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Exerbraining for schools: Combining body and brain training

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Abstract

The growing obesity problem has reinforced policymakers and educators to devise strategies that encourage introduction of novel and engaging physical activities in schools. At the same time, the gaming industry has introduced a game genre that requires the player to be physically involved in the game (e.g. Nintendo Wii, Kinect). In fact, exergames (physically activating games) is an emerging trend that may influence also the implementation of the physical education curriculum and classroom activities in the near future. In this paper we discuss the possibilities and limitations that exergames can provide for schools. We review exergaming practices that have been introduced to schools and propose a new form of exergaming, exerbraining that combines both body and brain training and thus could fit well to school context. We report the results of the case study in which we tested an exerbraining game involving mathematical content. The results showed that students enjoyed playing the game a lot and exerbraining games can provide effective learning solutions for schools.

Keywords: Exergame,; game-based learning; serious games,;mobile phone; accelerometer; school

1. Introduction

The potential use of games in educational settings is huge because a large and growing population is engaged with playing games. However, the popularity of games has also created problems. For example, obesity has become a big problem in many countries recently. It has been argued that traditional video games are one of the main reasons for physical inactivity [1, 2]. Furthermore, physical activity in schools has steadily declined since the 1970's. During this same period, the percentage of overweight children in the US, for example, has more than doubled [3]. The emerging exertion game genre tries to have an effect on this by encouraging players to perform physical movements during gameplay.

This article considers the possibilities that exergames provide for school settings, with an emphasis on a) exergaming solutions, b) their potential to improve physical health, social activity, and academic performance, and c) their use in school settings. Based on previous research we introduce a new serious game genre,

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exerbraining, that combine gameplay elements from brain training games and traditional exergames. Furthermore, we report the results of the case study in which we tested an exerbraining game called Brain Dive. Finally, the paper concludes with recommendations to facilitate the development effective exerbraining games for schools.

2. Exergames

According to Mueller et al. [4] exergames 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. An exertion game is controlled with an input mechanism that requires a player to intentionally invest physical exertion [5]. Exertion can be defined as an act of exerting, involving skeletal muscles, which results in physical fatigue, often associated with physical activity and sport.

2.1. Exergaming solutions The effects of exergaming

Exergaming is not a new phenomenon. It was introduced with the Atari 2600's footpad controller in the early 1980's and popularized with Konami's Dance Revolution product in the 1990's [6]. However, in recent years, the development of motion-based controllers has facilitated the advent of the exertion game genre. Currently, exertion games are specifically associated with Nintendo's Wii and recent research has used Wii games as test-beds in many different contexts [e.g. 7, 8]. Most commonly exertion game movements are detected via motion sensors, cameras, pressure sensors or GPS sensors depending on the type of the game.

In addition to smart phones, for example, Nintendo's Wiimote controller and some other manufacturers' controllers (e.g. PlayStation Move) can sense rotational orientation and translational acceleration along three-dimensional axes [9] that has provided new possibilities to design physically active games such as tennis and boxing (Wii Sports). Additionally, Nintendo has developed a Wii Fit fitness game (2008) that is controlled with balance board. Wii Fit aims to help people with low physical self-efficacy to become more comfortable with their bodies and exercising. In the Wii Sports games, players are required to move their bodies to control their virtual characters in the game, but the movements are quite small and intensity is usually low. However, research and tryouts have been also conducted in order to make the gaming more active with the help of heart rate measuring devices. The use of heart rate measurement immediately brings more intensity to the gaming experience and makes it automatically more energy requiring. For example, Nenonen et al. [10] have used heart rate as a control method in their game called Pulse Masters Biathlon. Besides motion sensors some platforms like PlayStation Move utilize camera based movement detection. Furthermore, GPS positioning has been used in outdoor games to generate location based game plots. The players have GPS enabled mobile devices and the game has been designed in a way that the location affects to the game logic. Such games are for example Taz company's FlagHunt, TrezrHunt and Moomin Party.

2.2. The effects of exergaming

According to Staiano and Calvert [11] exergame playing can lead in physical, social, and cognitive developments. Next the major findings about the impacts of exergaming are shortly reviewed.

2.2.1. Physical impacts

Many exergames can increase energy expenditure from sedentary or light levels to moderate levels [e.g. 12, 7], but only few exergames result in vigorous levels of energy expenditure. Effectiveness has been mainly assessed according to the energy expenditure level that is not solely an adequate measure for exertion games targeted for children. In growing children the neuromuscular system is rapidly developing. The coordination of movements improves when they are exposed to different environments and various movement patterns during physical activities. Muscles need activity [13], and bones need impacts to become strong [14].

For example, Wii games rarely cause needed impacts. Compare e.g. Wii Boxing with the actual boxing sport. Graves, Stratton, Ridgers & Cable (2007) [8] found that while playing the Wii uses significantly more energy than playing sedentary computer games. However, the energy used when playing active Wii games is not high to contribute towards the recommended daily amount of exercise in children. However, the playing styles affect greatly on energy expenditure; based on playing style some players expend more calories than the other. Nevertheless, according to [15] as people become more involved and successful with active-play games, they develop the skills that make it easier to engage in physical activity. They enjoy perceiving that their bodies are becoming more fit, and they experience more physical and emotional well-being. These rewards and benefits are motivating and can lead to more engagement in physical activity.

Papastergiou (2009) [12] has conducted a survey based on Dance Dance Revolution, which is based on a platform interface that requires the player to step onto different parts of the platform, based on onscreen instructions. Results showed that intensity levels were just enough to fulfill the recommendations of the American College of Sports Medicine (ACSM), which would indicate that exergames can be an effective form of exercise. Furthermore, Graf et al. [7] demonstrated that energy expenditure during active video game play is comparable to moderate-intensity walking. On the other hand Daley [16] criticizes the previous studies and calls for more extensive and methodologically robust research. He argues that, although studies have produced some encouraging results regarding the energy expenditure of exergames, active gaming is no substitute for real sports. All in all, whether the intensity is proper or not, players benefit from exergaming in some level; caloric expenditure, heart rate increment, and coordination skill developments [17, 11].

2.2.2. Psychosocial impacts

Game playing is usually a social event. According to Staiano and Calvert [11] exergame play may provide opportunities for social interaction that influence on friendship selection, self-esteem, moods, and motivation. In general, Social aspect of gaming may reduce the risk of social isolation and loneliness [18]. The results have indicated that social interaction and meeting of other players are important motivations to play games [19]. For example, Kiili et al. [6] found that team-based multiplayer games motivated adolescent children a lot and team play facilitated also flow experience. Some studies have showed that exergaming can increase the self-esteem [e.g. 20] and self-efficacy [e.g. 11] of overweight children. The nature of exergames may partly explain this; when playing exergames players usually directs their attention toward a screen instead of peers, which may reduce body self-consciousness during playing. Furthermore, Lieberman [19] found that children and adolescents enjoyed and sustained exercise more after they began playing exergames. Exergame playing may motivate players to increase also real-world physical activities [15].

2.2.3. Cognitive and academic impacts

Emerging research has shown that exergame interventions in schools can improve academic performance, reduce classroom absenteeism, tardiness, and negative classroom behaviors [15]. However, although only very limited evidence about the impact of exergaming in academic performance exists, great deal is known about the benefits of physical activity on cognitive functioning and academic performance. The results has indicated that increased physical activity has the potential to positively impact cognitive functioning, memory and academic achievement [21, 22].

Lind et al. [23] have studied the effects of attentional association and dissociation on exertional, affective and physiological responses to exercise. The study states that shifting one's attentional focus towards environmental stimuli (dissociation) instead of one's body (association) has been theorized to enhance psychological responses and attenuate physiological stress [23]. It suggest that exercising would benefit learning by enhancing the player's capability to respond while exercising.

2.2.4. Exergames in school settings

Exergames can provide engaging activities for schools. In some schools exergames are integrated into physical education classes. One example of such approach is West Virginia's statewide exergame curriculum [24]. According to Staiano and Calvert [11] for example in United States, exergames like DDR are being incorporated not only into physical education classes, but also to recesses, lunchtimes, and after-school programs. However, there is not much previous research done that would actually concentrate on the exergaming as a part of classroom activities. The research has mainly focused around different classroom activities promoting physical physical development.

3. Towards exerbraining games

The proposed exerbraining games are a new and unstudied branch of research in the era of serious games. Exerbraining games combine gameplay elements from brain training games (cognitively challenging games, see e.g. [36, 37]) and exergames (physically challenging games). According to Quinn [27], it is a real challenge to design engagement that integrates with educational effectiveness. The challenge of developing exerbraining games is even higher, because an exertion dimension has been added to this problem space. Next the theoretical foundation for exerbraining games is presented.

3.1. Theoretical foundation for exerbraining games

The framework for Exertion games [28], Dual flow model [29], Framework for sports engagement [30], and Cognitive load theory [31] form the foundation to design exerbraining games. The challenge is to balance the amount of physical, cognitive, and sensomotoric workloads in order to optimize learning and health effects.

According to Tenenbaum [32] exercise intensity impacts the focus of attention. Thus, the integration of learning content and exertion interfaces raises new game design challenges. Research on sports has shown that when the physical workload increases, attention allocation shifts from dissociation to association [e.g. 33, 34]. Association can be defined as turning focus inward and toward bodily sensations, while dissociation is focusing outward and away from body sensations [35].

Such natural attention change disturbs processing of game elements and that way also learning and problem solving. In other words, this means that during high physical workload it is hard to concentrate on problem-solving and game stimuli designed to enhance learning. Thus, we should develop solutions that take into account players' physical and cognitive constraints and in the ideal case adapt to them. Figure 1 presents a starting point to conceptually model this phenomenon. Vertical axis describes the amount of cognitive workload and horizontal axis the amount of physical workload. The dashed diagonal line illustrates the constraint that combination of cognitive and physical workloads form on performing challenges of the game; what higher the sum of workloads is, the higher the possibility to fail in the game is. The model is illustrating only the relationship of the components rather than precise values for each. Thus there are no units on the axis.

The balancing of workloads and adaptation to players characteristics is very challenging, because for example the cognitive workload is composed from several factors like amount of game elements, the amount of players, the amount of possible movements, the complexity of rules, the type of audio-visual implementation, game tempo, etc. Furthermore, the senso-motoric aspect creates more challenges for designers. However, despite of this complexity exerbraining games may provide an alternative learning solution that facilitate both academic and health goals.

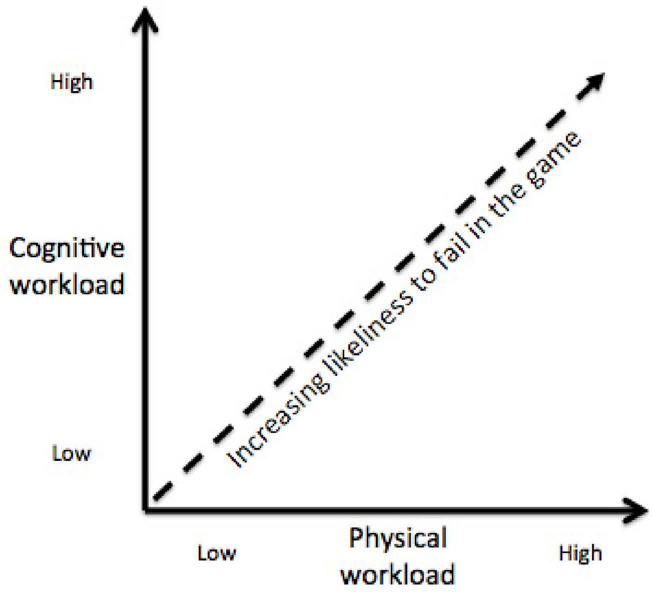

Fig. 1. Exerbraining model

3.2. Motivation to introduce exerbraining games in schools

As mentioned earlier exergames are increasingly introduced into the physical education courses in many countries. However, only little time is reserved for physical education in schools. Although the research results have shown that physical activities enhance learning, students spend the majority of their time sitting in a classroom, which is not an optimal solution either from learning or health perspectives. The demands of the curriculum and the time constraints make the introduction of exergames to schools very challenging. However, the proposed exerbraining games provide new possibilities for schools to increase physical activities, because they can be used as an alternative learning solution that can be applied on a day-to-day basis in elementary schools without interfering with the objectives of the curriculum. The aims of the proposed approach are convergent with the EU strategy for "Europe on Nutrition, Overweight and Obesity related health issues". One of the four pillars defined to tackle obesity is a clear reduction in high-risk behaviors, including lack of physical exercise and poor nutrition. According to this, the EU stresses the importance of introducing good practices regarding the provision of regular physical activity in schools.

4. Brain Dive case study

The objective of this case study is to study how students perceive an exerbraining game called Brain Dive and the game fits into classroom context.

4.1. Description of Brain Dive

Brain Dive is a single player exerbraining game, in which a player controls a fish character by running still (Figure 2). As a game controller the player uses mobile phone that is connected to Internet. The exerbraining mobile application detects player's movements from accelerometer data and sends them to the game. When player runs his black fish moves upward and when the player is still the fish moves downward (the speed of the fish is determined according to intensity of running). The running takes place at one spot and the game can be played for example from TV, laptop or projector screens.

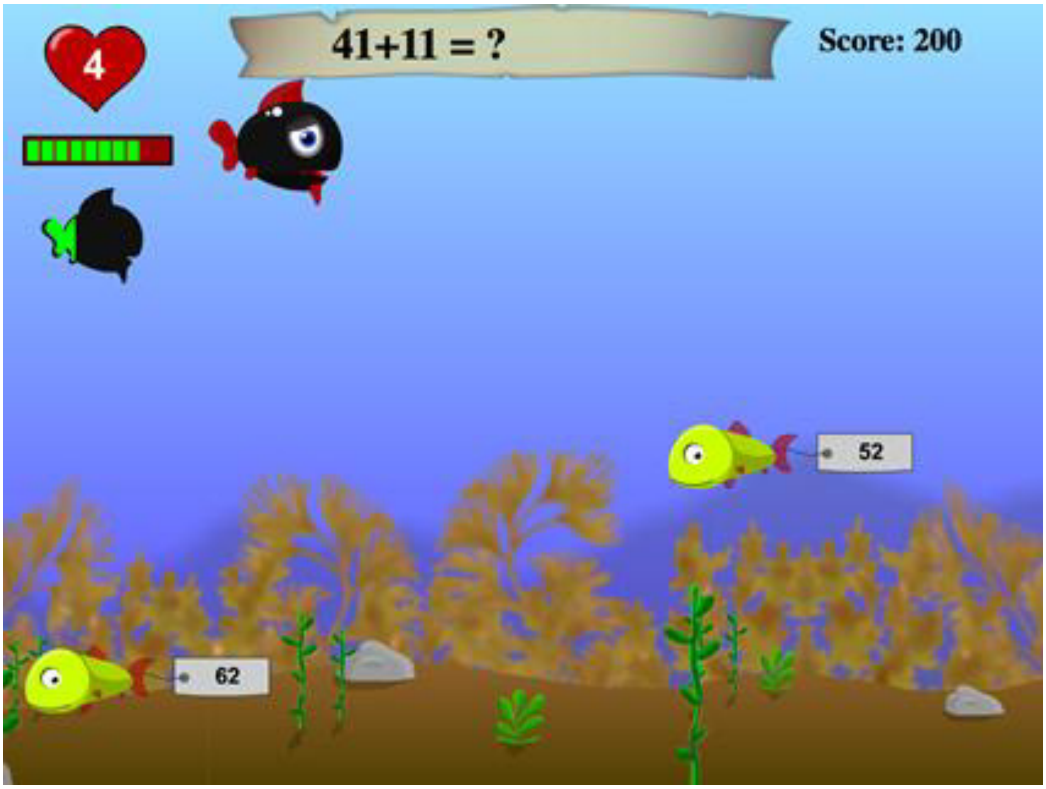

Fig. 2. Screenshot of Brain Dive game

Brain Dive game is designed for elementary school students and it includes mathematical and logical tasks. For example, in the first level player has to solve addition tasks. In figure 2 you can see that on the top of the screen there is a task panel that presents the active task (currently 41-11 = ?). In this case the player notices that the yellow fish approaching from right side drags the sign with number 52, so he decides to direct his own fish towards the yellow fish and solve the task by eating that fish. After that the new task is activated and game continues the same way until the level is completed. In the following levels player is challenged with more challenging calculation and reasoning tasks.

It is notable that this game is only a single player prototype. Even though, similar technological implementation enable also multiplayer games for the whole class, up to tens of players, which is not possible e.g. with Microsoft Kinect. There are also other statements that support the use of mobile phone over other already existing game consoles for example Kinect and Wii. First of all, there are lots of students that already posses an adequate smart phone that can be used as a game controller so the equipment is already there. Also the idea of playing on the wireless connection enables the gaming to take place almost anywhere, anytime – the only equipment needed will be the wireless connection, computer (games are played on web browsers) and a screen/projector to show the game. This means there will be no fees on any additional infrastructure such as expensive game consoles to every classroom separately. This also enables playing at home and in free time if wanted.

4.2. Participants

The pilot study was conducted in spring 2012, in Sipoonlahti elementary school. Altogether 53 third graders participated in the gaming sessions during the one school day. Both of the genders were equally represented and the average age of participants was around ten years.

4.3. Procedure

The students attended the gaming session in three groups formed from different classes. Each gaming session lasted 45 minutes. The gaming sessions started with a short introduction to the Brain Dive game and also the idea of using mobile phone as a game controller was introduced. Because one Brain Dive game can last over ten minutes students played the game as a team. In practice, students were organized into a queue and the first player had the mobile game controller and played the game for a while. The game session carried on by changing the next student in line to be the next actual player while the rest of the class were cheering and following game events.

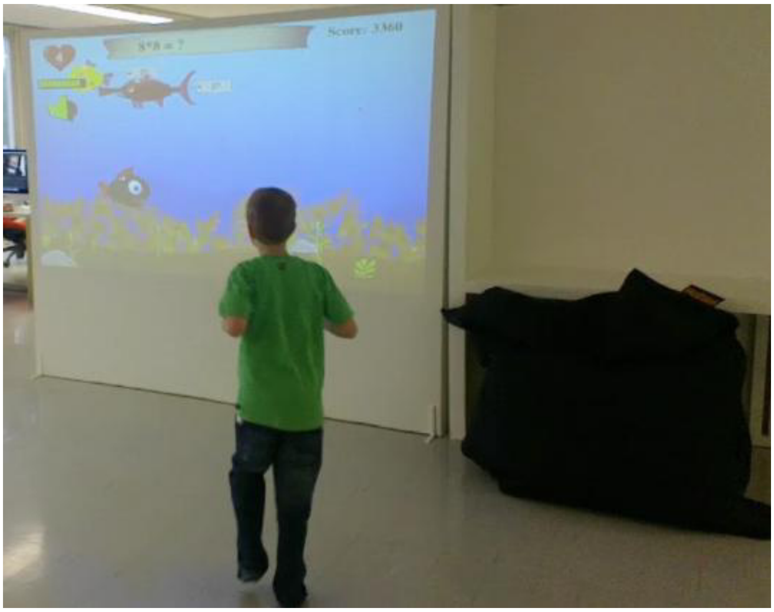

Fig. 3. A boy playing Brain Dive

Throughout the sessions, the students' behavior and experiences were observed by taking notes by two researchers. The observation focused on monitoring how the students perceived the game, how easy the adoption of the game was, how they act as a group when playing single player game as a team, and how the game fits the classroom context. The analysis of observation data concentrated on the 1) functionality of the game, 2) the motivating factors, 3) social aspects, 4) the learning benefits and 5) overall appreciation of the game experiment.

4.4. Results and discussion

In general, all the students enjoyed playing the Brain Dive game. Students adopted the idea of the game and the appropriate use of mobile phone as a game controller very fast. It could be argued that one mobile phone would not act as an ideal solution in the classroom that have several students in it and has its own dynamics. However, in this case the one mobile phone was enough in order to create successful gaming experience. After all, Brain Dive is a single player game, but there are also exergames that are designed for multiplayer purposes.

The clear majority was more than eager to give it a try in the first place and they would have wanted to play longer or try out different games that were available. The students were highly motivated to navigate the fish correctly (a.k.a. eat the fish with right answer) and therefore success and failure during the game was shown in extreme by screaming, jumping and in other anxious gestures. The tasks were perceived as appropriate to this age group and the game was not perceived physically too challenging. Furthermore, the levels and high score list motivated students a lot.

Very surprising and interesting finding was that the game that was originally designed as a single player game transformed into multiplayer game in the classroom. The social experience that the game provided motivated players a lot. In practice the game made the whole class to compete against the game as a group and it seemed that the actual player and the followers were equally immersed in the game world. In other words the game gathered all the students to run, think and solve the tasks at the same time. As result of this it was clear that while solving the mathematical tasks, the class was actually benefiting of playing both physically and cognitively. Since the Brain Dive offers several levels, different mathematical areas were handled during the game and the help of teammates were appreciated especially in the challenging tasks.

One interesting finding was that, if the students were disagreeing with each other, they started to justify and argue why their answer was right. By doing this, the students automatically explained the formulas and steps needed in solving the current task. From learning point of view this kind of behavior is important and fruitful. Such disagreements between students may generate a cognitive conflict that make a student dissatisfied with his or her existing conception of phenomenon, which may lead to conceptual change. Conceptual change is required in situations when the new information to be learned conflicts with a learner’s naïve, domain-specific theories. According to Ketamo and Kiili [36], conceptual change requires time and thus in mathematics learning games it is important to engage learners in playing for as long as possible in order to maximize the probability of conceptual change taking place. The observations of this study are convergent with this finding, while the communication and debate between students increased according to playing time.

The observation results support the basic assumption of the proposed exerbraining model. When the sum of cognitive and physical workload was high, players had difficulties to either solve the task or control the fish properly. This phenomenon appeared most clearly in last levels of the game and players that were not in good physical shape. In extreme cases the player stopped the running totally and concentrated on solving the task leading to losses of lives in the game or player get anxious and tried to aimlessly eat all fishes. These findings indicate that even in simple games some kind of adaptation system would be useful.

During the playing sessions occurred some problems. School's shaky Wi-Fi-connection caused the main problems. Due to this unreliable connection from time to time the mobile phones drop out of the game and the game control was lost for several seconds. This frustrated the students a bit, but since they were highly motivated to play, they also had a lot patience. In this sense the target group of this game was overall perfect. However, we have had similar tryouts for example with older participants and they experience such problems more radically that decreases the motivation to play. Therefore it is extremely important to introduce only technological solutions that are mature enough.

It is also noteworthy, that the participants of this study were conscientious and kind. When interpreting the results one must take into account that not all classes share as great team spirit as the participants of this study, which may lead to reluctance towards gaming in front of the whole class. In the perfect situation everyone is pursuing the same goal and trying to get there as a team. In worst scenario the actual player of the game becomes criticized and somewhat harassed by the others. However this did not seem to be a major issue in elementary level at least in our target group.

5. Conclusion

In this paper the concept of exerbraining was introduced and the implementation scenarios were discussed. The exerbraining games provide new possibilities for schools to increase physical activities, because they can be used as an alternative learning solution that can be applied on a day-to-day basis in schools without interfering with the objectives of the curriculum. In general, incorporating exerbraining games into schools and homes could promote students' healthier life style and combat against the emerging childhood obesity crisis. Exerbraining games could be used in schools in several ways. Games could be played for example in physical education classes, classrooms, hallways, and after-school program spaces.

Paper also reported the result of study in which the Brain Dive exerbraining game was tested. Technically Brain Dive is a web-based game and mobile phones are used as game controllers. Such solution is cost-effective, which may support the diffusion of exerbraining games into schools in the future. Because of the cloud-based solution exerbraining environments can be easily constructed and maintained. Additionally, cloud based solution enables students to play the games also at home and thus even exerbraining homework can be assigned. The use of mobile phones as game controllers is also very cost effective, since it is possible to exploit the devices that students already possess. As Kiili and Perttula [37] have argued, game controller is not a significant factor in playing experience. The crucial factor is the usability of the game controller – it just have to be easy to use and motion detection have to be accurate. They argue that the use of mobile phone as a game controller could widen the field of exergaming tremendously and facilitate the diffusion of exergames. Firstly, most of the students already have a game controller in their pocket. Secondly, individualized gaming information can be displayed on a screen of a phone or voice feedback can be utilized. Such interaction is not possible when using some other exergame controllers. Thirdly, the overwhelming feature in smart phones is a WLAN-connection, which allows the high amount of simultaneous players, fast data transfer and wide area connectivity. Especially, high amount of players has turned out to be very motivating factor in exergames [37]. Additionally, teachers have requested games that the whole class can play simultaneously.

Although the tested Brain Dive game included only mathematical content, exerbraning games can be developed from different school subjects. However, our previous studies have shown that exerbraining games that involve problem solving and teamwork motivate students most and can be used to boost the team spirit. As a part of FINNABLE 2020 project (http://www.finnable.fi/) we are currently designing such multiplayer exerbraining games that involve team-based problem solving phases following with physical execution of planned strategy. With such approach the challenges related to balancing of cognitive and physical workloads can be avoided.

To summarize, exerbraining have the potential to be integrated into the classrooms and even into the curriculum. In the future, we are eager to study whether exerbraining home assignments could become one of the most popular, engaging, and health-promoting school activities of the twenty-first century or not.

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