actor when flying. © Springer-Verlag Berlin Heidelberg 2004. Used with Permission.



students from Germany, Japan, Mexico, and the United States.

In contrast to PingPongPlus (Ishii et al., 1999) or Breakout for Two (F. Mueller et al., 2003), we wanted to design a collaborative environment for new physical experiences and sports activities. In a first face-to-face meeting of the project team, flying was identified as an interesting sports activity because humans can only experience this in a computer augmented environment or by means of specific avionic devices such as hang gliders.

We have therefore created the following concept: the player immerses via a head mounted display into a 3D virtual environment. She/he controls a flight simulation through her/his body motions. In a first explorative implementation two handles need to be grabbed by the hands; the flight direction can be changed via rotation of the torso, the height by pulling or pushing a lever horizontally (Figure 1). One of the reasons we chose to realize the flight movement in this 'starfighter' fashion was that it appeared to be the most natural way to the test persons we asked to 'fly' on a small table structure. A training effect is intensified by providing resistance for both concentric and exocentric movements; thus it is possible to realize extreme intensity and quick exhaustion. In further stages, we plan to include leg movements for acceleration and deceleration. The motions are captured by sensors located in the joints of the lever structure and transformed into electrical signals which are then being transmitted to a microcontroller and a PC. The data is used as input to control the flight simulation which is perceived by the player via a head mounted display. The player is hanging in a frame made of aluminum similar to the frame of a hang glider.

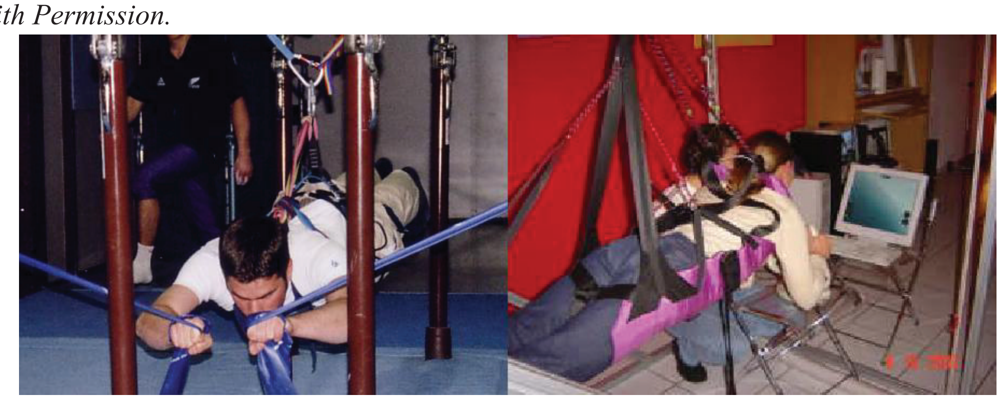
In the virtual space, the player has the possibility to solve different flying tasks and meet other persons and fly and exercise with them, even if they are in a geographically distant location in the real world. Whenever the players reach certain proximity in the virtual space, an audio channel is opened to allow for communication.

For creating the virtual environment we explored different popular 3D game engines and opted to tailor an existing game like Half-Life II for our purpose. This also supports addressing the need to arrive at a sufficient user base for efficient usage of the system, as it makes it easier to integrate other players which do not have the FlyGuy device, but can play with conventional hardware.

After detailing the concept, the team separated again and worked on its realization (mechanics, mechatronics, network structure, virtual environment, output devices, biomechanics, game plan, sports scientific aspects, etc.) in a distributed fashion.

In a second face-to-face meeting a functional prototype was assembled and tested. This prototype was built to explore technical design issues

Figure 2. Experimenting with early prototypes of the FlyGuy. © Springer-Verlag Berlin Heidelbert 2004. Used with Permission.



such as the location of the hanging anchor point and the fixture of the lever structure. Further functional design issues were explored such as the steering mechanisms (Figure 2). We also investigated which degrees of freedom and what kind of support is necessary to provide the basis for efficient and safe training.

We evaluated our concepts internally during the design process. It turned out that some aspects of the prototype's design worked out better than others. For example the horizontal flight posture and the steering of the flight simulation were rated positively and intuitive, while the usage of a fixed and stiff lever structure was regarded suboptimal because it does not match the idea of 'free' flight motions. Other aspects which need to be improved are the overly complicated access into the device and the lack of adaptability with regard to different user anthropometries.

TABLE TENNIS FOR THREE

Another prototype of the CSCS paradigm is 'Table Tennis for Three'. Table Tennis for Three is a tangible game that uses a real ball, bat and table but supports players in geographically distant locations. It is aimed at providing a health benefit by encouraging physical activity and training reflexes as well as hand-eye coordination. Just like table tennis, it is easy to learn and supports a sense of achievement quickly. Through the inclusion of a videoconference, the aim is to support similar benefits known from traditional casual table tennis play such as exercise, enjoyment and bringing people together to socialize.

Table Tennis for Three does not only overcome the need for collocation between participants, it also demonstrates the scaling opportunity of the CSCS concept by supporting three players simultaneously in three different locations, offering another example of a novel sports experience ~~facilitated by the paradigm~~.

Gameplay

Each player has a ball, a paddle and a table tennis table (Figure 3). Game play involves hitting the table tennis ball with the paddle against a backboard. This backboard is one half of a table tennis table, which is usually pushed together with the other half to create the playing surface. By tipping one of these halves from the horizontal to the vertical position it is possible for players to play the ball against the backboard created. This setup is familiar to table tennis players who have

Figure 3. Table tennis for three

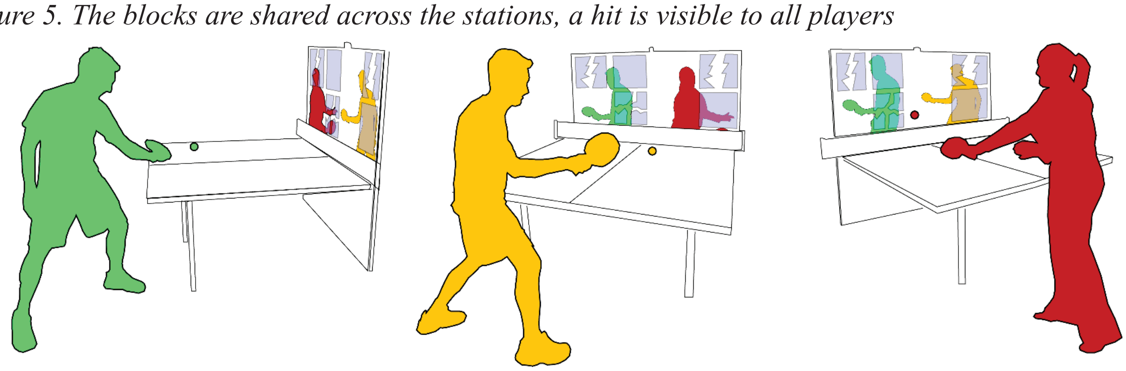
practiced by themselves by repeatedly bouncing the ball off the backboard with their paddle.

This backboard has projected images of eight large 'bricks' on it. These bricks are identical for all players, i.e. they are synchronized across all three stations. These bricks are semi-transparent and are projected onto the backboard with a projector mounted to the ceiling. In addition to the bricks, it also projects two video streams of the other players in the game (Figure 4). One player is positioned on the left of the backboard, and the other on the right. Each table has a set of loud speakers and each player wears a microphone so the three participants can converse with each other.

The backboard is equipped with sensors mounted on the back that detect when and which brick the players are hitting. These bricks 'break' when hit by the ball because the sensors register the location of the impact. All three players see the same brick layout and the same brick status. If a brick is hit once, it cracks a little. If it is hit again (regardless by which player), it cracks more. The crack appears on all three stations (Figure 5). If hit three times, it 'breaks' and is removed from play, revealing more of the underlying videoconferencing: the player 'broke' through to the remote player. However, only the player that hits the brick the third and final time receives the point. This helps to make the game more interesting

Figure 4. The distributed targets, overlaid on top of the video

Figure 5. The blocks are shared across the stations, a hit is visible to all players



because it offers players a number of strategies for winning the game. They can either try to crack as many bricks as possible by placing the ball quickly or they can poach points from other players by waiting for the opportunity to snatch away points through hitting bricks that have been already hit twice by the others.

Each brick that is completely broken scores one point, and the running score is displayed along the top end of the projection. ~~Feedback from early experiments revealed that it was not always clear for the players to determine who hit which brick. We therefore implemented a feature that when a brick was struck by a remote player, the local brick flashes in a color corresponding to the remote player.~~

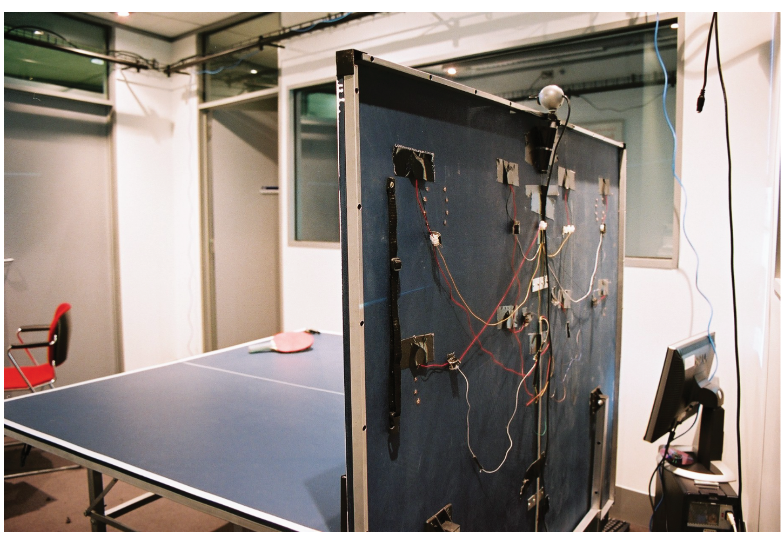
Play continues until all bricks have been cracked three times and been removed from play. At this point the player who has scored the most points is announced as the winner and after a delay of 15 seconds, the game resets all the bricks and play can recommence.

Technical Implementation

We operated Table Tennis for Three in three separate rooms connected via a LAN network connection. The backboards were instrumented so that the time and approximate location of a ball striking the table could be detected. Eight piezoelectric sensors were attached to the rear of the backboard in locations corresponding to the gameplay blocks projected on the front of the backboard (Figure 6). The sensors detect the sound vibrations in the wooden board created by a ball striking it. This approach is similar to the system described by Ishii et al. (1999), however, we were not able to achieve a highly accurate system with four sensors (which should cover the entire surface through interpolation), and therefore opted for the use of eight sensors.

The one sensor that receives the vibration signal first, exceeding a certain threshold, determines the location of the impact. After an analogue to digital (A/D) conversion and data acquisition, software concludes which of the bricks should be cracked. This information is sent to software that updates all other stations using client-server architecture. Each station then updates the graphical content accordingly, and synchronizes game data such as the score. A camera was placed in the centre of the upper edge of each backboard. This camera was used to capture and send video

Figure 6. Backboard with sensors



conferencing streams from each play station to the other two tables.

The videoconferencing implementation is deliberately kept independent from the technical gameplay component in order to provide an optimal videoconference experience. Developing a videoconferencing system is not a trivial task, and many open-source and commercial systems claim to offer the best compromise between bandwidth limitations and image and audio quality. These software (some of them are hardware) implementations balance the most effective compression codecs with en- and decoding CPU requirements, deal with varying network throughputs, provide circumventions for firewall issues, and minimize noise- and echo effects. In order to be able to always utilize the latest advances in videoconferencing technology, we implemented the Table Tennis for Three gameplay independently and placed it on top as a separate half-transparent layer. This ensures that any researcher who wants to recreate the system can take advantage of their existing videoconferencing infrastructure and is not locked into a proprietary system that might be outdated quickly.

User Experiences

An evaluation with 41 participants using observational data, questionnaires and interviews indicated that the participants enjoyed playing Table Tennis for Three and that they could see such a CSCS game being helpful in facilitating rapport between people who are physically apart but want to stay in touch (F. Mueller & Gibbs, 2007). In particular, they expressed a strong sense of "*playing together*" and commented on the fact that it "*gave them something to talk about*". The physicality of the *game allowed participants to quickly engage and interact, and most players reported that they had* fun, considered it a workout, forgot the world around them when playing, and wanted to play again. This user study strengthened our approach that the CSCS concept can contribute to a sense of social bond between geographically distant players while offering increased fitness incentives. Designers of CSCS games might be interested in knowing that our participants liked to practice their skills beforehand, showing 'practice' behavior comparable to traditional sports. However, at least two participants of Table Tennis for Three also reported on a negative experience. Both players mentioned they had trouble understanding the other players over the audio channel which was probably one factor that affected their experience. Such results shed light on future work needed on the CSCS concept, such as investigating the role of verbal support amongst participants. Such type of research will lead to further design recommendations for applications which support distributed sports experiences across multiple locations.

CONCLUSION

We have described the concept of Computer Supported Collaborative Sports and presented two prototypes that highlight the sportive and collaborative aspects of such computer augmented activities. The attempt to transfer the excitement of computer games to motivational aspects for fitness training and thereby allowing joint physical activities by partners far apart might mark an important trend in the future of entertainment computing and fitness-oriented sports.

- The introduction of computers into cooperative sports equipment does not only offer new areas of application for computers in entertainment but also opens up new dimensions in sports and fitness:
- There is a whole array of novel means to increase motivation to participate in sportive or health-sustaining activities.
- Linked via the internet, people in different locations can do sports, share physical fun or follow rehabilitation exercises together.

- The development of virtual worlds and connected input-output devices could offer sensory and emotional sensations that cannot be experienced otherwise; 'flying' being just one example.

To explore the design space out-lined in this paper, we need to implement a variety of different CSCS devices. The more we depart from sport activities given already in the physical world, the more effort need to be spent on the design process. While the input activities in the case of Table Tennis for Three were still rather close to their origin, in case of the FlyGuy a new repertoire of sportive movement had to be invented.

Moreover, we need more profound empirical evaluations of CSCS applications. We have collected so far mainly data on the devices' short term appropriation. However, long term data is needed to better understand how motivation develops and whether the intended health effects can be detected. We also need to better understand how different types of players appropriate these applications.

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