Schoolchildren's user experiences on a physical exercise game utilizing lighting and audio ☆

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ABSTRACT

Motivated by the troubling news on decreased exercise amount and increased obesity among children and adolescents, we investigated the possibilities of interactive lighting technology in encouraging children to participate in physical exercise in schools. We have created a story-driven physical exercise game based on light and sound utilizing a reasonably priced technological setup. The game has been evaluated with several groups of schoolchildren during physical education classes. The results show that a physical exercise game enhanced with lighting and audio keeps schoolchildren motivated both mentally and physically even after several playtimes. In subjective evaluations, participants still found the story of the game interesting after three playtimes, and were eager to exercise this way again.

1. Introduction

There is a great need to encourage children and adolescents to engage in physical activity. For example, only 29% of high school students in the United States report sufficient daily physical activity levels [5]. Time previously spent on physical activities is increasingly spent on video gaming and other forms of sedentary entertainment. Increasing children's motivation and interest in their health and physical activities is important, since childhood obesity is a serious and increasing challenge to public health [16], and regular physical activity in childhood and adolescence is shown to improve health and quality of life [14]. Physical education (PE) classes in schools play an important role in guiding children to lead a life with healthy amount of exercise. However, the time available for actual physical activity can be low [6]. Furthermore, there are children who may find physical exercise and sports unpleasant or uninteresting for various reasons, such as

poor coordination of movement. Supporting the improvement of physical abilities through games could potentially increase the chances of engaging in and benefitting from the positive outcomes of physical activities [12]. One way to foster health-related behavioral change is to use video games designed for this purpose [1]; exertion-based games have been shown to stimulate physical activity in inactive children [6] and to increase energy expenditure over sedentary activities [15]. This suggests that exertion-based games are a potential approach for promoting the physical health of children.

We have designed a game-based approach to physical exercises, where storytelling and dramatic elements, such as interactive lighting, inspire and guide children in the exercise activity. The aim of the system is to make physical activities more pleasant and motivating for those children who find current forms of exercise uninteresting or even intimidating. The proposed prototype is targeted for 7–12-year-old schoolchildren and is meant to be played during PE classes together as a large group under the supervision of a teacher.

Modern technology provides many possibilities for implementing exercise games, but we aimed at a solution that would also be economically viable for schools. The total cost of the implemented system is projected to be less than two thousand euros. It consists of a laptop computer, a set of audio speakers, a wireless gaming controller, or a mouse, and a set of computer-controlled lighting

fixtures mounted into a mobile trolley. The physical setup, augmented with additional hardware like motion sensors and a projector as necessary, can be utilized for many other uses in schools as well, for example in teaching mathematics or physics in a more immersive way. Although obviously very relevant for school context, pedagogical aspects are not in the core of this article. Instead, we focus on the entertainment aspects of the game. Thus, subjective experiences gathered from the children themselves form the central message and contribution of this article alongside with the introduction of a novel system for inspiring physical education classes.

The proposed prototype has been iteratively developed and studied in PE classes with several groups of schoolchildren [9]. First, a short version of the game was evaluated in order to validate the viability of the concept in general, and after extensive development work, a complete version has been studied with close to 300 schoolchildren in total. Here, we focus on the complete version and its evaluations. The results indicate that it is possible to create immersive and engaging, story-driven exercise games using a small set of lighting hardware and audio. Children's imagination can create rich experiences from rather simple elements, and the resulting experience helps minimize feelings of exclusion. Our long-term evaluation results also show that it is possible to maintain children's interest towards the game with rather simple stories and game elements.

In this article, we first cover related work on exercise games and their design challenges. Then, we introduce the context of our research, and the audio and lighting based exercise game we developed. Finally, we present our in situ evaluations and the results focusing on user experiences, and conclude by discussing the implications of our findings.

2. Related work

2.1. Exercise games

With the advances in consumer electronics, such as the introduction of the Nintendo Wii controller and the Microsoft Kinect, health and activity related games have become popular. Brox et al. [3] categorize such games into three genres: *educational games*, *persuasive games*, and *exergames*. Educational games are primarily designed for improving health literacy of both children and adult population. Persuasive games, on the other hand, attempt to persuade people to modify their behavior, be it increases in exercise or adjustments of dietary habits. Finally, exergames are video games that are used in an exercise activity [13]. Different definitions exist for exercise-based games. Whitehead et al. [15] for example, give a general definition for exergames as "*video games that provide encouragement to exercise, particularly for an audience that may be reluctant to engage in the more traditional forms of exercise*". Mueller et al. [10], on the other hand, stress the role of physical activity within the game, and define exertion games as "*digital games where the outcome of the game is predominately determined by physical effort*". Exergames can therefore be categorized according to their attributes along various dimensions, such as the nature of the gaming aspects, technological enablers, the type of physical activity, and engagement.

Especially in commercial exergames the game-related aspects create the biggest draw to the game, as one is rewarded for successful physical activity in the context of game-play session. On the other hand, there are also games that aim to change players' behavior in the long term. These games are most commonly mobile and provide incentives for physical activity during the day.

According to Yim and Graham [17], exergame user interfaces range from free-motion interfaces, i.e., games where the players can freely move their body, to traditional electronic interfaces. In between are systems utilizing exercise equipment like exercise bikes. They categorize game worlds as either *virtual*, like in traditional video games utilizing a TV screen, *augmented reality*, i.e., the view of real world overlaid with virtual elements, or *reality*. Most of the existing exergames reviewed by Yim and Graham are based on a virtual world or augmented reality and are either free-motion interfaces or utilize some form of equipment. Yim and Graham found no examples of exergames featuring augmented reality and utilizing either equipment or traditional electronic interfaces, but find both areas promising research avenues. Our game environment fits this gap, being a blend of augmented reality and reality approaches, as it combines physical activity in the real world with virtual elements by augmenting the room using interactive lighting. Although the players' activity takes place without equipment per se, the facilitator, i.e., the teacher in school-context, is equipped with a controller in order to direct the flow of the game.

In terms of the various attributes of physical activity, Mueller et al. [10] provide an exertion framework with four "lenses": the *responding* body, the *moving* body, the *sensing* body and the *relating* body. These lenses can be used to view the exercise activity from different perspectives. Another axis comes from the gaming side in the form of *rules*, *play* and *context*. Here, rules relate to the uncertainty and players' awareness of the exertion, play relates to how and in which rhythm the exertion is expressed, and context to the risks related to the physical exertion (e.g., injury) and how the system supports the development of understanding about one's body.

A critical aspect of game success deals with the fun and entertainment players derive from the game. Sinclair et al. [13] examine these issues in the context of the game's attractiveness, which ultimately controls whether players are compelled to exercise long and hard enough to derive health benefits (effectiveness). Their dual flow model, which combines attractiveness and effectiveness, is based on the concept of flow state by Csikszentmihalyi [4] – a concept that has been applied also to video games and is applicable in the context of sports and other similar physical activities as well. Sinclair et al. build their framework by considering the optimal area in the two-dimensional range of the game's challenge level and skill level both from psychological and physiological sides.

2.2. Design of exercise games

To be successful exergames must both attract players, so that they are played enough to provide gains, and make the players actually exercise effectively during the game play [13]. Many authors have provided requirements and guidelines on how to reach these goals. Baranowski et al. [1] list features, which make games appealing and potentially efficient as behavior change tools. While their discussion considers video games in general for health-related targets, these features apply well to exergames. Interactivity and personalized, interactive goal setting and tailored feedback form the key aspects. However, they put more focus on the immersive and attention maintaining nature of games and identify stories and fantasy as tools for reaching this goal. They also raise the point that immersion should be believable in order to be a component of intrinsic motivation.

While many exergames are aimed for solo play or a very small number of players, many researchers raise the issue of social aspects in exercise motivation. Technology can support shared exercise experiences over distance and one of the most interesting implementation comes from Park et al. [11], who have explicitly considered the concept of interpersonal synchrony to leverage the positive social effects of "*improving rapport and entitativity*" and also make exercises more enjoyable. They provide technical