The Design of Networked Exertion Games

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Abstract

Incorporating physical activity and exertion into pervasive gaming applications can provide health and social benefits. Prior research has resulted in several prototypes of pervasive games that encourage exertion as interaction form; however, no detailed critical account of the various approaches exists. We focus on networked exertion games and detail some of our work while identifying the remaining issues towards providing a coherent framework. We outline common lessons learned and use them as the basis for generalizations for the design of networked exertion games. We propose possible directions of further investigation, hoping to provide guidance for future work to facilitate greater awareness and exposure of exertion games and their benefits.

Keywords: Exertion Interface, physical, tangible, videoconferencing, sports, active, exhausting, team building, social interaction, connectedness, rapport, bond, table tennis, ping pong, muscle, strength, jogging, running, soccer, football.

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1 Introduction

Participating in physical leisure activities such as sport can have many advantages; in particular health and social have been attributed as major benefits. From a physical health perspective, physical activity can contribute to a healthier body, reducing the risk of obesity, cardiovascular disease, diabetes, and more [PPB+95]. From a social and mental health viewpoint, physical group activities are believed to teach social skills [MSWM03], encourage team-building and support individual growth and community development [GH01]. Some argue sport can foster social integration and personal enjoyment [WB90, LS01], provide opportunities to meet and communicate with other people, bring people together from various cultural backgrounds, and can contribute positively to self-esteem and well-being [Bai05]. Although some research asks for further proof of specific benefits [LS01], there seems to be a considerable amount of evidence in favor of a positive relationship with physical and mental health [Bai05, Fen94].

The social benefit that can increase participants' well being and mental health has been pointed out as being also of benefit to the growth of social capital [HW04, Put00]. The author of the book "Bowling Alone", Putnam, argues that social capital requires social networks, which are most effectively developed through participation in shared activities [Put00]. In particular, sports participation provides a focus for social activity. It can be helpful in facilitating social introductions, provides an opportunity to develop networks and reduce social isolation, and hence has potential to support the development of social capital. Physical leisure activities can facilitate bonds between people, resulting in loyalty and team-spirit. Sports

clubs not only function as a place to exercise, but also as a social space, Putnam argues. Team sports in particular are considered as character-building. However, with current physical leisure activities, participants have to be in the same geographical location. Recent research in pervasive gaming has led to several computer-augmented leisure activities, some of them include a networking component to support geographically distant participants. Work on persuasive technology has investigated the motivational benefits computer-augmentation of exercise equipment can contribute [Fog02], and our approach combines these two advantages: it motivates distant players to participate in physical activities together through social support, while in turn helps them strengthening their bond via the activity, all facilitated by use of interactive technology. We are describing some of our examples in order to point out remaining issues towards a coherent framework to describe, design and understand these novel pervasive gaming systems.

2 Related Work

Several researchers have investigated the convergence of pervasive computing technology and physical activities. Related work derived recently from a CSCW perspective, and the term *Computer Supported Cooperative Sports* [MST+07] has been coined. To encompass social play, some use *Computer Supported Cooperative Play* [IWO+99]. *Long-Distance Sports* are described in [Mar04], but the authors focus on commercial products that have mainly limited capability in terms of distributed interaction. More advanced prototypes exist in research labs, but they have rarely been evaluated in terms of social and health effects.

A mature project is *NetAthlon* [Net07], which allows riders of exercise bicycles to race against other remote riders, represented by three-dimensional avatars, using either a screen on the handlebar or a head-mounted display. However, the bike does not support audio or video interaction between the cyclists. The *Virtual Fitness Center* [MAV03] uses a similar approach with exercise bicycles 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. Conversely, the map information affects the pedaling efforts.

An early attempt (built in 1986) of physical activity over a network is *Telephonic Arm Wrestling*, in which the player arm-wrestles the opponent over a phone line [Wre04]. The idea of arm-wrestling an opponent far away has been implemented in several museums across the USA, but the experience for the museum visitors has not been evaluated [Art04]. *Tug-of-War* has also been networked: at the New York Hall of Science two teams of high-school students were involved in a tug-of-war 13 miles apart from each other [oSPR05]. More Exertion Interfaces are described in [Bra05].

The advent of a new style of computer games with sports-like interaction has also arisen. The move by Nintendo away from a traditional game pad as input device for their latest console signals that the entertainment market might incorporate more sportive activity: the console comes with a controller that contains accelerometers and infrared sensors. In order to hit the virtual tennis ball, the player uses the controller like a racquet [Spo08]. Another example is *EyeToy Kinetic* [Eye08], a personal training workout game, which tracks a user's body movements using a webcam to provide a personalized workout program in the living room.

The authors of [LT98] define an "action interface", which enables remote participants to play table tennis together. The players make an arm-movement as if they are trying to hit the ball, however, the ball exists only on the screen, so they never experience force feedback regardless of whether they hit the ball or not.

Investigation of the social factors in motivating people to exercise has been described by McElroy in [McE02]. Various devices have been designed to support a motivational component, especially for joggers: the *Nike+iPod Sport Kit* [App08] connects to an MP3 player that tracks individual exercise performance and stops the music to verbally report on progress. *MPTrain* [OFM06] is a mobile device that monitors heart rate and speed during exercise. The device selects music with a particular tempo to encourage the user to slow down, speed up, or keep pace. Although these devices can support an individual user, they do not take advantage of the motivational benefits that can occur in a social setting of exercising with other people. Shakra [BMA+06] supports physical activity awareness in a mobile setting, and the authors report on the beneficial aspect of competitive progress exchange as encouragement to exercise more. *Chick Clique* [TFAG06] and *Houston* [CESL06] are other mobile phone applications that monitor step count and display it alongside the step count of friends. The pri-

mary focus of these devices is on everyday activity, not on a dedicated exercise session. A project that supports the distributed social interaction between participants to motivate physical activity is *Actively Mobile* [Bov05]. However, the system is merely a mobile phone connection between participants, and does not augment the exercise with any additional data that the users could benefit from.

3 Overview

Many pervasive games have emerged recently that utilize physical activity or full-body movements as input for their gameplay. For the purpose of this paper, we focus on networked physical games, which allow geographically distant users to play together. These leisure games aim to combine the advantages of information and telecommunication technology (connecting geographically distant participants) with the advantages of exertion activities (health and social benefits). People often have difficulty finding local activity partners with similar physical capabilities in order to ensure a mutually enjoyable experience [OMT07]. One possible way to overcome this challenge is to expand the range of potential activity partners by allowing people to engage in pervasive games with remote partners.

In the remaining sections of this paper, we are presenting the most relevant projects of our own work and outline the games' foci and their shortcomings. We then provide an overview of the remaining issues, which we believe can serve as a starting point towards a conceptual framework that aids designers in creating successful exertion games for distributed participants.

4 Breakout for Two

Breakout for Two [MAP03] is a cross between soccer and the computer game "Breakout". The players, who are located in two different rooms, both kick a ball against a physical wall. On each wall is a life-size videoconference projection of the remote player, enabling the participants to interact with each other via audio and video. They hit a soccer ball in the direction of the other player, but it comes back, bouncing off the wall. Eight semi-transparent virtual blocks are overlaid on the video stream, which each player has to strike in order to score. Vision detection technology determines the impact of the ball and game logic decides whether a block was hit. The virtual blocks are shared between the locations, meaning both players always see the same block states. If one of the two players strikes any of the blocks once, they "crack". On the third hit, the block "breaks" and disappears. The player only receives a point if the block breaks. This scoring theme was implemented to enable a tactical approach to the game, in which 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. However, the harder the player hits a block, the more it cracks, so a player can also choose to crack the blocks faster through really hard hits, a design choice to promote physical exertion.

Figure 1: Breakout for Two

4.1 Focus

The focus of *Breakout for Two* was the empirical demonstration that an *Exertion Interface* [MAP03] can be superior in facilitating social connectedness between geographically distant participants compared to a keyboard interaction. An experiment with 56 participants -none of whom knew each other beforehand- was conducted in which the players either played the *Breakout for Two* game or an analogous keyboard-based game, but using the same videoconferencing component [MAP03]. The participants were subsequently surveyed with a questionnaire and an interview. The results were that the exertion-players said that they got to know the other person better, had more fun, became better friends, and were happier with the transmitted audio and video quality in comparison to those who played the non-exertion game.

Figure 2: Airhockey over a Distance

4.2 Issues

This work demonstrated that a particular pervasive game, *Breakout for Two*, can be superior in facilitating social connectedness in contrast to an analogous keyboard-based game. It is not clear if the results transfer effortlessly to other games, or if the effects are restricted to this particular game. Furthermore, although the game can also be played with tennis racquets, the experiment focused on using a soccer ball; however, the ball was used with hands and feet.

Although the participants perceived the videoconference quality differently depending on whether they played the exertion or the non-exertion game, it is not clear how the exertion affected the participants' perception. Also, the large size of the videoconference might have also contributed to the effect, but the extent is unknown.

In addition, the *Breakout for Two* game is centered on competition, and although a cooperative game has been implemented, it was not tested as part of the experiment. Furthermore, the participants were strangers before the experiment; examining the bonding effect on existing friendships was not part of the investigation.

5 Airhockey over a Distance

Airhockey over a Distance [MCOW06] is a networked airhockey game that replicates the tangible object of interaction, the puck, across geographically separate tables. Two players are facing an airhockey table each, but they are in different locations. A videoconferencing screen is mounted above the halfway line with the aim of creating the illusion that the table extends onto the other half across the distance. The players can see and hear each other through a digital video (DV) quality videoconference. Both players shoot a real puck back and forth, trying to score a goal, similar to traditional airhockey. However, once the puck passes the midway-line, its location is detected, and a corresponding physical puck is shot out at the other table. The local puck travels through a small gap between the table and the videoconferencing screen, and is caught by a catchment tray. On the remote end, several rotating puck cannons shoot pucks out of an array; however, there is always only one puck visible for both players at a time. Networking delays were addressed through the use of a high-speed dedicated network as well as "virtually" extending the table, so as to introducing additional length to the perceived dimensions of the table, which increases the time the puck can travel between locations.

5.1 Focus

Airhockey over a Distance was built to introduce people over a distance by utilizing the social power of a quick, casual game that can be played in social spaces like canteens of distributed enterprises. Its focus is on the physicality of the interaction object, the puck, and its replication on the remote end. This concept is derived from the perception that recreating a traditional net-based sport such as tennis or volleyball over a distance would require a complex mechanical setup of ball machines that reproduce the ball at the right speed, angle and position on the remote end. To simplify this endeavor, airhockey was chosen as a template game because the interaction area is limited to a 2D instead of a 3D surface. *Airhockey over a Distance* was designed as ice-breaker between geographically distant participants, and evaluation showed that players valued a feeling of playing together on one shared table [MCOW06].

5.2 Issues

Feedback from fellow researchers in the area showed that they judged the replication approach to be superior to the "substitution-through-gameplay" attempt from *Breakout for Two* to simulate a back-and-forth action players exhibit with a ball. A comparative experiment

Figure 3: Push'N'Pull

could shed light on this issue and determine a favorable approach. However, even if the physical replication would turn out to be superior, it is unclear if the additional mechanical effort is justified.

6 Push'N'Pull

Push'N'Pull [MST+07] is a networked exercise machine that supports exertion through cooperative gameplay. Two participants stand at controller stations in separate locations. Each controller station contains of a "Power Grid" [IL08] exercise machine, a video camera and a monitor providing the same high-quality videoconference as in *Airhockey over a Distance*. In contrast to *Breakout for Two*, this setup was designed to require less floor space to be more suitable for generic indoor environments. The "Power Grid" device contains an isometric exercise bar, which requires physical exertion of different muscles. Although the bar does not move when pushed, it measures the force that is applied and outputs it to the local and the remote computer over a standard TCP/IP network connection in a LAN environment. This exertion input is used to control a cooperative game in which two participants command a shared virtual object on the screen in front of them. The task is to use the shared object to chase and capture graphical particles on the screen that have an avoidance behavior before time runs out. These particles are harder to catch if only one player is acting on them, encouraging the cooperation and communication of both parties to complete the task. If both players push and pull in the same direction, their combined forces make it easier to win the game

6.1 Focus

The focus of *Push'N'Pull* was on the use of an exercise machine with isometric force in order to control a cooperative game. Usage of the system revealed that participants were using a wide-range of forces: some used gentle pressure, others a steady force, and yet others applied full-body movements into pulling and tugging the device. Participants exhibited the use of hand-gestures and facial expressions, but also reported on the lack of haptic feedback.

6.2 Issues

Push'N'Pull demonstrated that a cooperative exertion game can be enjoyed by geographically distant participants; however, it is unclear if the cooperation affects the interaction in a different way than a competitive game would. Furthermore, the substitution of force-feedback with isometric force seemed to have confused the participants; forcefully interacting with a computer device seems to elicit force-feedback expectations.

7 Table Tennis for Three

Table Tennis for Three [MG06] is an extension of *Breakout for Two*, applied to a game of table tennis-like interactions. Our intention was to explore the scaling aspect of such interactions, and also see how the proposed gameplay is perceived with different types of equipment. *Table Tennis for Three* extends the concept to three players in three locations: the players hit virtual blocks with a table tennis paddle and ball, however, each player is playing against two opponents. A projector mounted to the ceiling projects two video streams of the other players side by side. The blocks

Figure 4: Table Tennis for Three

are identical for all three players, i.e. they are synchronized across all three stations. Piezoelectric sensors attached to the back of the flipped-up side of the table tennis table measure the sound of a ball's impact to determine its location, which is distributed amongst all three tables via a TCP/IP network connection that also supports the videoconferencing component.

An evaluation with 41 participants using questionnaires and interviews indicated that the participants enjoyed playing *Table Tennis for Three* and they could imagine such a physical network game being helpful in facilitating rapport between people who are physically apart but want to stay in touch. In particular, they commented on the fact that the game "gave them something to talk about" in a videoconferencing environment. Most players reported that they had fun, considered it a workout, forgot the world around them when playing, and wanted to play again.

7.1 Focus

Table Tennis for Three is an evolutionary project following *Breakout for Two* to test the scalability of the approach. It showed that three players in three locations can play a physical game together. It has been evaluated with participants who knew each other beforehand as well as with strangers. Due to the fact that body movements exhibited in table tennis are generally not as forceful as in soccer, the players probably exhibited different levels of exertion; however, these movements have not been categorized to allow for analysis.

Figure 5: Jogging over a Distance

7.2 Issues

Although *Table Tennis for Three* demonstrated that the networked exertion game Breakout for Two scales to three players, it is still undetermined if a further increase of locations and players is feasible. In particular, it is unclear how the videoconferencing screens would need to be positioned in order to provide a clear view for a large amount of players. Having several audio channels open simultaneously might lead to a crowded auditory space in which it is not obvious whom the players are addressing in their speech. Also, the likelihood of networking issues rises with an increase of participants.

8 Jogging over a Distance

Jogging over a Distance offers social joggers a "jogging together" experience although geographically apart. In *Jogging over a Distance*, social joggers start jogging at the same time, but in different locations. They wear a microphone and headset through which they can communicate during their run. The system is context-aware, in particular, it knows the two joggers' relative speeds. A jogger can gain an increased sense of presence of the other person because they

hear through spatialized audio if their jogging partner is running faster or slower. While each partner jogs, speed data is collected and used to position the audio of their conversation on a 2D sound plane, oriented horizontally around the jogger's head. As one jogger speaks, their partner hears the localized audio and is able to detect whether the audio is coming from the front, the side, or from behind, and thus if the other person is jogging faster, at the same pace, or slower. Similar to a collocated setting, the audio cues runners when to speed up or slow down in order to "stay" with their partner. For joggers with differing athletic abilities who would like to have the experience of running together, a baseline pace variable can be adjusted that allows runners to challenge their individual pace while jogging with friends who run at different speeds.

8.1 Focus

Unlike the previous examples, *Jogging over a Distance* does not rely on a video link between the participants, but rather focuses on an audio-only experience. The physicality of the activity might limit cognitively demanding interactions, such as looking at a screen. Furthermore, the jogger might not want to be visually distracted from the natural environment, in particular because the focus is on outdoor jogging.

Jogging, we believe, is a suitable example in which technology should be "calm" [WB96], in order not to interfere with the users' current practice, while simultaneously enhancing their experience in an unobtrusive way. Joggers often wear headphones to listen to music, and therefore the use of such devices would not be unfamiliar to the participants.

8.2 Issues

Jogging over a Distance has not been empirically evaluated with participants in the envisioned outdoor environment. Although the exertion activity directly controls the networked experience, the resulting augmentation has yet to be demonstrated as being effective for an increased motivational support between the participants. The effect chain -exertion, social support and presence awareness can lead to motivation which in turn leads to a more effective workout- is yet to be validated.

9 General Lessons Learned

By reflecting on the aforementioned examples, we have identified general lessons learned from designing these systems. We have generalized salient themes and findings that we believe could be applicable for the design of future networked exertion games. These themes concern the amount of exertion supported, the communication channel and its synchronicity, social "together" experiences, audience interactions, and their relation to sport.

- Exertion games should support maximum exertion. Once participants realized that they can be very forceful with the interaction devices, they exerted themselves to a strong extent and were self-assessing the maximum strength they can apply. Experiencing one's physical limits seemed to be conducive to the experience, we observed from the participants. They told us they enjoyed pushing their physical capabilities. Although not empirically validated, we have the suspicion that an exertion system that reacts to a player's extreme physical activity on an open scale will be enjoyed more by participants than a game that reacts differently only up to a certain point because it reached a threshold. Some users might not reach this threshold, but others would value if they receive feedback or recognition for their excessive effort, we believe.

- Audio is the premium communication channel. Participants were forgiving of glitches and compression artifacts in the video stream, however, many audio issues were quickly pointed out. Players were very particular about being able to understand one another clearly, but we could not identify any correlation between prior videoconferencing experience and forgiveness of audio difficulties. A clear audio channel seemed to be of high importance for an interaction between distributed participants.

- Networked exertion requires a synchronous interaction channel in all of our examples. This should not imply that asynchronous exertion is not possible, especially because we noticed the synchronicity requires coordination efforts between the participants before the game that are not trivial. All parties need to be in the right location at the same time with the appropriate equipment, be available for the duration of the game,

and be in the right clothing and mindset for the exertion activity. This could be a logistical hurdle that can affect the likelihood of a successful interaction, and should be taken into account when designing new experiences.

- Breaks are social. We observed a large proportion of the social interaction happening in breaks that either the gameplay dictated or the participants picked themselves, whether collaboratively or individually. Catching breath allows for interaction, we found out. During the game, players are mostly focused on the activity and sometimes seem to regard the interaction as distraction. We suspect because people are exhausted and need to catch some breath, they have breaks, in which they start talking. The participants' arousal level is increased due to the exertion activity, which increases the chances to engage in social interaction with others. Such social interactions were not limited to breaks during the game, idle moments before and especially after the game were also used for interactions with the remote partner.

- Supporting a "together" experience contributes to a joyful experience. Players seemed to be particularly engaged in activities that provided them with a playing "together" experience. Participants valued the experience of playing with another person, in contrast to having the feeling of playing with a computer. Elements of tactic and strategy can play a positive role in contributing to this perception.

- Although networked exertion games bring geographically distant players together, local fellow players and supporters should not be forgotten in the experience mix [RBOF05]. Opportunities for local players to join were always welcomed by our participants, and having spectators, local or remote, often contributed as motivational factor.

- Exertion games, just like sports, are enjoyed by many, but not by all. Some might be excluded because of physical capabilities, and others might simply "not be into it", as one participant expressed. Generally, a positive attitude towards sports seems to contribute to an engaging exertion game experience. Some participants were surprised how their reserved attitude was diluted once having played a few rounds of a game. In summary, physical activity is not for everyone, and, similar to collocated sport, we believe aiming to engage everyone in such activity should not be a goal for such experiences, but rather serve those who value physical exertion and give others the opportunity to try out such activities.

10 Common Remaining Issues

We now report on remaining issues we identified in the presented designs, with the aim of pointing towards potentially rewarding directions for future research. In the following diagram we propose a loose affinity between these concepts, influenced by reflections of the general lessons learned. "Framework" and "Design Requirements" are more high-level conceptual concepts, were the bottom row concerns implementation and user-base support opportunities. The medium row deals with evaluation issues yet to be investigated. In our presentation of the remaining issues, we follow this conceptual order.

Framework	Design Requirements	
Longitudinal Investigation	In-Context Use	Empirical Investigation of Benefits
Scalability	Team Support	Target Group

Table 1: Remaining Issues

10.1 Framework

Most prototypes evolved out of a design research approach, often inspired by traditional non-computer exertion games. This approach does not begin with theoretical abstract concepts that the design could be easily grounded in. Some researchers have started investigating theoretical frameworks for movement-based interactions: Benford et al. [BSK+03] created a framework for sensible and sensable systems, and Bellotti et al. [BBE+02] provides another framework for physical interaction. Larssen et al. [LLRE04] tested both frameworks against two Eyetoy games, but does not come to a conclusion which framework is more suitable. It should be noted that the Eyetoy games are vision-based, and do therefore not support force-feedback, quite different to our aforementioned prototypes. Dourish [Dou01] developed foundations of embodied interactions; however, he is more concerned with any type of tangible interface rather than focusing

on exertion. There is currently no dedicated framework that has been verified to be applicable for exertion activity; this could provide an area for future research. Furthermore, none of these frameworks address explicitly the augmentation of physical gaming with networking advantages, and therefore do not provide guidance how they can be applied to a theoretical understanding of the social effects in a distributed environment. However, building on these frameworks, an extension with exertion in mind could generate a construct that can serve as theory for other researchers to base their work on.

10.2 Design Requirements

Quantitative analysis could provide insights on what successful design components for networked exertion games are. For example, which factors of the videoconference provide the most benefit? What is the best compromise between framerate, resolution and bandwidth limitations? We have already identified that the audio channel has a salient role in the interaction channel, however, in which instances is directional audio beneficial? What sampling rates are adequate? Which body muscles should be exercised most in order to gain an ideal health benefit? Looking at existing sports activities in collocated environments can serve as inspiration here, as our instances with table tennis, for example, has demonstrated. Our systems also suggest that engaging gameplay can contribute to an enjoyable experience that can have an effect on the physical activity users perform. This gameplay, however, needs to consider the distributed situation of the players and encourage a "together" experience; such themes could be used to guide future designs. Other inspirational questions could be "What would a ubiquitous computing environment for networked exertion games look like without technical limitations?" This leads to the fundamental question: "what makes a successful exertion game?" Future research will probably not conclude with a definite answer, but can guide critical investigations and analysis that allow for a scientific approach to further understand implementation issues and deepening our understanding to improve on designs systematically.

10.3 Longitudinal Investigation

None of the described designs' use has been investigated over an extended period of time. Most of them have been exposed to users only briefly for the duration of the experiment. Investigations that are concerned with long-term usage could lead to valuable insights into usage patterns over time, and contribute to our understanding of how users adopt such pervasive technology once the novelty effect wears off. Would people play these games repeatedly, for an extended period of time? Do people become better at them, and if so, does this limit the enjoyment, or, in contrast, does the improvement present an ongoing challenge? Do these games supplement traditional games, or have they replaced existing gaming activity?

10.4 In-Context Use

Possibly due to the short-time frame of the evaluations the described prototypes were exposed to, a detailed in-context analysis is lacking. Participants only had the opportunity to play while being part of an experiment, but did not have the chance of making these games part of their daily lives in a non-observed environment. Although some of the applications are portable or at least technical reasons do not prevent an installation in people's homes, designers have often refrained from leaving users alone with their prototypes, possibly due to the fragile status or cost of equipment. However, in-context studies could provide valuable insight into the use of such games and reveal information on which games are more accepted and used than others, possibly suggesting rewarding ingredients for future pervasive games.

10.5 Empirical Investigation of Benefits

Exertion Interfaces can facilitate health benefits and many pervasive games were developed with the obesity problem in mind [BMA+06, TFAG06, CESL06]. The designers hope to address some of the issues of today's sedentary lifestyle by encouraging physical activity promoted through pervasive games. However, it has not been empirically demonstrated sufficiently yet how physical activity facilitated by exertion games results in increased fitness and weight loss. Such correlations can be complex, as research in traditional sports activities has shown. However, it is generally understood that regular moderate exercise is beneficial for the human body [PPB+95]. How can pervasive games support moderate exercise, while simultaneously ensure that they do not put the user in a state of over-exhaustion? Measuring physiological data such as heart rate during game play could influence game

levels, supporting a suitable health state. Acquiring such user status could also be used to measure the effect on the player's health. Interesting questions on this issue are: How many calories were burned during a game, and how could the game adapt to increase that count, while simultaneously ensuring an enjoyable experience? What is an optimal heart rate level for each individual player, and how could the system determine and promote that? What is an ideal heart rate in terms of calories burnt, but also in terms of arousal level conducive to social interaction? Could a pervasive system analyze and adjust to these conditions? Finding answers to these questions could provide valuable insights for the future of such games. Furthermore, providing evidence could advance research in promoting a well-being aspect, encompassing physical but also social and mental health.

10.6 Scalability

Table Tennis for Three is an extension of the *Breakout for Two* game that can be played in three different locations, and can hence be regarded as an early attempt to provide evidence of the concept's ability to scale. However, demonstration of support for multiple players in multiple locations is still outstanding. Several questions would need addressing before further designs could take shape: how can the interaction support multiple participants? In the case of the videoconference, how can one ensure adequate spatial distribution of the video feeds? How do the players address one another? Is it possible to play with hundreds or even thousands of players, similar to MMOGs (Massively Multi-player Online Games)? An easily deployable way to achieve scalability would be to incorporate avatar based actions, where each avatar is controlled by a member of a team using an *Exertion Interface*. This could be combined with spatially distributed voice communication systems to handle audio channel clutter [GWB06].

10.7 Team Support

The designs we described either support individuals or teams of two, but not more than two. With the increase of locations more players and therefore more teams could play simultaneously. Conventionally, if multiple teams are involved, they take turns, but in networked games, all teams could theoretically participate at the same time. The gameplay, however, would need to support this. We see at least two options for future designs to incorporate multiple teams: either supporting simultaneous play with gameplay designed for this setup, or developing a turn-taking approach with the advantage of having traditional games as template for successful implementation. Another novel aspect the networked augmentation to gameplay can facilitate is the creation of distributed teams. In particular, competitive games could be envisioned in which the opponents of a player are collocated, but his/her teammates are far away. A study of the formation of social rapport between these participants could provide valuable insights on the establishment of bonds between remote and local players under the same conditions.

10.8 Target Group

Applications such as *Chick Clique* [TFAG06] were designed with a specific target group in mind, and the prototype is tailored to those people's needs and preferences. The presented designs however are targeting a broader fitness-friendly crowd with a general interest in gaming and physical activity. The exertion component gives designers of future systems the opportunity to provide for professional athletes, a target group not previously exposed extensively to pervasive games. Although (semi-) professional sportspeople might find the fragility of current prototypes in pervasive gaming unsuitable for competitive use, support for training purposes could be envisioned. If *Sports over a Distance* [MST+07] is a reality, coaching over a distance should also be possible.

11 Future Work

We are now working on conceptualizing these findings into a coherent framework that extends existing theoretical work around the notion of exertion and sociability between distributed participants. Furthermore, the generalizations drawn from the presented work need to be verified across more examples. Conceptual themes need to be identified, which could be followed by investigations into the appropriation of use of these games. In particular, a longitudinal study beyond the novelty effect could provide valuable insights for other researchers.

12 Conclusions

We have argued for the incorporation of physical activity and exertion into pervasive games because of

their possible health and social benefits. We have presented an overview of current designs that leverage demanding full-body interactions in order to provide players with an enhanced gaming experience while supporting physical activity in a networked environment to facilitate social aspects. This approach support players in geographically distant locations, and hence presents new opportunities in contrast to existing physical games and sports activities, but also new challenges. Based on remaining issues we identified through reflections on the designs and questions that arose from evaluation work, we described opportunities for future work. Further analysis will contribute to our understanding of how exertion in networked games can be used most effectively. With our work, we hope to provide guidance for other researchers in the area and to facilitate greater awareness and exposure of networked exertion games and their benefits.

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