A Framework for Exertion Interactions over a Distance

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ABSTRACT

Exertion games are an emerging form of computer games that aim to leverage the advantages of sports and exercise in order to support physical, social and mental health benefits. Despite the increased attention these games received recently, there is a lack of understanding of what role the game's design plays in encouraging people to invest physical effort into these games. We aim to contribute to this understanding by presenting a framework for "Exertion Interactions over a Distance", consisting of three core concepts: exertion, sociality and engagement. To demonstrate the usefulness of our framework we utilize a networked game called "Remote Impact" that encourages intense physical exertion. We hope our work can support researchers in gaining an understanding of this exciting new field, whilst also aiding designers in the creation of new games, leveraging the associated benefits of exertion.

Author Keywords

Framework, design space, Exertion Interface, physical, tangible, videoconferencing, sports, exhausting, social.

CR Categories

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

INTRODUCTION

Physical exertion, such as exhibited in sports, has been attributed to major benefits. From a physical health perspective, sport can contribute to weight loss, addressing the obesity issue, and reduce the risk of cardiovascular disease, diabetes, several types of cancer and more [Pate et al. 1995]. From a social and mental health viewpoint, sport is believed to teach social skills, provide opportunities to socialize [Weinberg and Gould 2006], encourage team-building and support individual growth and community development [Gratton and Henry 2001].

Despite the many benefits of exertion, involvement in exertion activities varies: for example, most people in the developed world do not achieve the minimum amount of recommended exercise [Weinberg and Gould 2006]. There are many reasons why people do not engage in physical activity. Amongst the main factors are concerns that most prescribed exercise programs are not engaging enough [Ratey 2008]. Also, most people prefer to exercise with others, and joining peers for sports activities has been found to increase uptake, engagement, and satisfaction [Weinberg and Gould 2006], however, finding suitable partners can be difficult [O'Brien and Mueller 2007]. In fact, many of the proposed strategies that aim to increase participation in physical activity suggest involving social support mechanisms as well as facilitating intrinsic motivation by making the exertion experience enjoyable and meaningful [Weinberg and Gould 2006].

Game research has begun to contribute to this area, mainly through designs that augment sport activities with an interactive game component to facilitate an increased level of engagement. These designs often comprise of attaching a workout machine to a game console, such as connecting an exercise bike to an XBox [PCGamerbike] or a foot-stepper to a Playstation [Gamercize]. The aim of these approaches is to foster engagement with the game to distract the user from the discomfort that comes with exercise [Fogg 2002]. These approaches have been criticized, however, for relying on activities such as stair-climbing and treadmill-running that have high drop-out rates [Bogost 2007], activities which users have described as lacking purpose and meaning [Weinberg and Gould 2006]. Other approaches such as the Nintendo Wii [Wii] and the Eyetoy [EyeToy] allow for less monotonous free-form movements, however, their benefit in terms of energy expenditure has been criticized for not being high enough to contribute towards the recommended daily amount [Graves et al. 2007]. It has also been suggested that these games do not properly support the social rituals that are afforded by exertion activity, in particular when compared with traditional sports [Bogost 2007].

Most emerging interactive systems that consider exertion aim to address individual aspects associated with non-participation in physical activity. They either try to increase engagement, but fall short in supporting the creation of a meaningful exertion activity, or they facilitate a more meaningful activity, but can only generate limited exertion levels well below those associated with traditional sports. Some systems focus on promoting the exertion aspect, but fall short in facilitating social support mechanisms. Despite the potential to contribute to successful exercise participation, there seems to be a lack of understanding of how informed game design can integrate these exertion and social aspects successfully. In order to support the development of such an understanding, we offer a theoretical framework that is aimed at guiding research in this area.

We believe that one of the key advantages of augmenting exertion activities with technological advances is the opportunity to support distributed participants. Supporting geographically distant participants can expand the number of possible sports-partners, enabling activities that otherwise might fail if no local co-participant is available [Weinberg and Gould 2006]. Supporting distributed participants also allows for utilizing social support structures despite being apart [Mueller et al. 2003]. We therefore focus on supporting participants in geographically distant locations in our investigations on exertion games.

OVERVIEW

We begin by describing related work on frameworks and systems that consider exertion in computer games. We then argue that a dedicated framework has the opportunity to highlight the unique aspects exertion can contribute to interactive systems in a way no previous work has done. We explain our proposed framework of "Exertion Interactions over a Distance". This framework has three core concepts, exertion, engagement and sociality, and we argue that "meaning" can ascribe a value aspect to these concepts. To demonstrate the usefulness of our framework, we utilize a networked game called "Remote Impact", which encourages intense physical exertion. We conclude with a research agenda for future work in light of the opportunities and dangers of facilitating exertion in interactive games.

RELATED WORK

Frameworks

Prior work has considered the importance of the user's body in interactive systems [Dourish 2001]. As a result of this research, theoretical models have emerged to better understand the role of bodily interactions [Loke et al. 2007]. For example, Larssen et al. applied three movement-based frameworks to an analysis of a game played with an EyeToy camera [Larssen et al. 2004]. They found that although these frameworks can be useful in analyzing specific aspects of the game, there is still a lack of understanding of the role of the body in interactive systems, in particular when it comes to exertion in games.

Bianchi-Berthouze et al. investigated the benefits of including bodily actions in interactive games. Their work found that such an approach could unleash regulatory properties of emotion, leading to more engagement in games [Bianchi-Berthouze et al. 2007]. In a follow-up study, the researchers investigated the effects of introducing a co-player to such a game [Lindley et al. 2008]. The authors found that the quality of the engagement changes, from "hard fun" to "social fun", and suggest that this change was facilitated by the bodily movements that were "natural to the scenario of the game".

De Kort et al. describe a framework for the sociality characteristics in games, arguing that "gaming is often as much about social interaction, as it is about interaction with the game content" [de Kort and Ijsselsteijn 2008]. Some of their sociality characteristics have been considered in the exertion work by Fogtmann [Fogtmann et al. 2008], which builds upon the findings on "kinesthetic movements" [Moen 2006], suggesting a link between mediated social and exertion activities. However, there is still a lack of theoretical understanding how these social concepts take shape in exertion interactions that are supported by interactive systems.

Exertion in Interactive Systems

Exertion has been considered in computer games before, however, mostly from an implementation rather than a conceptual perspective. Hämäläinen et al. developed an exertion game that tracks martial art athletes to map their movements onto virtual avatars [Hämäläinen et al. 2005]. Although multiple players can play "Kick Ass Kung Fu" simultaneously, there is no analytical understanding of how the engagement of the game and social aspects interact, and how this interaction is supported by the design.

Mueller et al. have created a physically effortful game that can be played over a distance based on soccer. Although exertion and connectedness as concepts were used in a user study, it is still to be investigated how the engagement from the game contributed to its success [Mueller et al. 2003].

The Virtual Fitness Center [Mokka et al. 2003] uses 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 environment data. Unfortunately, this system has not been evaluated, therefore it is unclear how social support from co-riders affected performance, and how much the feedback from the virtual environment contributed to engagement.

APPROACH

Prior work has investigated exertion in interactive systems, and designs exist that consider social and engagement aspects in regards to exertion. However, there is a lack of understanding as to how these aspects are facilitated through the game's design. We aim to contribute to this understanding by presenting a framework that encompasses three aspects: exertion, sociality and engagement. As we focus on networked games, we call our framework "Exertion Interactions over a Distance".

EXERTION INTERACTIONS OVER A DISTANCE

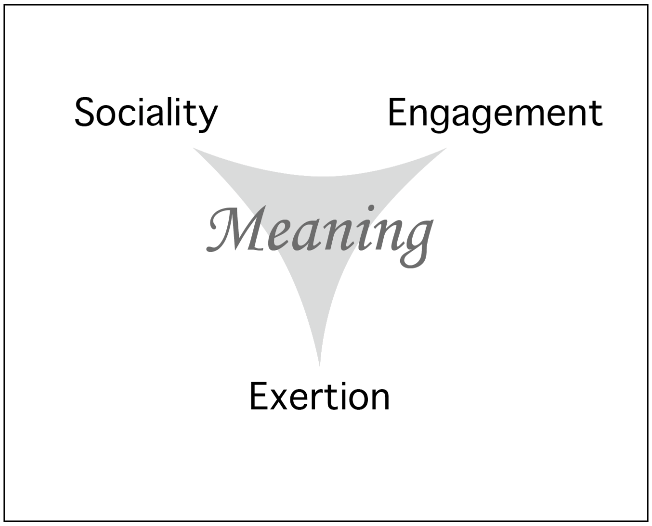

Fig. 1: Framework for Exertion Interactions over a Distance

Our framework consists of 3 core concepts: exertion, sociality and engagement (Figure 1). The centerpiece 'meaning' provides a lens to see how these concepts are interwoven and mutually engaged. We begin by discussing the role of meaning and then describe each concept, including how meaning can add a value aspect to each.

Meaning

We use the notion of meaning to ascribe a value aspect to our framework. Meaning can refer to the value of an activity around one of the core concepts – exertion, sociality and engagement -, but more importantly, it interweaves them all, offering a way of describing and analyzing the quality of their interrelationships. Just like McCarthy and Wright, we use meaning to understand the user's engagement with technology [McCarthy and Wright 2004], as meaning is "constructed in practical acts of engagement" with the physical and social world [Wright 2008]. We believe meaning can also help us understand the sociality aspect in distributed social interactions, as suggested by Dourish [Dourish 2001], and we further suggest that meaning is also useful when trying to analyze how these aspects relate to exertion: Weinberg and Gould laid the groundwork by suggesting that exertion activities can be evaluated in terms of how meaningful they are [Weinberg and Gould 2006]. Considering the notion of meaning can help us understand exertion, as exertion can describe a quality of the interaction, while, in turn, "interaction creates meaning" [Hummels et al. 2007].

Exertion

Exertion refers to the act of exerting, involving skeletal muscles, which results in physical fatigue, often associated with physical sport. An exertion interaction utilizes an input mechanism in which the user is investing physical exertion. An exertion interface has been previously defined as being physically exhausting and requiring intense physical effort [Mueller et al. 2003].

Exertion and Meaning

People need to "see purpose and meaning" in their exertion activities, otherwise participation rates will drop [Weinberg and Gould 2006]. One way of making exertion activity meaningful is by augmenting it with an interactive game experience, however it must be meaningful to the user in regards to the activity. For example, we propose that exercise bicycles connected to computer screens should map the pedaling efforts to the characteristics of the virtual world, so that if the avatar climbs up a hill, the user has to invest more effort, attributing meaning (getting over the hill) to the exertion activity (pedaling harder).

Another way of supporting the construction of meaning in exertion activities could be to orient the actions on the real, physical world. We borrow the term "naïve physics" [Jacob et al. 2007] to explain this further. Naïve physics is the informal human perception of basic physical principles, or in other words, common sense knowledge about the physical world. This includes concepts like gravity, friction and velocity [Jacob et al. 2007]. We postulate that an exertion action could be made more meaningful if a player who hits a virtual object experiences kinesthetic feedback, as the player would expect this feedback in the real world.

Sociality

Sociality is the extent to which a system can give rise to and support social interactions between the users of that system. This extent depends on the quality of the social affordances inherent in the system [Kreijns et al. 2002]. Gaver calls them affordances for sociality [Gaver 1996], and they can derive from the physical environment, but can also be facilitated by opportunities for verbal and non-verbal communication.

Sociality and Meaning

Providing a context for sociality, for example through aspects of a game that offer "a reason to communicate" [Mueller et al. 2007b], can facilitate opportunities for social interaction [de Kort and Ijsselsteijn 2008]. When players participate in social play, they communicate via gameplay, and aspects of the game become "a context for stylized communication, mediated through social interaction" [Salen and Zimmerman 2003]. This meaning making through social interaction has been suggested to influence engagement [de Kort and Ijsselsteijn 2008] and exertion [Weinberg and Gould 2006].

An example of facilitating meaningful sociality is the support of awareness of a player's own, but also his/her partner's exertion level. Physical fatigue is a key element in exertion interactions, and knowing one's own and the other's level of fatigue can help to determine how to play the game and therefore provide a context for social interaction.

Engagement

Engagement can be described as our involvement with technology [McCarthy and Wright 2004]. Engagement in games is most commonly associated with a player's involvement with the gameplay. Here, it includes engagement with the exertion activities facilitated by the game. It has been suggested that this engagement increases if the exertion increases [Bianchi-Berthouze et al. 2007], however, as exertion can quickly result in fatigue, negative effects on engagement can occur quickly, a characteristic salient to exertion interactions.

Engagement and Meaning

One way of facilitating engagement in exertion interactions is by supporting meaningful play. For meaningful play to occur, a player should be able to perceive the immediate outcome of an (exertion) action, and the outcome of this action should be woven into the game system as a whole [Salen and Zimmerman 2003].

REMOTE IMPACT

Fig. 2: Remote Impact

We now demonstrate how our framework can be useful in the analysis a distributed exertion game. We use "Remote Impact" (Figure 2), a distributed game inspired by combat sport, as it encourages intense physical exertion [Mueller et al. 2008a, Mueller et al. 2007a]. We show how our framework helps in structuring user data, and supports identifying characteristic themes.

Gameplay

The gameplay of Remote Impact is as follows: Two remote players enter identical interaction spaces. They are facing a sensitive padded playing area, on which two shadows are projected, that of the remote person, and their own shadow. These shadows appear to be created by a light source behind each of the players, i.e. if they step closer to the interaction area, their shadows increase in size. If the players face the interaction surface, they can stand as if standing next to each other, because each surface shows the silhouettes of both people. The interaction areas are large enough to cover both body shapes from head to toe, each spanning a complete surface area of 2.10 x 2.50 meters. The players can also hear each other through an echo- and noise-cancelling videoconferencing-quality speakerphone.

Once the game starts, both players try to execute impacts on each other's shadow. They can target any area of their partner's body, and administer hits with their hands, feet, arms, legs, or their entire body. They can hit with a flat hand or use their fists. An impact on the remote person's shadow area is considered a successful hit. The bigger the intensity of the hit, the more points are scored. The players' scores are visible to both parties. If a hit is placed within the shadow area of the remote person, a visual indicator in a comic "pow"-style is displayed on the impact spot and a sound effect is played to indicate for both players that a successful hit occurred. The player with the most points wins the game.

Technical Implementation

Each station consists of a dedicated impact area, constructed of mattress-like foam and two layers of fabric. The foam is covered with a durable, but soft and lightweight rip-stop cover sheet. We wanted to detect the location as well as the intensity of hits and kicks without exposing technology that the user could break during the exertion action. We found no existing system that could meet our requirements; therefore we created our own sensing system. The impact of the user's body is measured by detecting the deformation of the surface area: upon impact, the fabric exhibits pulling forces which extent all the way across to the edges of the impact area. Along the edges of the interaction area are stretch sensors, which stretch when an impact occurs. Our sensing system forms a grid of 42 distinct impact locations that we found sufficient considering that most impacts occur with a fist or foot. Our approach for large surface interaction has the advantage that the sensors and electronics are moved away from the impact area, encouraging users to exhibit intense physical effort. Unlike many other large-scale interactive surfaces, our sensing system can differentiate between fast successive impacts, detects the intensity of hits, and supports multi-touch.

Image Recognition

One challenge we faced was the cone-shape capture area of the cameras, used for the videoconferencing system. Videoconferencing systems require the actors to stay a certain distance away from the projection screen, because this is where the camera is located, often attached to, or peaking through, a hole in the projection surface, capturing the local action. But such camera placement is problematic for impact games when the player needs to actually contact the projection surface. The conical capturing area of the videoconferencing camera does not provide adequate coverage when the player approaches the contact surface, in particular once she/he blocks all available light from entering the camera lens.

We therefore opted for an alternative approach to visualize the surface actions on the remote end: a camera mounted *behind* the user captures his/her actions. This captures all body movements, even when interacting with the surface area close-up. However, instead of distributing the videostream of the participant's back to the remote end, we use image analysis to detect the contours of the person and display his/her silhouette instead, reducing the unfamiliarity of videoconferencing a person's backside. We use a segmentation algorithm and distribute the generated vision analysis result over a network connection to the remote end. The user is able to determine the other person's body interactions in real-size, even when this person is standing close to the projection surface. However, the silhouette functionality takes away any facial expressions that might contribute to the enjoyment and social interactions between remote participants [Mueller et al. 2007b].

ANALYSIS

Exertion

Remote Impact encourages extreme physical effort by rewarding players with more points if they hit the surface area hard. It also supports interactions with all limbs and the torso, even concurrently, encouraging a full-body workout. Remote Impact also takes into account a person's location, hence encouraging the players to move back and forth, further demanding physical effort.

Players' exertion actions can help construct meaning because they are modeled after combat sports, in which "a player tries to control the opponent", interacting with one another's activity [Mueller et al. 2008b]. The players' actions involve concepts of "offence" and "defense" during gameplay via their bodies, characteristic of traditional combat games [Mueller et al. 2008b], hence the exertion activity supports meaning making for the players based on their prior knowledge.

The concept of naïve physics incorporated into the design helps the user to experience meaningful exertion. When hitting the surface area, the player experiences kinesthetic feedback, in contrast to, for example, the Nintendo Wii boxing game, another combat inspired game in which the user has to hit "thin air" in order to score points, with no kinesthetic feedback [Wii Sports]. Players expect such feedback from the real world [Jacob et al. 2007], hence Remote Impact is better aligned with naïve physics than Wii's boxing. It should be noted, however, that this approach to feedback through a deformation of a mattress represents a design tradeoff [Jacob et al. 2007], a more advanced system would also consider kinesthetic feedback coming from the remote player.

Remote Impact also supports an aspect of spatial scale: the remote player is projected in life-size, in contrast to a miniaturized representation. By comparing the size of their opponent with their own, players can estimate the amount of exertion needed to win the game, a design aspect contributing to the construction of meaning between exertion action and engagement.

Technological constraints can limit the detection capabilities of exertion actions, for example, many sensor systems in commercial games cannot adequately account for simultaneous actions of multiple limbs. Remote Impact supports the creation of meaning better as the sensing system does not require the players to artificially constrain themselves and interact sequentially: in the real world, exertion actions can happen simultaneously, and Remote Impact's detection system recognizes these actions simultaneously.

Sociality

Players in Remote Impact can communicate via an always-on two-way audioconference. Remote Impact also includes a life-size videostream of the remote person, artistically rendered as a shadow. Participants can therefore add meaning to their interaction through body language via their shadow representation. Research has shown that players can communicate affect through body posture [Bianchi-Berthouze et al. 2007]. The players in Remote Impact have therefore the opportunity to assess the remote person's exertion levels via their shadow's posture, but also via their breathing that they hear over the audioconference, adding to the sociality between the two sites.

Besides using a videoconferencing component, people have used touch to communicate meaning across geographically distant locations [Jocelyn and Karon 2007]. The players in Remote Impact have also the opportunity to communicate through touch, contributing to their social interaction, however, the current implementation is a design tradeoff: the feedback on the remote end is visual instead of kinesthetic. On the other hand, the system supports varying degrees of intensity, and hence allows players to "send a message" [Mueller et al. 2009], inscribing meaning via the associated score and the impact's distributed noise.

Engagement

Remote Impact aims to support engagement by modeling the gameplay on an existing exertion activity; it encourages actions known from combat sports such as wrestling, martial arts or boxing. These actions facilitate engagement of the entire body by supporting full-body contact; for the system, these activities are "sensable", "sensible" and "desirable" [Benford et al. 2005], in contrast to many exertion games in which technological fragility often limits full-body contact.

Meaningful engagement is facilitated through meaningful play: the player perceives the immediate outcome of exertion actions through visual, audio and kinesthetic feedback. In terms of integration, the outcome of an exertion action is woven into the game system as hits score points. The more points a player scores, the more likely she/he will defeat the other player though exposing oneself with a hitting action makes one vulnerable to being hit. This makes Remote Impact a game of offense and defense similar to combat sports, aiming to facilitate comparable engagement.

USER STUDY

In order to understand how participants play Remote Impact, we invited 20 volunteers. They were asked to organize themselves into pairs, and each team played a dedicated gaming session of at least 20 min and was interviewed together afterwards. The game interactions as well as the interviews were videotaped for a coding analysis. The interview was semi-structured, and the participants were encouraged to freely share their opinions. Our goal was not a formal evaluation per se, but rather to investigate what kinds of results an analysis that is guided by our framework could produce.

Exertion

People used excessive force when playing, and were kicking, slapping, boxing and slamming vigorously. During the interviews, participants expressed that they were much more exhausted than they thought they would be. Some of them were very out of breath: "This is the toughest exercise I had for weeks" and "This is more exhausting than the hour of squash I played earlier." Some participants asked if they could break because they felt too exhausted to continue.

Stress relief

One participant noted that the game had a "therapeutic effect" on him. He wanted to have the game in his workplace, because "that could be a great tool to let off steam in high stress work environments". Two participants, who played following their working day, commented: "We should do that everyday after work, to get rid of our aggression".

Sociality

One participant made an interesting point in regards to the sociality of related physical body experiences such as combat sports: Although martial arts are not traditionally regarded as team sports, the technological augmentation "turns it into a more social experience, extending its traditional role".

Shadow

One participant noted in the interview that she missed the ability to see the other person's facial expressions: "Especially if it is a stranger, it would be important to see how serious she or he is taking it". She suggested a videoconference display attached to the side, because "you would only need it during the breaks, when you have time to breath".

Engagement

Competitiveness

Although designed as a social game, players appeared to appreciate the competitiveness of the game, indicated by their comments such as: "This time I will beat you". However, some players got so involved in hitting successively that it seemed that they were unable to divert their visual focus to glance at the score.

Interaction Style

Some players followed a clear offensive approach in which they were trying to hit as often as possible, whereas others were more concerned about not getting hit. Neither tactic seemed to provide a distinct advantage. The strategy changed the nature of the exercise, however: people with a defensive style were using their legs more by running left and right, and some were bending down, trying to minimize their shadow surface area, whereas offense players were quickly out of breath because of their fast intensive hits.

Physical Contact

When asked if it was awkward that the game required hitting another person, the participants said that they did not see it as such. Some said that the stylized representation helped regarding the object to be hit as a "comic figure". Others compared it to computer game characters, and one player mentioned that it is "like in sport: you get your aggression out, but that does not mean if you are a boxer, you are beating up other people on the street".

Framework helps identifying opportunities

Our framework helped us identifying unique aspects characteristic to exertion games that might be missed otherwise. For example, by using our framework, we identified the themes physical contact and interaction style as described above. By relating them back to the three core concepts while being sensitized to the notion of meaning, we found the notion of risk, in particular physical risk, an important aspect in order to understand exertion games. Risk is associated with the irreversibility of the users' actions [Klemmer and Hartmann 2006], but can also be related to the risk of having an unpleasant physical experience by the means of the interaction. We were surprised how much participants valued the reduction of risk in Remote Impact when compared to traditional combat sports: "It's great that you cannot get injured!" One player had participated in recreational boxing before and compared the Remote Impact experience in terms of the risk for the other player and himself. We also observed that several players exploited this reduction of risk and played a purely "offense" approach by hitting as hard and as often as possible, without being concerned of getting hit. Risk is an important element of most sports; some even say that if a sport does not hurt, it was not a good game [Weinberg and Gould 2006]. This complex role of risk in exertion interactions is an opportunity for future work.

FUTURE WORK

So far, our work has focused on computer games in a competitive environment. Although the encouragement of exertion seems to facilitate competitive aspects in games [Mueller et al. 2009], collaboration behavior seems to be an intriguing area for future investigation, as sports research suggests social facilitation effects amongst participants [Weinberg and Gould 2006]. We also encourage future research that can contribute to our understanding of exertion games in which multiple players are involved, in particular how sociality aspects change when teams instead of individuals are playing against one another. Furthermore, we have also yet to consider the influence of audience members in exertion games.

DISCUSSION AND CONCLUSIONS

We have presented a framework for Exertion Interactions over a Distance to contribute to our understanding of exertion in interactive systems, with a focus on networked computer games. We explained our choice of three core concepts, exertion, sociality and engagement, and argue that by considering the notion of meaning, we can gain insights into how these concepts are intertwined while also ascribe a value aspect to them.

We have demonstrated that our framework can be useful in the analysis of exertion games; our example application was a novel competitive exertion game that supports distributed participants called Remote Impact. The framework helped identifying where design tradeoffs were made and aided in recognizing opportunities for improvement. We also used our framework to support an analysis of player data. The framework helped in structuring the analysis and identifying salient characteristic aspects. The framework also aided in revealing opportunities for future research, such as the augmentation of risk in exertion interactions.

We hope our framework can support researchers in analyzing existing exertion games, while also guide designers in creating future systems. Research in other application domains such as work and education might also benefit from our framework as these areas begin to consider the many benefits of exertion. We hope with our approach we are able to guide future research in this exciting new area.

FUTURE WORK

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