# Jogging over a Distance between Europe and Australia

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**ABSTRACT**

Exertion activities, such as jogging, require users to invest intense physical effort and are associated with physical and social health benefits. Despite the benefits, our understanding of exertion activities is limited, especially when it comes to social experiences. In order to begin understanding how to design for technologically augmented social exertion experiences, we present "Jogging over a Distance", a system in which spatialized audio based on heart rate allowed runners as far apart as Europe and Australia to run together. Our analysis revealed how certain aspects of the design facilitated a social experience, and consequently we describe a framework for designing augmented exertion activities. We make recommendations as to how designers could use this framework to aid the development of future social systems that aim to utilize the benefits of exertion.

**ACM Classification:** H5.2. Information Interfaces and presentation (e.g., HCI): User Interfaces.

**General terms:** Design, Human Factors

**Keywords**

Exertion Interface, whole-body interaction, exergame, exergaming, audio, spatialization, sports, running, mobile phone, heart rate, physiological data.

Fig. 1. Jogging over a Distance between London, UK, and Melbourne, Australia.

## INTRODUCTION

Over the past few years, a number of computer systems have emerged that place the user's muscles in the centre of the experience, fostering physical exertion as part of the interaction. By "exertion" interactions we mean interactions with technology that require intense physical effort from the user [23]. Current systems that support exertion interactions often measure performance achieved by the user, and allow for social exchange around this performance after the experience. For example, technologically-augmented treadmills measure covered distance over time, and some internet-enabled systems even allow uploading this data to social network sites, supporting distributed participants [1]. Mobile systems such as the Nike+ support outdoor exercising, providing a runner with performance feedback upon a button press, and a subsequent opportunity to upload and share this data back home at the PC, where it becomes part of an online challenge game, combined with text chat, about who ran the most miles over a certain time period. [3].

We are presenting new work that aims to combine the benefits of these approaches while offering a different way of looking at comparative performance. Our approach offers an investigation into the use of technological augmentation that: a) informs the exertion activity throughout instead of just in the end, b) allows the integration with networking advances to allow distributed participants to exercise together, and c) draws on physiological data for social comparison. The insights gained can help us create more engaging systems in the future, and we believe more engaging experiences will lead to participants coming back and exercising harder, longer and more often.

Supporting exercise participation is important, as various benefits, in particular social and physical, are attributed to exertion activities [44]. For example, studies suggest that participating in physical exercise together can facilitate social relationships [30], and that sports activities can contribute to team-building, bonding and social rapport experiences [33, 44]. Sports research has also investigated effects in the opposite direction: Social facilitation theory suggests that having others join an exertion activity can contribute positively to the exertion outcome [9, 11, 16, 44]. Recent research suggests that such social benefits can emerge even in mediated environments [23]. However, as computationally augmented exertion is a relatively new phenomenon, there is, so far, only a limited understanding of the role of design in supporting the relationship between exertion and social factors, especially in mediated environments [11, 16].

In order to contribute to such an understanding, we investigate "Jogging over a Distance", a system that supports social jogging partners who want to run together, but are geographically apart, and investigate the user experience when using the system.

Jogging over a Distance is a prototype that can be used outdoors. It includes an integrated audio channel delivered via a headset to enable participants to communicate at any time. The communication channel is spatialized so that runners can experience a sense of being 'ahead', 'behind' or next to each other, as known from co-located jogging. However, the spatialization is controlled by the difference in participant's target heart rate, allowing joggers with different physical capabilities to run together, something they cannot do when co-located.

Jogging over a Distance is for runners who consider jogging a *social* activity: jogging together is used to motivate and challenge one another to go jogging in the first place, to jog faster, and maybe even further [30]. Most social joggers are not primarily focused on performance improvement; rather they value the social benefits that arise from participating in an exertion activity together. For example, they use jogging as an opportunity to 'catch up' with what is going on in each other's lives, where the exertion activity of jogging functions as social lubricant [30].

It is important to acknowledge that not all joggers like to talk when exercising, but for our target group, this is an essential part of the experience [30]. Being able to talk while jogging can also help identify if the exertion level is too high: some doctors recommend that newly aspiring joggers pace themselves in a way where they can still speak without much difficulty [32].

We believe that when mediating such social jogging activity, it is important for designers to retain the social affordances of exercising together. Without consideration of the underlying elements involved, exertion systems might leave participants acting independently, i.e. jogging "alone", and hence missing out on the benefits of jogging together [24, 42].

In this work, we focus on the activity of social jogging to investigate how to design for technologically augmented social exertion activities. Our position is that in focusing on the user experience of engaging with these systems, we can contribute to knowledge of the underlying elements involved; in turn, this knowledge can help create more engaging systems and experiences that lead to more captivated users and hence to sustained and repeated participation. This knowledge can be readily applied to the design of augmented exertion systems, such as technologically equipped treadmills and exercise bikes and also to mobile exercise support systems such as implemented in sports watches and mobile phones. Exertion activities are also recently being attended to by the computer game industry, spurred by systems such as Nintendo's Wii [28] and Microsoft's Kinetec [20], and we believe our insights might also be useful in informing the design of activities supported by such systems.

## OVERVIEW

Our introduction detailed our motivation for investigating how technology can enhance social exertion activities, and explained our focus on the activity "jogging". Next, we detail prior work and identify a lack of understanding of how technology can support the tight coupling between exertion and the social aspects of the exercise activity. We then describe a study of Jogging over a Distance and present salient themes derived from the analysis of user data that involved jogging partners being apart on the opposite ends of the world, revealing insights into how a social exertion experience was facilitated despite the distance. Finally, we suggest how future designs could implement these themes by framing them as design dimensions.

## BACKGROUND

Research in exertion interactions suggests that design can facilitate the relationship between social experiences and exertion [8, 16, 21]. However, what we do not know much about is how to design for this relationship [11, 16]. This has been attributed to a lack of prototypes that allow exploring this relationship, as well as a limited amount of studies that investigate the user experience with these systems [21]. Lindley et al. found that the nature of the interaction changes from "hard fun" to more social play in a commercial computer game when participants are involving their bodies as promoted by the game's design [16], but it has not yet been explored how the design achieved this. De Kort et al. explains that users have an intrinsic need to experience their physical and social environments kinesthetically, and hence embodied interactions are important in facilitating social affordances [11], with Webb et al. arguing further that social affordances can be designed for [43]. However, there has not been much exploration in how to design for these affordances when exertion is involved, in particular when it comes to distributed environments, as mediated communication can pose additional challenges but also opportunities [40].

Practice-based researchers have explored the role of design in supporting these bodily interactions through the creation of augmented exertion activities that often support geographically distributed participants. For example, the VR exercise bike allows for distributed races in an online environment [6]. Self-reported anecdotal evidence from participants suggests that knowing the heart rate from remote riders motivated them to cycle faster. In the Shakra system [2], where the aim is to increase participants' daily step-count with an augmented pedometer system, comparing each other's progress was found to encourage participants to exercise more frequently. However, the authors do not provide guidelines on how to design for this social progress exchange. Similarly, the Fish'N'Steps pedometer system [15] used peer pressure to encourage increased participation. Consolvo et al. found in another distributed pedometer-based system that awareness of activity and social influence mechanisms are important themes for design [10]. These pedometer systems differ from the distributed VR exercise bike system in that their social support is temporally or contextually detached – feedback occurs only upon explicit request, usually after the exertion activity back at the desktop PC rather than as part of the activity. The exception might be Marshall's performance piece in which users must run in order to be able to continue listening to a poem delivered via a mobile phone [18].

This paper aims to extend these studies with a view on how users experience the social elements of exertion interactions *throughout* the activity, rather than as a post experience, in order to offer insights into how design can facilitate these interactions. In order to do so, we conducted a qualitative analysis of the user experience with Jogging over a Distance.

It is important to note that our focus is not on investigating implications for behavioral change or isolated performance improvements. Prior work has already demonstrated that technology augmentation can result in behavioral change [15]. We acknowledge that the subject of performance improvement (i.e. an increase in pace) is pertinent, however, this is predominantly investigated in sports science, aimed at serious athletes rather than social participants [31]. Similarly, we also acknowledge that supporting behavioral change, such as making exercise part of a healthy lifestyle that is sustainable over years, is important, however, getting people to improve their ongoing involvement with exercise is a long and complex process [19] which is beyond the scope of this paper. In this work, we focus on the user experience and make the assumption that engaging user experiences can facilitate long-term behavioral change. We take the stance that through rigorous analysis of user data we can learn about aspects of the design that facilitated engagement, and by applying this knowledge to future designs we can enhance engagement that in turn leads to increased user participation.

## JOGGING OVER A DISTANCE

With Jogging over a Distance, two jogging partners arrange to run at the same time (Fig. 1). Each jogger wears a headset and a wireless heart rate monitor strapped around their chest. They also wear a small pouch around their waist, which contains a mini computer and a mobile phone. Although the audio could be transmitted via VoIP, the mobile phone voice channel helps keep latency to a minimum. Before the run, the system prompts users to enter their preferred target heart rate (often known through the use of heart rate monitors, otherwise acquired through a 'test' run), which allows users to specify the physical effort they plan to invest based on their fitness levels and goals.

While the participants jog, their heart rate data is sent wirelessly to a server. Each jogger can hear the audio of their jogging partner, captured through a microphone on the headset. The participants' relative heart rate data affects the position of the audio in a 2D plane that is oriented horizontally around the jogger's head. Etter et al.'s work [14] describes that spatialized audio can support people running around outdoors, however, running aggravates sound localization [17]. To overcome this problem, the spatialization effect is amplified as described in Mueller et al. [22].

The spatialized audio provides an indication of the relative heart rate of the jogging partner. When both joggers are at their preferred heart rate, they hear the audio coming from right beside them, as if they were running side-by-side. The same applies when both joggers divert from their preferred heart rate at the same percentage, for example, if both joggers raise their heart rate to 110%, the audio stays in the center. However, if one of the partner's heart rate increases, the audio sounds as if it is moving ahead of the other runner, or if the heart rate decreases, the audio sounds as if it is coming from behind the jogger. This way, the jogger is able to detect whether their partner is putting in more, the same, or less, effort, based on the relative heart rate to one another. The system lets the jogger know when he or she needs to speed up or slow down in order to 'stay' with their partner.

### Design Rationale

Jogging over a Distance is unique as it offers opportunities for social interaction throughout the duration of a distributed exertion activity, unlike most other jogging support systems such as Nike+ [3] and Fish'n'Steps [15], which support social exchange only after the exercise occurred. These systems focus on absolute performance, i.e. distance travelled over time, however Jogging over a Distance goes a different way and considers the users' heart rate data. Research systems such as those presented by Nenonen et al. [26] and de Oliveira et al. [12] have already demonstrated that heart rate data can be successfully used to control interactive experiences; we present its first use in an outdoor environment across countries. Lastly, Jogging over a Distance does not use heart rate data directly, but adjusts it computationally relative to the heart rate of the other person in order to allow people with different physical capabilities to enjoy a jog together; something they could not do if they were co-located. The design approach was to see the physical distance between the joggers not as a problem the technology needs to 'address', but rather as an opportunity for new experiences.

This research is part of a multi-stage investigation into the user experience of computationally augmented exertion activities. Previously, we examined the use of location information to enhance exertion performance, and audio to support communication between joggers [30]. We identified its contribution to the experience compared to when jogging alone [25], situating our work between sports and computer games [22]. We have since created several versions of Jogging over a Distance, based on feedback from this prior work. We dismissed approaches that used a handheld display, as reading while running is difficult due to the movement, and users found it unsafe as the focus away from the jogging path might cause them to trip and fear of injury is an important issue for joggers. We considered indoor treadmill use, however, many joggers prefer the outdoor experience with the changing surroundings as stimulant combined with the health benefit of being in fresh air. We also tested several GPS-based implementations [25], but were never satisfied with the accuracy of reported pace. Lastly, most step-counters were too inaccurate for the demands of our joggers. We are aware that an audio approach using headphones might isolate joggers from the sounds of approaching traffic when running in urban environments, and hence have also experimented with using motorized laser pointers mounted to the joggers to indicate how far ahead the other person is. We found the running movement causing too much jerkiness for the laser light to be suitable as position indicator, and hence decided to focus on the audio-only approach as our joggers prefer running in parks where there is no traffic, and the use of headphones is familiar to them through their experience of jogging with iPods. This paper presents findings from the latest system.

## STUDY

As we are interested in the jogging experience rather than the pace performance, we used a qualitative approach to gather data from our participants. We used audio recordings from interview data after participants ran in pairs using Jogging over a Distance. Each run was between 25 and 45 minutes long, and interviews lasted for up to 2 hours. The interviews contained open-ended questions about their experience and their interactions with one another. We took extensive notes during and after the interviews to allow for further reflection and analysis.

### Participants

We report on 14 runs. We invited potential volunteers from our personal contacts who fit our profile of social jogger (jogging with others, but not regularly in competitions) via email, also asking if they know of additional participants who have jogged before and can recruit a partner they would like to run with, looking out especially for joggers who migrated to one of our other international locations and wanted to run with their old jogging partners again. This worked well; overall, we had 17 participants, four joggers wanted to run a series of runs with different partners, which we welcomed and marked in the analysis. For a listing of jogging pair constellations see table 1. All pairs had prior social relationships: they were either friends or siblings. The participants were all volunteers and were not monetarily compensated for their efforts.

| Participant | jogged with participant | how often |
|---|---|---|
| 1 (Australia) | 2 (UK) | 4 times |
| 1 (Australia) | 3 (Australia) | once |
| 1 (Australia) | 4 (Australia) | once |
| 4 (Australia) | 5 (Germany) | once |
| 6 (Australia) | 7 (Australia) | once |
| 6 (Australia) | 8 (UK) | once |
| 8 (UK) | 9 (Australia) | once |
| 10 (Australia) | 11 (Australia) | once |
| 12 (Australia) | 13 (Australia) | once |
| 14 (Australia) | 15 (Australia) | once |
| 16 (Australia) | 17 (Australia) | once |

Table 1. List of participant constellations.

Seven runs were with participants in the same city (Melbourne, Australia), where runners were jogging on different paths. The other seven runs were with participants separated by over 16,000 kilometers, where one jogger was in Australia and their partner in Europe (UK or Germany).

We asked the participants if they had a preferred heart rate they would like to run at, and if so, entered that as the baseline into the system. If they did not know their preferred heart rate, we provided them with a heart rate monitor before the study to let them determine which heart rate they would be most comfortable with.

The participants were between 26 and 44 years old. Seven participants were female and ten were male. Their jogging experience varied from jogging regularly between 2-4 times a week (6 participants), to others running only occasionally (11 participants). During the course of the study, they jogged for an average of 39 minutes, covering a total of over 85 km.

### Data Analysis

We analyzed the interview data using a grounded coding process to identify salient themes. Using an iterative process, we refined the themes by drawing on the notes we took and created affinity diagrams [27]. We also included our participants in the data analysis process to understand their experience [41], for example, we discussed their logged heart rate data with them in order to unpack how their experience evolved throughout the run.

## SOCIAL EXPERIENCE

Our initial findings demonstrate that Jogging over a Distance can facilitate a social experience. In the following section, we detail our evidence for this claim, and also describe the themes that supported the emergence of this social experience (Fig. 2). Furthermore, we suggest how to frame these themes as design guidelines for future distributed exertion systems.

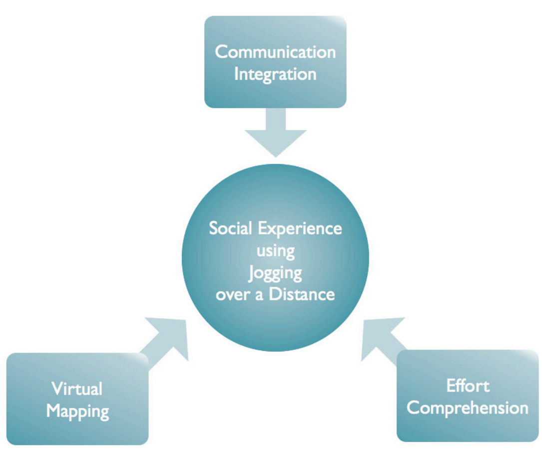


Fig. 2. Three themes that facilitated a social experience using Jogging over a Distance.

Participants remarked on how the system facilitated a social experience similar to that experienced in co-located jogging: *"It was great, because we jogged together" [P6], "This was almost as good as jogging together" [P9], "I felt like he was there with me…" [P8, 2nd]*. In some cases, the system provided an even better experience than co-located jogging: *"This was much better than jogging together, because I never had to slow down and wait for my partner" [P3]*. Different physical capabilities were dismissed: *"We could jog together, even though [partner] is so much fitter" [P4]*. Social presence, (we use the working definition of "sense of being with another" [7]) also played an important role in enjoyment of the activity: *"It was good to have him with me, as he made me forget about the jogging" [P9]*. This sharing of an experience affected how much effort some participants invested: seven participants said they jogged further than they would have if they were alone: *"Because I could hear him jogging, I kept on running, if I would have been on my own, I would have stopped earlier" [P4]*.

### Communication Integration

Communication Integration refers to the tight link between the audio and the physical effort the joggers invested.

The Jogging over a Distance system encouraged participants to adjust their speed based on their desire to talk: the spatialization meant that the communication volume was at its maximum (and hence communication was easiest) when both participants were investing the same physical effort and hence 'running side-by-side'. In contrast, the 'further' runners were apart, the softer the volume got: *"I wanted to talk, so I tried to run as fast [sic] as [X]" [P2]*. This was similar to co-located jogging, where both partners have to run at the same speed in order to be able to talk. On the other hand, unlike in conventional jogging, the system never lowered the volume so much that they could not talk: even when very far apart they could still communicate. Participants appreciated this, especially from a safety perspective, as the time-difference between the countries meant that some joggers had to run at night, where they felt safer being able to communicate with someone at any time.

It was also interesting to note that talking was not the only way to determine one's relative position: our joggers said they also inferred it through the breathing of the other person, as the audio-only approach sensitized them to it: *"You listen to the breathing more, because that's what you concentrate on, because you can't see the other person, so you concentrate on that more, and that makes you feel like you are interacting." [P13]*. However, it was easier to identify if the other person was ahead or behind if she/he was talking, hence participants sometimes appeared to be talking just for that reason: *"We often just asked 'Are you in front?' to figure out where the other person is" [P9, 10]*.

### Effort Comprehension

Effort Comprehension refers to the ability of the system to support players in understanding their exertion investment through the use of heart rate data.

By using the heart rate of the participants to affect the interaction, the focus was on the participants' 'effort' rather than the traditional focus on sporting 'performance', i.e. how far they ran in which time. The system gave the participants a new perspective to understand their body and its capabilities and limitations through the heart rate sensing technology, offering insights into the activity difficult to acquire without the technology. Participants found using heart rate in this manner engaging, as it was novel compared to their previous jogging experiences: *"It was interesting to run with a heart rate" [P4]*. The technological augmentation provided an opportunity to contribute to kinesthetic literacy [4], (Moen calls it movement literacy [21]) described as the participants' knowledge about their body and its capabilities: *"You feel good about yourself afterwards [... while] I learned something about my heart rate" [P9]*.

However, the theme Effort Comprehension through the implementation of a heart rate-based approach also posed challenges for some of our participants, in particular a more performance-oriented pair discussed extensively during the interview how they should understand their experience: P16 and P17 were training for a 'fun-run' at the time of the study. Their usual running route is around a park, where they often include a competitive element to see who finishes the round first in order to 'push' each other to faster times. As with the other participants from the same city, we asked them to run around the same track, but in opposite directions to simulate an 'over a distance' scenario. After the run, they reported that they competed throughout the jog by trying to get their voice 'in front', however, when they both approached the finish line from two different directions, P16, who was 'behind' for most of the time in terms of the audio space, crossed the finish line first. As a result, there were two different ways of judging the outcome for these participants: based on the new understanding of their efforts through the heart rate data, or their traditional 'crossing the line' convention. As a result, they were discussing who actually won the race, and decided that crossing the finishing line is still their determinant for success in this competitive approach.

For participants who ran in different parks this conventional finish line approach was not available. However, it was important to compare their efforts, but less in a competitive sense (maybe because they were not training for a particular event), but rather in a collaborative way of helping each other through the associated discomfort of jogging, knowing that their partner was equally investing into the activity: *"...you know the other person is going through the same experience, you know she is also exerting herself, makes you feel as if you are in this together" [P8, 1st]*. *"Just knowing that someone else is going through the same pain right now makes it more endurable" [P9]*.

### Virtual Mapping

Virtual Mapping refers to the ability of the system to translate exertion from the player into digital representations at various degrees of granularity.

Jogging over a Distance maps the players' exertion investment to a shared digital space, in which these representations are 'leveled'. Participants compared it to the use of a handicap in golf. In Jogging over a Distance, this approach enables participants of different physical capabilities to run together even though their speed might be very different. This approach addresses a common need among joggers: *"We tried running together [previously] but stopped doing it because we run so differently, but this way we could run together, it was great!" [P9]*.

However, getting this mapping right is not straightforward. Although some of our joggers experimented with different baseline heart rate values to start off with, their form on the day, track conditions, and other contextual variables affected their run, and they commented afterwards that they should have selected a different baseline value to start off with.

## DISCUSSION

Based on participant feedback, we now discuss how the social experience was facilitated in Jogging over a Distance by the three themes.

The data that led to these themes also showed that any design recommendations that emerge from these themes are not clear-cut: for each theme, we presented instances where the theme was prominent and contributed to a positive experience, but also examples where the theme was a hindrance or detrimental in some instances. As a result, we now frame each theme as a design dimension (inspired by the use of design dimensions for tangible user interfaces [13]), which is characterized on one end by an extensive use of the associated concept, and on the other end by a limited use. Neither end should be seen as a more desirable design goal: both have advantages and disadvantages. Which direction a designer will go in his/her thinking during the design process depends on the rules of the game, its context and target users. In this sense, the themes are "things to think about" when designing an exertion game, while the designer should also consider the location on each dimension to aid the design process further.

### Communication Integration

Our previous work on mediated jogging involved running with a mobile phone [30] where the communication channel was not affected by the exertion and vice versa. In contrast, the Jogging over a Distance system features a tight coupling between the exertion and the communication channel. This means that the system's output, i.e. one's relative position, is delivered through the same medium as the communication channel, keeping the focus on one medium, in contrast to, for example, a separate mobile display, that might distract users from their running environment and cause accidents.

Moreover, in Jogging over a Distance, the introduction of a spatial aspect to the communication channel facilitated this integration, as action in the exertion space (jogging) caused changes in the communication space (direction of the audio). As both participants' bodies were moving spatially, an associated spatial aspect to their communication channel emerged. This is similar to the experience from co-located jogging, where people share a physical space. It has been suggested that social presence can benefit from spatial properties [7], and our results resonate with this, as for our participants, the emergence of a spatial virtual environment contributed to the social aspect of the activity as this virtual environment – the audio space - was shared amongst the participants. Unlike other approaches that use a moving body to convey a sense of social presence [5, 36], we have shown that it is not necessarily the changing location of the body that is needed for facilitating social presence, but rather that physiological information resulting from the body moving, i.e. heart rate, can also contribute to it.

The data has shown that there are benefits for a not-so-tight Communication Integration as well. In Jogging over a Distance, a design choice was made to feature integration not as tight as known from traditional jogging: even if the participants are very far 'apart', they can still talk to each other (although with limited volume). This design decision was initially implemented in case of a need to trouble-shoot technical issues, but participants found it valuable as a safety tool, because jogging in the dark in parks has security issues associated with it and they found it comforting to be able to talk to someone at all times.

As a result, we now frame Communication Integration as a design dimension in order to serve as aid in the design process of future exertion systems that aim for social experiences.

#### *Communication Integration as Design Dimension*

**Communication Integration refers to the tight link between the communication channel, most often featuring video, audio, or text, and the physical effort players invest**. This can be a two-way link: for example, a system could require players to invest physical effort to be able to communicate, while the players are also required to communicate in order to become aware of each other's efforts. This integration can be tight or loose, or, in other words, ranging in terms of the quality of the link from high to low. An example of low quality integration could be a treadmill-based exertion system, where the communication channel is a separate videoconference that is set up independently, placed at the side of the treadmill. Such integration does not foster the interrelationship between exertion and social aspects; however, it makes communication readily available for participants, as they can communicate at any time. It is up to the designers to balance the integration between tight and loose based on their design intentions for social interaction.

### Effort Comprehension

In Jogging over a Distance, Effort Comprehension was facilitated by providing players with indicators of their heart rate, offering insights into their bodily capabilities, fostering kinesthetic literacy, that are otherwise – without the technology – difficult to achieve. This insight was intertwined with a social aspect, as the heart rate was represented in the audio space only in relation to the other player, making any action a participant performs that changes the heart rate only meaningful in relation to the other participant. Furthermore, the data was not displayed numerically on a display, but rather subtly 'blended' into the activity, to not distract from the exertion activity in order to support focusing on the run while it was also important for the participants that their view was not diverted to prevent accidents.

The ability to consider heart rate, rather than conventional pace data, is an important opportunity for technology in exertion activities. The use of heart rate monitors enables novel experiences not known from traditional sports. Furthermore, it also highlights unique input mechanisms for designers when compared to traditional button-controlled systems. Prior research had already demonstrated that using physiological data can be used successfully as input for an exertion system if designed appropriately [12, 26, 39], and our study highlights its social potential when used in a distributed environment.

The data also showed that offering new opportunities for comprehending effort can lead to a conflict with our traditional knowledge of how to make sense of exertion: our traditional understanding of sports experiences is so focused on goals, records etc. that we find it difficult to understand the role of these new insights. So far, heart rate monitors are mainly used to train for an increase in traditional performance measures, but we believe they also have the potential to facilitate completely new experiences, however, we need to design them appropriately so that their data does not clash with our traditional knowledge. Our example with the 'fun run' pair taught us that the heart rate data works better if the participants are *not* co-located, as they then *lack* the ability to compare performance in a traditional way.

#### *Effort Comprehension as Design Dimension*

**Effort Comprehension refers to the ability of the system to support players in understanding their exertion investment.** Using support for physiological body data is one way to foster a deeper understanding of exertion investment. However, designers need to be aware that by providing more and more information about a user's body, it can distract from the exertion activity and hinder what Moen calls the 'pleasure of motion' [21]. Furthermore, pushing the limits on the dimension in terms of offering new ways of understanding exertion investment can also clash with our traditional way of looking at performance. Such a new understanding needs deliberate design considerations, as it might affect how we understand the goal of the game, and hence how we train towards these goals.

### Virtual Mapping

The mapping in exertion systems converts an exertion action performed by the body to a corresponding action in a digital domain. This mapping is often not a one-to-one relationship, but reduces complex physical movements to a simpler set of distinct movements in a virtual world, mostly due to limited sensing technology. This is often used in games to support players in having quick successes. For example, in Wii Sports Tennis [29] almost any up-down arm movement results in a successful serve, supporting beginners by fostering a fantasy element of 'anyone could play tennis'. Facilitating a fantasy component is one of the key elements why people play computer games, supporting the suspension of disbelief typically associated with computer gaming [35]. In Jogging over a Distance, this mapping involved a social component, furthering the fantasy element. The system mapped the physical effort a participant invested to a virtual audio world, but this mapping was also affected by the effort invested by the participant's partner. The input to the system was not the heart rate value, but the deviation to the desired target heart rate based on the partner's deviation, giving it a social component. In other words, the investment by the participants became meaningful only when seen in this social context. For our joggers it meant that the technological augmentation created an environment in which they could suspend their disbelief and engage in a fantasy that involved them running at the same level as their partner, even though that partner might be much fitter. In other words, as the spatialized audio introduced a virtual world to the experience, it enabled leveling, which in turn supported a fantasy world for the participants that was free of physical differences, where everyone can run with anyone.

This virtual mapping based on relative effort has previously been used by a treadmill-based exertion game [39]. The authors have shown that the leveling does not negatively affect the engagement with the game, and we also found that the leveling was not detrimental to the social experience if participants approached it with a social attitude.

In Jogging over a Distance, we believe the approach of adjusting people's efforts through leveling lends itself to the use of heart rate data, as heart rate is already a relative measure for people's physical capabilities.

#### *Virtual Mapping as Design Dimension*

**Virtual Mapping refers to the ability of the system to establish relationships between the exertion and representations in the digital domain**.

Mapping bodily investment to digital events can be highly detailed or very coarse, each offering benefits to the experience: a coarse matching allows beginners to quickly engage, fostering a fantasy aspect of being able to 'play like a pro'.

Finding a suitable mapping depends on many factors and is therefore not a straightforward task for the designer. Beginners benefit from a coarse mapping, and getting this mapping right might be easier than the mapping for advanced athletes, as for them any mismatch in the millimeter or millisecond range can mean the difference between success or failure, hence the demands on accurate mapping and its associated sensor technologies is much higher. Also, advanced participants might get frustrated when they cannot apply their skills from traditional sports if the mapping fails to consider the richness of movement, and, conversely, they are also not able to transfer any newly acquired bodily skills that they perceive to have obtained from a traditional sports activity. As a final note, designers might also want to consider dynamic game difficulty balancing, in which the mapping is automatically adapted based on the players fitness level in real-time.

## FUTURE WORK

Now that we expanded our understanding of exertion interactions, an interesting avenue for future research is the investigation of social aspects in larger activities, in both the physical and virtual space. Our conceptual notions will structure our future investigations into large-scale online sports, and our design themes will guide the development of additional prototypes. This might include notions of a spectator [34] and performance experience [37], which could add valuable insights into an extended understanding of social experiences in mediated exertion interactions.

## CONCLUSION

This paper has focused on the experience of distributed exertion activities, a topic that has gathered considerable interest over the recent years, as mediated exertion is believed to offer many health benefits. We assume that more engaging experiences facilitate increased exertion, and have therefore aimed to contribute to an understanding of what makes these experiences engaging. We argue that social support can enhance the engagement with the activity, and have therefore investigated how design can facilitate a social experience to support players who cannot be physically together.

We have shown how the design of Jogging over a Distance facilitated a social experience of participating in an exertion activity together. This offers insights into our understanding of how to foster social participation in exertion activities. To facilitate this increased understanding, we have presented three themes that aim to provide designers with 'things to think about' when creating exertion games. In particular, we have extended prior work on exertion games with theoretical concepts that can facilitate social experiences. In order to aid designers in the process of creating future exertion experiences, we have framed these themes as design dimensions, and have explained why a designer would chose either end of the dimension.

We have found that in Jogging over a Distance, the three dimensions and their positive ends stood out as they facilitated the social experience we were interested in. It should be noted, however, that the proposed design dimensions are not intended to provide a comprehensive list. We have only highlighted a limited number of them, and other exertion interactions might reveal additional implications for design. Furthermore, it should be also noted that it is the participant who ultimately chooses to invest exertion in an activity [44] and makes it a social experience [35], which design can only facilitate.

We also acknowledge that there is still more work to do: we have found that technology design can enhance the experience, but we also need to know if long-term studies can show if people do jog longer and more often due to the increased engagement. As with any new technology, participants might have also been intrigued due to the novelty, which might wear off after ongoing use. We tried to investigate this by having participants run multiple times, and further studies will shed more light on this. Also, we found organizing two participants in different time zones can be challenging; we can only imagine the administrative difficulties when future systems emerge that support larger groups.

This work has implications for theory and practice as it expands our understanding of the role of exertion in interactive experiences. This is particularly relevant when seen in the context of the rising trend in incorporating exertion in computer game experiences: Nintendo's Wiimote [28], Microsoft's Kinetec [20] and Sony's Move [38] are all additional components to the traditional console that enable exertion game play. We believe our insights can also be useful for the design of activities involving these technologies, contributing to the associated health benefits. Furthermore, we believe our work can provide guidance for designers who want to facilitate social experiences by adding exertion to an interaction, or enable multi-user support in existing exertion systems.

In sum, we hope our work contributes to an understanding of the relationship between social and exertion aspects, and what role technology design can play in facilitating this relationship in order to help designers and players to profit from the many benefits of exertion.

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