



HAL
open science

Multi-user virtual environments for physical education and sport training

Pooya Soltani, João Paulo Vilas-Boas

► **To cite this version:**

Pooya Soltani, João Paulo Vilas-Boas. Multi-user virtual environments for physical education and sport training. Cases on Immersive Virtual Reality Techniques, pp.20-41, 2019, 9781522559122. 10.4018/978-1-5225-5912-2.ch002 . hal-01973683

HAL Id: hal-01973683

<https://hal.science/hal-01973683>

Submitted on 16 Jul 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Multi-User Virtual Environments for Physical Education and Sport Training

Pooya Soltani

CNRS, ISM, Aix-Marseille University, France

Faculty of Sport, CIFP²D, LABIOMEPE, University of Porto, Portugal

Joao Paulo Vilas-Boas

Faculty of Sport, CIFP²D, LABIOMEPE, University of Porto, Portugal

ABSTRACT

For effective learning and training, virtual environments may provide lifelike opportunities, and researchers are actively investigating their potential for educational purposes. Minimal research attention has been paid to the integration of Multi-User Virtual Environments (MUVE) technology for teaching and practicing real sports. In this book chapter, the authors reviewed the justifications, possibilities, challenges, and future directions of using MUVE systems. The authors addressed issues such as informal learning, design, engagement, collaboration, learning style, learning evaluation, motivation, and gender, followed by the identification of required elements for successful implementations. In the second part, the authors talked about exergames, the necessity of evaluation, and examples on exploring the behavior of players during playing. Finally, insights on the application of sports exergames in teaching, practicing, and encouraging real sports were discussed.

Keywords: *Biomechanics, Electromyography, Learn, Motivation, Psychology, Physical Activity, Physiology, Swimming, Train, Usability, Virtual Reality, Exergame*

Soltani, P., & Vilas-Boas, J. P. (2019). Multi-user virtual environments for physical education and sport training. In K. Yang (ed.), *Cases on immersive virtual reality techniques*. Hershey, PA: IGI Global. doi:10.4018/978-1-5225-5912-2

INTRODUCTION

The new generation of students is growing up in a digital world, where they can multi-task and communicate the information rapidly (Prensky, 2001). Computer games and virtual environments are visibly present in the lives of these “digital natives” from a young age. They are comfortable with digital technologies and have different attitudes, expectations, and abilities towards technology (Beck & Wade, 2006). Advanced educational technologies can enhance several skills that traditional settings cannot account for (Passig, 2015). Students’ reading, writing, and communication have already been affected by the new technology, and educators are looking for possible engaging ways to increase their learning capabilities (Fee, 2007; Malliarakis, Tomos, Shabalina, Mozelius, & Balan, 2015). Rather than only considering the outcome, effective teaching also focuses on context, process, and learning outcome. It also considers identity, individuality, approach, and knowledge of the learners (Kyriacou, 2009). More schools are incorporating informal techniques into their curriculum, and as a result, the boundaries of formal and informal schooling are blurring (Ketelhut & Nelson, 2016). A shift from teacher-centered environments to student-centered interventions may also increase students’ motivation. Therefore, integrating technology into practice could be a viable tool for supporting different types of learners (Miyares, 2013). Debates also exist around the use of technology in sport learning and whether technology can eventually replace physical educators for promoting physical activity and health (Casey, Goodyear, & Armour, 2017).

In this book chapter, the authors talk about the integration of multi-user virtual environments (MUVE) technology for teaching and practicing sports. In the first part, the authors discuss various elements of the technology, and how virtual sports and sport exergames could be used in physical education. In the second part, the authors also characterize a swimming exergame from different aspects of biomechanics, physiology, and psychology. Based on the results of the chapter, physical education (PE) teachers and curriculum designer can decide how to use MUVE systems in their practice. Game designers could also benefit from the results of this book chapter to create more realistic and meaningful MUVE systems.

BACKGROUND

Three dimensional (3D) virtual environments resemble physical spaces and allow players to generate virtual selves (avatars) to interact with objects, virtual ambient, and other avatars. Impractical, costly, and dangerous real-life activities can be performed in virtual environments (Adams, Klowden, & Hannaford, 2001). These systems also have positive effects on learning and provide higher immersion, engagement, and motivation compared to common instruction techniques (Webster, 2016). Therefore, they may create opportunities for distance education and collaborative learning. Studies suggest that properly designed 3D virtual games may improve information retention and enable the situation to be practiced safely (Dutton, 2013). MUVE is a computer, server, or internet-based virtual environment that can be accessed by multiple users simultaneously. These systems provide low-cost and safe collaborative ambient for problem-based learning activities. They could offer similar learning outcome and satisfaction to the real-world conditions while being more pleasurable and informal compared to the stressful reality (Vrellis, Avouris, & Mikropoulos, 2016). MUVE systems provide the chance of deep learning experiences where various skills, cognitive, perceptual/motor, interpersonal, leadership, and team building could be considered at the same time (Chang & Lin, 2014; Clayton, 2017). MUVE-based interpersonal education is also easier to navigate and may fulfill pedagogical objectives (Morley et al., 2015). In recent years, there was a considerable hype around the use of virtual worlds in a variety of fields, but for efficient use of MUVE systems, some topics need to be addressed.

Various initiatives will have limited success if students are not motivated to participate actively in PE. Understanding the mechanism underlying motivation, engagement, and collaboration can optimize the system's interactions with students and increase the likelihood of realizing the potential benefits of PE participation. Gender also plays an important role in PE and overcoming traditional shortcomings (e.g.,

boys receiving more attention and feedback compared to girls) can ensure fair and active PE participation for everyone. In the following paragraphs, the authors will discuss these elements in MUVE systems.

Motivation

Educational and health-related virtual games can enhance players' motivation (Hamari et al., 2016). Motivation is the principal element of participation, progression, and retention in gaming environments (Konetes, 2010). According to Yee (2006), players are motivated to play games in three areas of *achievement* (progression within the game, understanding the game mechanics, and competing with others), *social* (socializing, building relationships with others, and teamwork), and *immersion* (discovering things within games, role-playing, customization, and escapism from real-life problems). Theories on need satisfaction also mention that people continue engaging in activities that satisfy motivational needs, such as competence, autonomy, or relatedness (Ryan & Deci, 2000). Different strategies can be used to create competition, cooperation, skills, role-playing, performance, and simulation (cf. Macklin & Sharp, 2016).

Each video game consists of *actions* (that players carry out to meet the game goals), *rules* (on how to play the game), *objects* (to reach the game goals), the *space* (defined by rules on which the game is played), and the *operators* (or players) of the game. To maximize the educational and health potential, virtual environments should increase players' inner desire to participate and enjoy the activity. Extrinsic motivation is also offered by the instructor or previously included rules of the game. In the academic or medical environment, extrinsic motivation is used for skill improvement or rehabilitation, through which the goal is to complete the course (Hansen, 2008). Additionally, paradigms that include both virtual and real environments might also be relevant in fostering health-related behaviors by using motivational reinforcement, personalized teaching methods, and social networking (Bordnick, Carter, & Traylor, 2011; Ershow, Peterson, Riley, Rizzo, & Wansink, 2011; Preziosa, Grassi, Gaggioli, & Riva, 2009). For example, they may clinically improve treatments of health problems such as obesity by increasing adherence through an extended sense of presence, anonymous targeted social support, and real-time feedback (Riva, Wiederhold, Mantovani, & Gaggioli, 2011).

Learning and Engagement

Teachers at all educational levels are concerned with students' engagement and learning. Although engagement might happen even without the use of technology, it can provide opportunities in ways that may otherwise be difficult to achieve (Kearsley & Shneiderman, 1998). With the recent shift in learning styles to informal and voluntary education (Clarke, Dede, & Dieterle, 2008), 3D MUVE systems could cover a broad range of educational pedagogies that extend from structured and rationalist approaches to social constructivist (Hollins & Robbins, 2009). MUVE systems may facilitate knowledge transfer from virtual to real environments in different types of participants (Freina & Canessa, 2015). Therefore, educators have many opportunities and challenges to create educational approaches with students who are familiar with these types of technologies. MUVE systems may also have the potential to increase students' engagement by offering dynamic and engaging student-centered learning environments that increase socializing, exploration, creativity, and discovery. Virtual environments such as Second Life seem to be viable learning environments because they are immersive and provide a sense of tele- and co-presence (Chen, 2016; Claman, 2015).

On the other hand, the previous adoption of learning content management systems and virtual learning environments such as Blackboard showed that such investments were mainly used for content structuring and presentation (Britain & Liber, 1999). Earlier educational MUVE systems such as Zora, SciCenter, MOOSE Crossing, and Whyville were also executed in informal settings like after-school programs, which may reflect the lack of acceptance as part of a curriculum in classrooms (Nelson & Ketelhut, 2007). Most MUVE users in informal settings may not also participate in the curriculum actively (Foley & Kobaissi, 2006). Complexity, open-ended nature, and division between formal and informal learning settings of MUVE systems may also cause students to "turn out" (Nelson & Ketelhut,

2007). In online learning environments, learners' engagement overrides learning success (Herrington, Oliver, & Reeves, 2003), and although MUVE applications may enhance communication behaviors (Tang, Lan, & Chang, 2012), lack of human interaction might be a problem in attaining proper levels of engagement (So & Brush, 2008). While students perceive virtual activities to be helpful, we should also keep in mind that the unstructuredness and informal aspects of using MUVE (as a form of self-discovery learning; Bruner, 1961) might be an obstacle in keeping learners interested in learning (Schmidt & Stewart, 2010; Hai-Jew, 2012). Bush (2009) also discussed that to keep students information-literate, educators should also be updated, learn from students, and welcome change. Other parameters such as identity conceptions, belief in the virtual world, and technical skills may also affect players' cohesion and learning within virtual worlds (deNoyelles & Kyeong-Ju Seo, 2012).

Collaborative Learning

Several studies have been performed in MUVE settings to understand the effects of games on collaboration, presence levels, team building, and teamwork (Bluemink, Hämäläinen, Manninen, & Järvelä, 2010; de Leo, Goodman, Radici, Secrhist, & Mastaglio, 2011; Ellis, Luther, Bessiere, & Kellogg, 2008; Roberts, Wolff, Otto, & Steed, 2003). Researchers have observed that increased sense of shared presence, social interaction and collaborative learning, and lower social anxiety are associated with such systems (Cook, 2009; Dede, Nelson, Ketelhut, Clarke, & Bowman, 2004). Using MUVE systems as part of collaborative team-based projects improves students' self-efficacy beliefs (Scullion, Baxter, & Stansfield, 2015). Kang et al. (2016) described the participatory design process with school teachers and suggested that a combination of physical interaction, sensing, and visualization in MUVE promote engagement, and shapes social interactions and playful experiences. By gaining collaborative experience, students increase their skill levels and feel more competent with technology (Nickerson, Corter, Esche, & Chassapis, 2007). Because of visual components of MUVE, students may also feel more connected and co-present (Leonard, Withers, & Sherblom, 2011).

The collaborative social environments may also provide opportunities to address the commitment problems. Bozanta, Kutlu, Nowlan, and Shirmohammadi (2016) mentioned that serious games are beneficial for team cohesion in MUVE environments, which could result in effective intra-group communication (Evans & Jarvis, 1980) and increased team performance (Dionne, Yammarino, Atwater, & Spangler, 2004). By using collaborative virtual environments, people can work together over networks to share experience and different tasks (Park & Kenyon, 1999). Shared virtual environments have the potential to be used for problem-solving and act as online communities (Meyers, 2009). In collaborative learning, the whole task is done by the group, and each person makes a contribution in line with the overall cognitive, interactive, and social goals. The interaction between players plays a great role in completing the task and creates an interdependence of players while developing interpersonal skills (Lorenzo, Sicilia, & Sanchez, 2012).

General guidelines (Arango, Chang, Esche, & Chassapis, 2007) for successful implementation of learning in virtual environments include: contextualizing learning in a way that makes sense to the learners, objective-based learning in which each activity should meet an objective and correctly represent the theoretical models that were previously studied by the learners, challenges that are coherent with learners' abilities, exploratory learning that allows learners to make their own decisions and see the consequences of their actions, and feedback to motivate student and enhance their performance continuously.

Design

As designers should consider interaction elements, feedback components, pedagogical, and other graphical aspects, developing a 3D MUVE environment is a complicated process (Harel & Papert, 1991). Integration factors involve pedagogical (relevance and complexity), contextual (players' prior experience, duration, and frequency of events), and logistical (usability, technical support, and hardware issues; Mayrath, Traphagan, Jarmon, Trivedi, & Resta, 2010). Pedagogical principles include curriculum content,

technological content, and subject knowledge content (de Freitas & Jarvis, 2007). The flexible structure of virtual environments may cause learners to lose their attention (Ho, Rappa, & Chee, 2009). Strategies should be tailored carefully to avoid overloading players with unnecessary information and inhibiting overall learning (Ritz & Buss, 2016). Virtual worlds also increase interactivity and put students in the spatial dimension. Therefore, for better usage of these systems, users' technical skills should be improved (Petraou, 2010). Additionally, the complexity of virtual environments that require significant computing power and high-speed internet to run smoothly are among issues that might make educators hesitate to use them. The cost of developing virtual worlds is another matter that is highly dependent on the amount of required modeling (Dutton, 2013).

Gender

Historically, gender was a good predictor of participation in virtual environments such as video games. Male and female players are different in type and duration play (Lowrie & Jorgensen, 2011). Four categories of memory task that could be affected by gender include spatial, verbal, autobiographical, and emotional. It is commonly agreed that males have better performance in spatial tasks and females in verbal tasks (Li, 2014). Additionally, male players spend more time playing video games and prefer action games compared to female players who prefer games featuring adventure, simulation, role-playing, and strategy. Moreover, males prefer games that require visual and spatial skills (e.g., dealing with maps), while females are interested in problem-solving video games. A previous study also suggests that female players are more active in virtual dance active video games and have more physical activity levels because they accept the platform as an activity consistent with their gender norms (Gao, Podlog, & Lee, 2014). Female players may also choose virtual activities that are considered as feminine, are accepted by their classmates, and are in line with their socially approved gender roles (Whitehead & Biddle, 2008). In the same way, female non-gamers tend to relate identity with physical appearance while male gamers were associating identity with personality characteristics. Moreover, female players who use virtual experimentation learn more, but male players outperform their counterparts (Ketelhut, Nelson, Clarke, & Dede, 2010). Previous research on the cognitive engagement of students also shows that male students tend to show higher levels of cognitive engagement such as self-regulation, task-focused learning, and resource management (Mandinach & Corno, 1985). On the other hand, Brom, Preuss, & Klement (2011) showed no gender differences in emotional engagement between the two genders.

VIRTUAL SPORTS FOR PHYSICAL EDUCATION

The popularity of the video game industry is ever increasing. The majority of young people own game devices and spend considerable amounts of time playing video games (Rideout, Foehr, & Roberts, 2010). Many people prefer to play video games during their leisure times than to read books or watch movies (Entertainment Software Association, 2018). Video games are usually blamed for providing aggression, violence, and making the children sedentary (Anderson et al., 2010; Lee & Peng, 2006). Insufficient physical activity (PA) which is one of the main parameters of mortality and obesity is also associated with sedentary gaming. Despite concerns regarding psychological effects of video games on the academic performance of players (Maass, Kollhorster, Riediger, MacDonald, & Lohaus, 2011), many educational researchers believe that these games could benefit the academic engagement of students, and are investigating the role of video games, their learning potential, and engagement (Young et al. 2012). These video games show reasons that might contribute to increase the quality and quantity of improved attention, executive functions, and reasoning (Neugnot-Ceroli, Gagner, & Beauchamp, 2015). Video games could also involve competition, collaboration, and might help in the development of learning communities sharing (Gee, 2008). They could also motivate players by using positive emotions to grab attention, memory, and motor skills to process information. Physical education and sports are important parts of the primary school curriculum around the world (Lindberg, Seo, & Laine, 2016). However, several reasons including instructors' lack of skills, time, and support, might contribute to reducing the quality and quantity of physical education (Lindberg, Seo, & Laine, 2016).

One exciting way of incorporating technology and teaching is by using active video games (exergames) that include visual or auditory stimulus. It provides an illusion of interacting with a virtual world and provides immediate feedback. Although it does not completely block the field of view of players, it is still capable of immersing players (Soltani, 2018). This new approach uses motion sensor technology and involves movements of body limbs during gaming. Exergames are increasingly popular as they combine gaming and exercise so that the motivation to play can encourage the individual to participate in some levels of physical activity. During the games, players have to perform active tasks such as jumping, running, dancing, virtual cycling, boxing, or tennis. Exergames might have the potential to produce more minutes of PA while being socially acceptable among both students and physical education teachers (Fogel, Miltenberger, Graves, & Koehler, 2010).

EXERGAME EVALUATION

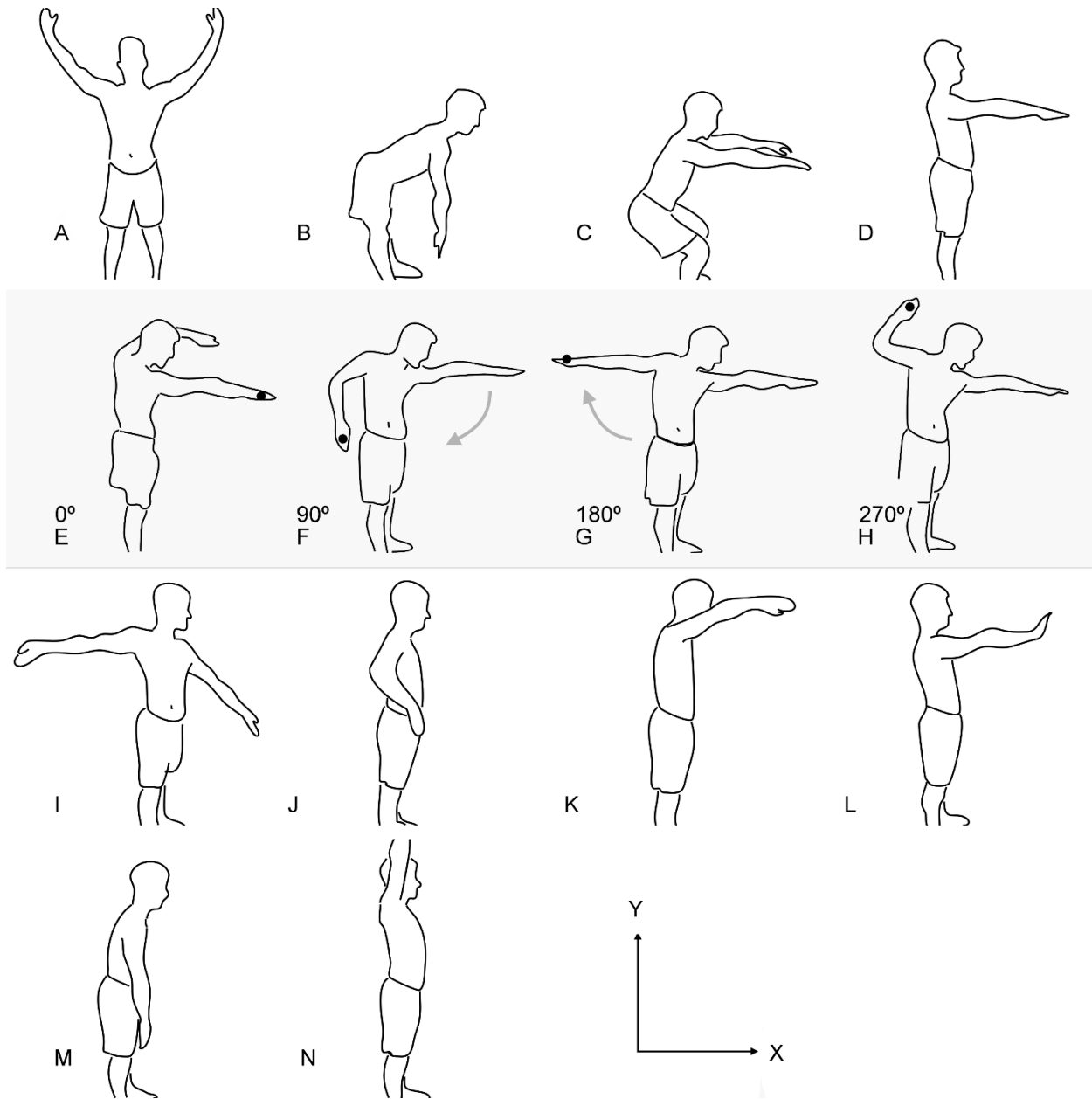
Sport exergames are replications of real-world activities. Because they might be used for purposes such as instruction and training, they are also referred as serious games (Susi, Johannesson, & Backland, 2007). To successfully apply them in other contexts, they should be fun and provide challenges, skill, knowledge, or attitude that could be used in real-world scenarios. With various informal and voluntary learning tools and if sport exergames can improve motor skills of real sports, they might potentially facilitate familiarity with sports. To maximize their effectiveness and attractiveness, and augment their health benefits, sport exergames should be evaluated holistically. In this part, the authors analyzed a swimming exergame from different aspects of biomechanics, physiology, and psychology. The primary purpose of the biomechanical evaluation is to understand human movements better and to reveal that movements can be performed in many different ways. Another purpose of the biomechanical analysis is to increase safety. Because exergame activities involve repeated upper- and lower-limb movements, biomechanical procedures can estimate the internal loads and angles, and human-computer interaction is monitored carefully to guarantee safer experience and protect players from muscular overload.

For a realistic and meaningful experience, various design and safety considerations should also be met; especially when MUVE systems are intended to be used unsupervised and within the venerable community. Exercise physiology testing aims to understand how human systems work under different exercise conditions. Such situations might affect force production and neural control of movement pattern. Physiology also offers tools to monitor players' health via standardized tests and considers design and safety issues for unsupervised use. Finally, as motivating may ensure participation, progression, and retention in the MUVE systems, the psychological evaluation deals with players' enjoyment and motivation for playing. It also evaluates whether MUVE systems could establish a connection between virtual and real sport participation. Considering gender in this holistic framework allows tailoring various game elements carefully for both female and male players.

SWIMMING EXERGAME

Out of the water, subjects played different techniques of a swimming exergame with Microsoft Xbox and Kinect (Michael Phelps: Push the Limit, 505 Games, Italy). The game was divided into two phases of normal and fast, both controlled by visual on-screen feedback. Players had to stand in front of the Kinect sensor and bend forward (Parts B and C in Figure 1 below). With the visual command, they had to return to the standing position with arms in front (Part D in Figure 1). Afterward, they had to swim according to each technique and move the avatar inside the game (Parts E to L in Figure 1). To prevent players from swimming too slow or too fast, an on-screen visual feedback indicated if the speed was moderate. In the middle of the second lap, there was a possibility of swimming as fast as possible without any limitation (Push the Limit). At the end of the event, players had to drop their upper limbs (Part M in Figure 1) and then raise one to finish the race (Part N in Figure 1). For all studies, participants were categorized based on gender, exergame experience, in-game performance, and real swimming background.

Figure 1. Body Position during Different Phases of The Game



A: Cheering; B: Preparatory position for front crawl, breaststroke, and butterfly; C: Preparatory position for backstroke; D: Start; E-H: Front crawl movements; I: Backstroke; J: Breaststroke; K: Butterfly; L: Return; M: Preparatory position to terminate the race; N: Termination position. (Source: Soltani et al., 2017a)

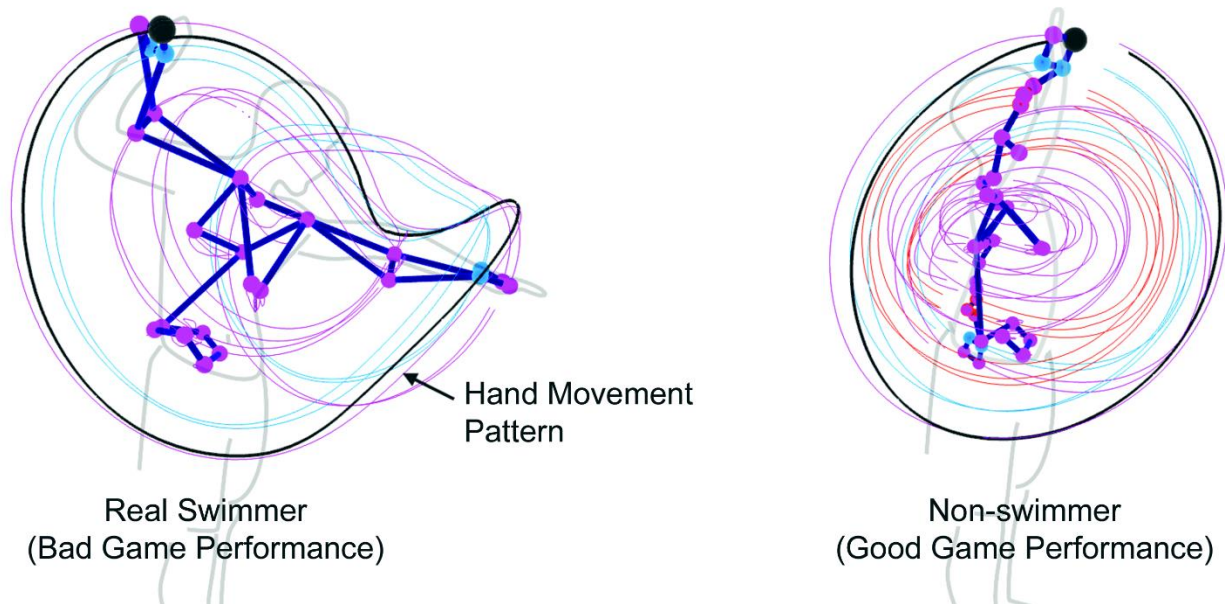
Biomechanical Evaluation

To understand the movement patterns of players, reflective markers were placed on the anatomical landmarks of the players, and their movements were captured using a 3D motion analysis system (Qualisys Track Manager, Qualisys AB, Sweden) and processed using a biomechanical analysis software (Visual3D, C-Motion Inc., U.S.A.). Due to lack of forces applied to the body from water and different body positions, kinematic differences were expectable. The evaluation showed that subjects had similar biomechanical parameters and, for better performance inside the game, they were encouraged to change their movement patterns (Table 1). Participants with real swimming background had the intention to keep their movement patterns close to real swimming, but as the device was not able to detect their precise

movements, they change their patterns to just win the game (Figure 2). Additionally, experienced players were also playing the game with less effort (Soltani, Figueiredo, Fernandes, & Vilas-Boas, 2016).

The ideal goal of sport exergames would be to mimic the real-sport movements, but because of passive-playing nature of many games, players use different ways to exert. Movement patterns may vary depending on games, systems, and players' experiences. Movement comparisons show differences in anticipatory performance in which skilled players are more attentive to the game mechanics and such information could be interpreted as movement adaptation or learning (Soltani et al., 2016). In the game, players frequently mentioned that their real swimming movements were not applied inside the game correctly and they were encouraged to do simple movements just to win the game. Detailed biomechanical evaluation during the game design phase might help in the elimination of some of these boundaries and provide a more meaningful experience, especially if participation in real sport happens before virtual sport participation (Mueller, Agamanolis, Vetere, & Gibbs, 2009). It should be noted that there are also some modifiable and non-modifiable parameters while designing virtual sports. Non-modifiable limitations (lack of real forces from water or holding a physical object in hand) may result in differences in movement patterns and the sense of performing a real activity. Modifiable parameters are those imposed on players by the gaming platforms that affect posture and muscle loading, and might lead to cheating (Lui, Szeto, & Jones, 2011).

Figure 2. Movement Patterns of Real Swimmer vs. Non-Swimmer during Virtual Swimming



Source: Soltani et al., 2016.

Physiological Evaluation

Compared to traditional methods of measuring the impacts of video games (e.g., questionnaires), physiological measurements provide more objective responses of players' experiences. While real-world sport activities may usually generate higher muscle activation compared to virtual equivalents, evaluating muscle activation during the gameplay can be used to make sport exergames closer to real activities.

Electromyography (EMG) profiling offers information in real time about the timing of muscle activities. It also allows understanding the changes in muscular activity during training and learning adaptations. With higher exergame engagement, muscle activation levels may also increase, and speed-based exergames might be used to create physical demand and to avoid boredom when players' engagements diminish (Soltani et al., 2017a). Twenty subjects played the swimming video game and activation of *biceps brachii* (BB), *triceps brachii* (TB), *upper trapezius* (UT), *latissimus dorsi* (LD), *erector spinae* (ES) muscles were monitored in two different playing velocities. Although higher muscle activation was seen in fast gameplay compared to the normal phase, after normalizing the muscle activation to the playing velocity, selective behavior was observed between the muscles (Table 2). More specifically, higher muscle activation was found in muscles that were responsible for pragmatic gameplay (swimming just to win the game). For example, during the front crawl, differences were observed between LD and ES. These two muscles are responsible for lowering the arms to start a new cycle to quickly finish the game. With this selective behavior in activating the muscles that contribute to swimming, the video game may not be used as a training device.

Heart rate, the rate of perceived exertion, and energy expenditure are other physiological parameters for measuring the intensity of exergames. These are particularly important as exergames are often promoted as means of increasing PA. Forty players played the game and oxygen uptake, and blood lactate were collected during the gameplay. From these two values, energy expenditure was measured which was also not different between performing groups. Only higher heart rate was observed in players with real swimming experience and only in the first technique. This shows that real swimmers tend to exert higher at the beginning of the gameplay, but as soon as they understood the mechanics of the game, they changed their behavior just to win the game. Each player was also filmed during the activity to measure the activity time. Total playing time, effective playing time, resting time, and effort to rest ratio were also calculated using video analysis. Recordings were tagged as total playing time (TPT), and effective playing time (EPT) in which players' movements were necessary to advance within the game. The results also showed that novice players had higher TPT and EPT compared to experienced counterparts (Table 3; Soltani et al., 2017b). This shows that novice players need more time to adapt to the game mechanics. It might also be possible that short-term positive results of an increase in PA levels are due to lack of experience of the players.

Table 1. Biomechanical Parameters of Swimming Exergame

| Variables | | Swimming experience | | Exergame experience | | Gender | |
|--------------------|--------|---------------------|--------------|---------------------|--------------|--------------|--------------|
| | | Swimmer | Non-swimmer | Experienced | Novice | Male | Female |
| Total time (s) | | 49.97±3.58 | 49.36±2.50 | 49.24±1.82 | 50.17±3.96 | 49.29±2.69 | 51.55±4.61 |
| Number of cycle | Normal | 29.20±4.73 | 28.82±3.57 | 27.82±1.70 | 29.86±5.35 | 28.11±2.82 | 32.27±6.90 |
| | Fast | 10.23±2.23 | 10.36±3.35 | 9.71±1.82 | 10.59±2.81 | 9.94±2.04 | 11.27±3.55 |
| Hand path distance | | 120.51±30 | 120.36±19.70 | 117.82±25.99 | 122.03±29.41 | 117.91±28.30 | 128.64±26.49 |
| Trunk rotation (°) | Normal | 40.17±15.85 | 32.09±8.58 | 41.29±15.15 | 36.45±14.52 | 39.60±15.47 | 33.91±11.91 |
| | Fast | 36.66±13.25 | 29.91±11.51 | 36.00±14.90 | 34.48±12.10 | 35.46±13.78 | 33.73±10.93 |

Data are presented as mean±SD.

Table 2. Activation of Various Muscles during Front Crawl

| Event | Velocity | BB | TB | LD | UT | ES |
|------------------|----------|-----------|------------|------------|------------|-----------|
| Crawl | Normal | 10.0±4.5* | 17.2±14.2* | 12.3±12.8* | 53.9±39.6* | 7.9±3.9* |
| | Fast | 19.1±7.9 | 24.5±12.7 | 31.5±30.9 | 80.65±55.1 | 18.2±10.2 |
| Crawl normalized | Normal | 3.8±2.3 | 6.4±5.7 | 4.5±5.6* | 19.8±14.3 | 2.9±1.7* |
| | Fast | 4.5±2.2 | 5.8±3.3 | 7.8±9.1 | 19.2±13.4 | 4.3±2.3 |

*: Differences were observed between normal and fast swimming in muscles.

Table 3. Physiological Evaluation of Swimming Exergame

| Variables | | Swimming experience | | Exergame experience | | Gender | |
|---|-----------------------------|---------------------|-------------|---------------------|------------|------------|------------|
| | | Swimmer | Non-swimmer | Experienced | Novice | Male | Female |
| [La ⁻] (mmol.l ⁻¹) | [La ⁻] Activity | 3.0±1.4 | 2.3±0.8 | 2.4±1.0 | 3.0±1.3 | 2.7±1.2 | 2.1±0.5 |
| | Crawl | 3.0±3.0 | 2.0±0.7 | 2.1±1.6 | 3.0±2.7 | 2.5±2.3 | 2.0±0.7 |
| | Backstroke | 2.7±1.0 | 2.1±0.8 | 2.2±0.9 | 2.7±1.0 | 2.5±1.0 | 1.9±0.6 |
| | Breaststroke | 3.0±0.9 | 2.5±0.6 | 2.6±0.7 | 3.0±0.9 | 2.8±0.8 | 2.3±0.5 |
| | Butterfly | 3.3±2.1 | 2.7±1.4 | 2.6±1.4 | 3.5±2.1 | 3.1±1.9 | 2.4±0.8 |
| EE (kJ) | EE _{TOTAL} | 113.4±40.4 | 97.4±24.1 | 95.3±24.4 | 119.3±39.5 | 111.0±33.5 | 82.2±15.7 |
| | EE _{LAC} | 12.9±11.6 | 7.8±5.0 | 7.9±6.7 | 13.5±10.6 | 11.3±9.4 | 5.7±2.7 |
| | EE _{AER} | 100.5±32.8 | 89.6±23.0 | 87.4±22.4 | 105.8±32.6 | 99.7±28.6 | 76.4±14.6 |
| | Lactic (%) | 10.2±6.6 | 8.0±4.8 | 8.0±5.5 | 10.5±5.8 | 9.6±6.2 | 6.8±2.7 |
| | Aerobic (%) | 89.7±6.6 | 91.9±4.8 | 91.9±5.5 | 89.4±5.8 | 90.3±6.2 | 93.0±2.7 |
| HR (bpm) | HR-Total | 94.1±18.3 | 85.5±12.5 | 88.4±16.9 | 89.8±13.5 | 88.3±15.6 | 91.2±15.4 |
| | HR-Activity | 105.7±15.7 | 97.9±13.9 | 99.0±13.1 | 104.0±17.5 | 99.2±14.7 | 107.3±15.1 |
| | Crawl | 105.9±17.9* | 96.8±11.8 | 100.0±15.3 | 101.1±15.1 | 98.8±15.8 | 106.1±11.0 |
| | Backstroke | 105.8±13.8 | 103.0±16.6 | 101.6±12.0 | 108.0±19.4 | 102.1±14.9 | 111.1±16.3 |
| | Breaststroke | 105.4±17.8 | 99.3±16.9 | 96.9±15.0 | 104.5±19.6 | 98.2±17.0 | 106.0±17.3 |
| RPE | Butterfly | 106.0±15.8 | 98.2±16.9 | 97.8±15.5 | 103.7±17.0 | 98.3±16.3 | 106.4±18.8 |
| | RPE Activity | 2.9±1.1 | 3.0±1.2 | 2.8±1.2 | 3.2±1.2 | 2.9±1.2 | 3.2±1.4 |
| | Crawl | 2.6±1.3 | 2.0±1.2 | 2.1±1.3 | 2.4±1.2 | 2.2±1.3 | 2.2±1.3 |
| | Backstroke | 2.8±1.0 | 3.0±1.6 | 2.6±1.3 | 3.4±1.5 | 2.7±1.3 | 3.6±1.5 |
| | Breaststroke | 3.0±1.4 | 3.2±1.5 | 3.0±1.5 | 3.3±1.5 | 3.0±1.4 | 3.5±1.6 |
| Activity profile | Butterfly | 3.4±1.7 | 4.0±1.5 | 3.6±1.7 | 3.9±1.3 | 3.8±1.5 | 3.6±1.9 |
| | Active (%) | 54.5±4.4 | 58.5±9.5 | 55.8±8.6 | 58.6±7.1 | 56.4±7.2 | 58.5±10.9 |
| | Rest (%) | 44.3±5.0 | 44.0±7.8 | 45.5±7.2 | 42.0±5.4 | 43.3±6.1 | 47.0±8.3 |
| | E:R | 1.2±0.2 | 1.3±0.4 | 1.2±0.3 | 1.4±0.3 | 1.3±0.3 | 1.2±0.2 |

*: Differences were observed between normal and fast swimming in muscles; EE_{LAC}: Anaerobic energy contribution; EE_{AER}: Aerobic energy contribution; Lactic: Relative anaerobic lactic percentage; Aerobic: relative aerobic percentage; HR-Total: HR from the onset of activity until the end of the last technique; HR-Activity: mean HR during the four swimming events; RPE Activity: Mean RPE during the four swimming techniques; E:R: effort to rest ratio.

Psychological Evaluation

In the psychology part, the authors discuss both assessment of enjoyment as well as its role in changing PA and exercise intention. The concept is usually assessed by PA enjoyment scale (i.e., PACES) (Kendzierski & DeCarlo, 1991) which includes 18 items and requires respondents to select a point along a 7-point continuum between two opposite descriptors related to the enjoyment of PA (enjoy and hate, dislike and like, etc.). It is a robust predictor and correlator of PA behavior in children, youth, and older adults. The authors also used game experience questionnaire that deals with consumers' dynamic perceptions and responses of games and consists of different components including flow, a state in which there is a balance between the difficulty of the task and the skills that the performers possess (Csikszentmihalyi, 1991). With the occurrence of flow, players become immersed, ignoring the world around them (Brown & Cairns, 2004). A state of deep involvement in the game is recognized as absorption (Agarwal & Karahanna, 2000). Presence is also a psychological feeling of being in a virtual environment (Slater, Usoh, & Steed, 1994), and shows how engaged people are while playing video games (Schmierbach, Limperos, & Woolley, 2012). The System Usability Scale (SUS) is a measurement of learning, control, and understanding a game, and offers a reliable tool for measuring usability. With ten questions of five responses (from strongly agree to strongly disagree), the game usability scale allows evaluating a wide variety of products and services. Items ask about whether the player would like to use the system frequently, if they found it unnecessarily complex, or if they need support to use the system. Additionally, the changes in intentions before and after the gameplay were monitored using the following items before and after the gameplay: "If I had a chance, I would participate in physical activity later today" and "If I had a chance to participate in physical activity, I would choose swimming."

Twenty players participated in this study and filled the questionnaires after the gameplay. Twelve participants were female. Overall, psychological parameters were not different between performing groups, but female players with real and exergame experience enjoyed the game more (Table 4). The video game also earned a good usability score with high acceptability. GEQ components were also not different between performing groups, but in general, subjects rated the absorption part lower, which might have been affected by the perceived usefulness of the game (Agarwal & Karahana, 2000). As feedback functionality affects immersion of the players (Nogueira, Torres, Rodrigues, Oliveira, & Nacke, 2016), and while the movements of different players were detected similarly, they might have immersed equally. Moreover, physical activity intentions did not change but swimming intentions increased for all subjects. A possible explanation might be that exercise intentions of those who frequently exercise may not be affected by a single session of video game playing. Another explanation is that those who do not exercise regularly might think that the benefits obtained through exergame participation are enough and there is no need for further exercising.

Table 1. Biomechanical Parameters of Swimming Exergame

| Variables | | Swimming experience | | Exergame experience | | Gender | |
|--------------------|--------|---------------------|--------------|---------------------|--------------|--------------|--------------|
| | | Swimmer | Non-swimmer | Experienced | Novice | Male | Female |
| Total time (s) | | 49.97±3.58 | 49.36±2.50 | 49.24±1.82 | 50.17±3.96 | 49.29±2.69 | 51.55±4.61 |
| Number of cycle | Normal | 29.20±4.73 | 28.82±3.57 | 27.82±1.70 | 29.86±5.35 | 28.11±2.82 | 32.27±6.90 |
| | Fast | 10.23±2.23 | 10.36±3.35 | 9.71±1.82 | 10.59±2.81 | 9.94±2.04 | 11.27±3.55 |
| Hand path distance | | 120.51±30 | 120.36±19.70 | 117.82±25.99 | 122.03±29.41 | 117.91±28.30 | 128.64±26.49 |
| Trunk rotation (°) | Normal | 40.17±15.85 | 32.09±8.58 | 41.29±15.15 | 36.45±14.52 | 39.60±15.47 | 33.91±11.91 |
| | Fast | 36.66±13.25 | 29.91±11.51 | 36.00±14.90 | 34.48±12.10 | 35.46±13.78 | 33.73±10.93 |

Data are presented as mean±SD.

CONCLUSION

Physical education is emerging regarding the use of technology in classes. Virtual environments such as sport exergames might provide promising short-term results in increasing energy expenditure and physical activity levels. However, data from this study showed that as players gain experience, they might change their gameplay behavior and therefore, these games may not offer long-term maintenance of physical activity and may not be used as a teaching or training device. Instructors and users who think that virtual environments might have a place in education should understand that due to a lack of institutional resources, a lack of familiarity, and other hesitations, it may still not be practical to use such systems in practice and research sites (Johnson, 2011). Moreover, traditional methods might still be more cost-effective and more efficient and therefore, should not be fully ignored (Webster, 2016). PE teachers should justify why and how they want to use exergames in their practice and properly design ways for their students to interact with games. A combination of techniques (virtual and traditional instruction) might provide a more effective learning experience (Webster, 2016) due to shorter training time and possible long-term retention of knowledge and skills. Future studies should also examine whether physical activity and sport participation intentions result in actual exercise participation.

RECOMMENDATIONS AND FUTURE DIRECTIONS

While evaluating players' behaviors, various parameters such as gender, ethnicity, activity levels, and exercise background should be considered. Larger sample size might increase the power of analysis, and therefore conclusions made upon the results might be more realistic. It should also be noted that acquiring biophysical data is relatively time-consuming which might not be tolerable for some participants. The novelty of exergames might also cause players to rate their psychological variables (e.g., enjoyment) higher. While the majority of studies on exergame evaluation show promising short-term results for increasing PA levels, results in this study show that even after short exposure to the sport exergames, players change the movement patterns and reduce their activity levels. Future studies should analyze players' movements and behavior over longer periods of gameplay. Other studies may also look at the possibility of using virtual sports in decreasing fear of real activity (e.g., aqua-phobia). Creating a fitness index for each game based on psycho-biophysical evaluation could be another interesting area to use exergames in PA effectively.

ACKNOWLEDGMENT

Pooya Soltani was supported by Institut Carnot STAR and Collège de France.

REFERENCES

- Adams, R. J., Klowden, D., & Hannaford, B. (2001). Virtual training for a manual assembly task. *Haptics-e*, 2(2), 1-7. Retrieved December 2, 2018, from <http://hdl.handle.net/1773/34884>
- Agarwal, R., & Karahanna, E. (2000). Time flies when you're having fun: Cognitive absorption and beliefs about information technology usage. *MIS Quarterly*, 24(4), 665-694. doi:10.2307/3250951
- Anderson, C. A., Shibuya, A., Ihori, N., Swing, E. L., Bushman, B. J., Sakamoto, A., . . . Saleem, M. (2010). Violent video game effects on aggression, empathy, and prosocial behavior in Eastern and Western countries: A meta-analytic review. *Psychological Bulletin*, 136(2), 151-173. doi:10.1037/a0018251
- Arango, F., Chang, C., Esche, S. K., & Chassapis, C. (2007). A scenario for collaborative learning in virtual engineering laboratories. In *37th Annual Frontiers in Education Conference-global Engineering: Knowledge without Borders, Opportunities Without Passports* (pp. F3G-7). IEEE. doi:10.1109/FIE.2007.4417818
- Beck, J. C., & Wade, M. (2006). *The kids are alright: How the gamer generation is changing the workplace*. Cambridge, M.A.: Harvard Business Review Press.
- Bluemink, J., Hämäläinen, R., Manninen, T., & Järvelä, S. (2010). Group-level analysis on multiplayer game collaboration: How do the individuals shape the group interaction? *Interactive Learning*

- Environments*, 18(4), 365-383. doi:10.1080/10494820802602444
- Bordnick, P. S., Carter, B. L., & Traylor, A. C. (2011). What virtual reality research in addictions can tell us about the future of obesity assessment and treatment. *Journal of Diabetes Science and Technology*, 5(2), 265-271. doi:10.1177/193229681100500210
- Bozanta, A., Kutlu, B., Nowlan, N., & Shirmohammadi, S. (2016). Effects of serious games on perceived team cohesiveness in a multi-user virtual environment. *Computers in Human Behavior*, 59, 380-388. doi:10.1016/j.chb.2016.02.042
- Britain, S., & Liber, O. (1999). *A framework for pedagogical evaluation of virtual learning environments*. Retrieved December 2, 2018, from <http://www.leeds.ac.uk/educol/documents/00001237.htm>¹
- Brom, C., Preuss, M., & Klement, D. (2011). Are educational computer micro-games engaging and effective for knowledge acquisition at high-schools? A quasi-experimental study. *Computers & Education*, 57(3), 1971-1988. doi:10.1016/j.compedu.2011.04.007
- Brown, E., & Cairns, P. (2004). *A grounded investigation of game immersion*. Paper presented at the CHI '04 Extended Abstracts on Human Factors in Computing Systems, Vienna, Austria. doi: 10.1145/985921.986048
- Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review*, 31, 21-32.
- Bush, G. (2009). Thinking around the corner: The power of information literacy. *Phi Delta Kappan*, 90(6), 446-447. doi:10.1177/003172170909000615
- Casey, A., Goodyear, V. A., & Armour, K. M. (2017). Rethinking the relationship between pedagogy, technology and learning in health and physical education. *Sport, Education and Society*, 22(2), 288-304. doi:10.1080/13573322.2016.1226792
- Chang, S. M., & Lin, S. S. (2014). Team knowledge with motivation in a successful MMORPG game team: A case study. *Computers & Education*, 73, 129-140. doi:10.1016/j.compedu.2013.09.024
- Chen, J. C. (2016). The crossroads of English language learners, task-based instruction, and 3D multi-user virtual learning in Second Life. *Computers & Education*, 102, 152-171. doi:10.1016/j.compedu.2016.08.004
- Claman, F. L. (2015). The impact of multiuser virtual environments on student engagement. *Nurse Education in Practice*, 15(1), 13-16. doi:10.1016/j.nepr.2014.11.006
- Clarke, J., Dede, C., Dieterle, E. (2008). Emerging technologies for collaborative, mediated, immersive learning. In: J. Voogt, G. Knezek (Eds.), *The international handbook of technology in primary and secondary education* (pp. 901-909). New York: Springer. doi:10.1007/978-0-387-73315-9_55
- Clayton, A. S. (2017). *Multiplayer educational role playing games (MPERPGs) and the application of leadership* (Ph.D.). Phoenix, AZ: Grand Canyon University.
- Cook, A. D. (2009). *A case study of the manifestations and significance of social presence in a multi-user virtual environment* (Ph.D.). Saskatoon, SK, Canada: University of Saskatchewan.
- Csikszentmihalyi, M. (1991). *Flow: The psychology of optimal experience* (Vol. 41). New York: Harper Perennial.
- Dede, C., Nelson, B., Ketelhut, D. J., Clarke, J., & Bowman, C. (2004). Design-based research strategies for studying situated learning in a multi-user virtual environment. In *Proceedings of the 6th International Conference on Learning Sciences* (pp. 158-165). Santa Monica, CA: International Society of the Learning Sciences.
- de Freitas, S., & Jarvis, S. (2007). Serious games engaging training solutions: A research and development project for supporting training needs. *British Journal of Educational Technology*, 38(3), 523-525. doi:10.1111/j.1467-8535.2007.00716.x
- de Leo, G., Goodman, K. S., Radici, E., Secrhist, S. R., & Mastaglio, T. W. (2011). Level of presence in team-building activities: Gaming component in virtual environments. *The International Journal of Multimedia & Its Applications*, 3(2), 1-10. doi:10.5121/ijma.2011.3201
- deNoyelles, A., & Kyeong-Ju Seo, K. (2012). Inspiring equal contribution and opportunity in a 3D multi-

¹ All of the external links have been also saved on the Internet Archive WayBack Machine.

- user virtual environment: Bringing together men gamers and women non-gamers in Second Life®. *Computers & Education*, 58(1), 21-29. doi:10.1016/j.compedu.2011.07.007
- Dionne, S. D., Yammarino, F. J., Atwater, L. E., & Spangler, W. D. (2004). Transformational leadership and team performance. *Journal of Organizational Change Management*, 17(2), 177-193. doi:10.1108/09534810410530601
- Dutton, G. (2013). Is 3-D/virtual training dead? *Training*, 50(5), 38-39.
- Ellis, J. B., Luther, K., Bessiere, K., & Kellogg, W. A. (2008). Games for virtual team building. In *Proceedings of the 7th ACM Conference on Designing Interactive Systems* (pp. 295-304). ACM. doi:10.1145/1394445.1394477
- Entertainment Software Association (2018). *2018 essential facts about the computer and video game industry*. Retrieved December 2, 2018, from http://www.theesa.com/wp-content/uploads/2018/05/EF2018_FINAL.pdf
- Ershow, A. G., Peterson, C. M., Riley, W. T., Rizzo, A. S., & Wansink, B. (2011). Virtual reality technologies for research and education in obesity and diabetes: Research needs and opportunities. *Journal of Diabetes Science and Technology*, 5(2), 212-224. doi:10.1177/193229681100500202
- Evans, N. J., & Jarvis, P. A. (1980). Group cohesion: A review and reevaluation. *Small Group Behavior*, 11(4), 359-370. doi:10.1177/104649648001100401
- Fee, K. (2007). *Delivering E-Learning*. London: Kogan Page Limited.
- Fogel, V. A., Miltenberger, R. G., Graves, R., & Koehler, S. (2010). The effects of exergaming on physical activity among inactive children in a physical education classroom. *Journal of Applied Behavior Analysis*, 43(4), 591-600. doi:10.1901/jaba.2010.43-591
- Foley, B., & Kobaiissi, A. (2006). Using virtual chat to study in informal learning in online environments. In *the annual meeting of the American Educational Research Association*. San Francisco, CA.
- Freina, L., & Canessa, A. (2015). Immersive vs desktop virtual reality in game based learning. In *9th European Conference on Games Based Learning: ECGBL2015*. Steinkjer, Norway: Academic Conferences and Publishing Limited.
- Gao, Z., Podlog, L., & Lee, J. (2014). Children's situational motivation, rate of perceived exertion and physical activity levels in exergaming: Associations and gender differences. In J. Graham (Ed.), *Video games: Parents' perceptions, role of social media and effects on behavior* (pp. 17-28). Hauppauge, NY: Nova Science Publishers.
- Gee, J. (2008). Learning and Games. In K. Salen (Ed.), *The ecology of games: Connecting youth, games, and learning* (pp. 21-40). Cambridge, MA: The MIT Press.
- Hai-Jew, S. (2012). Addressing the "commitment problem": Driving long-term persistent. In Hai-Jew, S.L., (Ed.), *Constructing self-discovery learning spaces online: Scaffolding and decision making technologies* (1st ed.). Harshey, PA: IGI Global. doi:10.4018/978-1-61350-320-1.ch013
- Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior*, 54, 170-179. doi: 10.1016/j.chb.2015.07.045
- Hansen, M. (2008). Versatile, immersive, creative and dynamic virtual 3-D healthcare learning environments: A review of the literature. *Journal of Medical Internet Research*, 10(3), e26. doi:10.2196/jmir.1051
- Harel, I. E., & Papert, S. E. (1991). *Constructionism*. Ablex Publishing.
- Herrington, J., Oliver, R., & Reeves, T. C. (2003). Patterns of engagement in authentic online learning environments. *Australasian Journal of Educational Technology*, 19(1), 59-71. doi:10.14742/ajet.1701
- Ho, C. M. L., Rappa, N. A., & Chee, Y. S. (2009). Designing and implementing virtual enactive role-play and structured argumentation: Promises and pitfalls. *Computer Assisted Language Learning*, 22(5), 381-408. doi:10.1080/09588220903184732
- Hollins, P., & Robbins, S. (2018). The educational affordances of multi user virtual environments. In D.

- Heider (Ed.), *Living virtually: Researching new worlds*. New York: Peter Lang Publishing.
- Johnson, J. (2011). *Second Life 's future in education* (Ph.D.). Capella University.
- Kang, S., Norooz, L., Oguamanam, V., Plane, A. C., Clegg, T. L., & Froehlich, J. E. (2016). SharedPhys: Live physiological sensing, whole-body interaction, and large-screen visualizations to support shared inquiry experiences. In *Proceedings of the 15th International Conference on Interaction Design and Children* (pp. 275-287). ACM. doi:10.1145/2930674.2930710
- Kearsley, G., & Shneiderman, B. (1998). Engagement theory: A framework for technology-based teaching and learning. *Educational Technology*, 38(5), 20-23.
- Kendzierski, D., & DeCarlo, K. J. (1991). Physical activity enjoyment scale: Two validation studies. *Journal of Sport & Exercise Psychology*, 13, 50–64. doi:10.1123/jsep.13.1.50
- Ketelhut, D. J., & Nelson, B. C. (2016). Blending formal and informal learning environments: The case of SAVE science. In *Proceedings of the 10th European Conference on Games Based Learning, ECGBL 2016* (pp. 314-318). Dechema e.V.
- Ketelhut, D. J., Nelson, B. C., Clarke, J., & Dede, C. (2010). A multi-user virtual environment for building and assessing higher order inquiry skills in science. *British Journal of Educational Technology*, 41(1), 56-68. doi:10.1111/j.1467-8535.2009.01036.x
- Konetes, G. D. (2010). The function of intrinsic and extrinsic motivation in educational virtual games and simulations. *Journal of Emerging Technologies in Web Intelligence*, 2(1), 23-26. doi:10.4304/jetwi.2.1.23-26
- Kyriacou, C. (2009). *Effective teaching in schools. Theory and practice*. United Kingdom: Stanley Thornes Publishers Ltd.
- Lee, K. M., & Peng, W. (2006). What do we know about social and psychological effects of computer games? A comprehensive review of the current literature. In Vorderer, P., & Bryant, J. (Eds.), *Playing video games: Motives, responses, and consequences* (pp. 327-345). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Leonard, L., Withers, L. A., & Sherblom, J. C. (2011). Collaborating virtually: Using "Second Life" to teach collaboration. *Communication Teacher*, 25(1), 42-47. doi:10.1080/17404622.2010.527297
- Li, R. (2014). Why women see differently from the way men see? A review of sex differences in cognition and sports. *Journal of Sport and Health Science*, 3(3), 155-162. doi:10.1016/j.jshs.2014.03.012
- Lindberg, R., Seo, J., & Laine, T. H. (2016). Enhancing physical education with exergames and wearable technology. *IEEE Transactions on Learning Technologies*, 9(4), 328-341. doi:10.1109/TLT.2016.2556671
- Lorenzo, C. M., Sicilia, M. Á., & Sánchez, S. (2012). Studying the effectiveness of multi-user immersive environments for collaborative evaluation tasks. *Computers & Education*, 59(4), 1361-1376. doi:10.1016/j.compedu.2012.06.002
- Lowrie, T., & Jorgensen, R. (2011). Gender differences in students' mathematics game playing. *Computers & Education*, 57(4), 2244–2248. doi:10.1016/j.compedu.2011.06.010
- Lui, D. P. Y., Szeto, G. P. Y., & Jones, A. Y. M. (2011). The pattern of electronic game use and related bodily discomfort in Hong Kong primary school children. *Computers & Education*, 57(2), 1665-1674. doi:10.1016/j.compedu.2011.03.008
- Macklin, C., & Sharp, J. (2016). *Games, Design and Play: A detailed approach to iterative game design*. Boston, MA: Addison-Wesley Professional.
- Mandinach, E. B., & Corno, L. (1985). Cognitive engagement variations among students of different ability level and sex in a computer problem solving game. *Sex Roles*, 13(3), 241–251. doi:10.1007/BF00287914
- Malliarakis, C., Tomos, F., Shabalina, O., Mozelius, P., & Balan, O. C. (2015). How to build an ineffective serious game: Worst practices in serious game design. In *9th European Conference on Games Based Learning: ECGBL2015* (pp. 338-345). Steinkjer, Norway: Academic Conferences and Publishing Limited.
- Maass, A., Kollhorster, K., Riediger, A., MacDonald, V., & Lohaus, A. (2011). Effects of violent and

- nonviolent computer game content on memory performance in adolescents. *European Journal of Psychology of Education*, 26(3), 339–353. doi:10.1007/s10212-010-0047-0
- Mayrath, M. C., Traphagan, T., Jarmon, L., Trivedi, A., & Resta, P. (2010). Teaching with virtual worlds: Factors to consider for instructional use of Second Life. *Journal of Educational Computing Research*, 43(4), 403-444. doi:10.2190/EC.43.4.a
- Meyers, E. M. (2009). Tip of the iceberg: Meaning, identity, and literacy in preteen virtual worlds. *Journal of Education for Library & Information Science*, 50(4), 226-236.
- Miyares, G. M. (2013). *Underachieving gifted science students and multi-user virtual environments* (Ph.D.). Fort Lauderdale, FL: Nova Southeastern University.
- Morley, M., Riesen, E., Burr, A., Clendinneng, D., Ogilvie, S., & Murray, M. A. (2015). Interprofessional education for pre-licensure learners in a multi-user virtual environment: Lessons learned from students, instructors, and administrators. In *ICERI2015: 8th International Conference of Education, Research and Innovation* (pp. 4796-4805). Seville, Spain.
- Mueller, F., Agamanolis, S., Vetere, F., & Gibbs, M. R. (2009). A framework for exertion interactions over a distance. In *Proceedings of the 2009 ACM SIGGRAPH Symposium on Video Games, Sandbox '09* (pp. 143-150). New Orleans, LA: ACM. doi:10.1145/1581073.1581096
- Nelson, B. C., & Ketelhut, D. J. (2007). Scientific inquiry in educational multi-user virtual environments. *Educational Psychology Review*, 19(3), 265-283. doi:10.1007/s10648-007-9048-1
- Neugnot-Cerlioli, M., Gagner, C., & Beauchamp, M. H. (2015). The use of games in pediatric cognitive intervention: a systematic review. *International Journal of Physical Medicine & Rehabilitation*, 3(4), 1000286. doi:10.4172/2329-9096.1000286
- Nickerson, J. V., Corter, J. E., Esche, S. K., & Chassapis, C. (2007). A model for evaluating the effectiveness of remote engineering laboratories and simulations in education. *Computers & Education*, 49(3), 708-725. doi:10.1016/j.compedu.2005.11.019
- Nogueira, P. A., Torres, V., Rodrigues, R., Oliveira, E., & Nacke, L. E. (2016). Vanishing scares: biofeedback modulation of affective player experiences in a procedural horror game. *Journal on Multimodal User Interfaces*, 10(1), 31-62. doi:10.1007/s12193-015-0208-1
- Park, K. S., & Kenyon, R. V. (1999). Effects of network characteristics on human performance in a collaborative virtual environment. In *Proceedings of Virtual Reality (VR)* (pp. 104). Houston, TX, USA. doi:10.1109/VR.1999.756940.
- Passig, D. (2015). Revisiting the Flynn effect through 3D immersive virtual reality (IVR). *Computers & Education*, 88, 327-342. doi:10.1016/j.compedu.2015.05.008
- Petrakou, A. (2010). Interacting through avatars: Virtual world as a context for online education. *Computers & Education*, 54(4), 1020-1027. doi:10.1016/j.compedu.2009.10.007
- Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the Horizon*, 9(5), 1-6. doi:10.1108/10748120110424816
- Preziosa, A., Grassi, A., Gaggioli, A., & Riva, G. (2009). Therapeutic applications of the mobile phone. *British Journal of Guidance & Counselling*, 37(3), 313-325. doi:10.1080/03069880902957031
- Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). Generation M²: Media in the Lives of 8- to 18-year-olds. The Kaiser Family Foundation. Retrieved December 2, 2018, <http://www.kff.org/other/event/generation-m2-media-in-the-lives-of/>
- Ritz, L., & Buss, A. (2016). A framework for aligning instructional design strategies with affordances of CAVE immersive virtual reality systems. *TechTrends: Linking Research & Practice to Improve Learning*, 60(6), 549-556. doi:10.1007/s11528-016-0085-9
- Riva, G., Wiederhold, B. K., Mantovani, F., & Gaggioli, A. (2011). Interreality: The experiential use of technology in the treatment of obesity. *Clinical Practice and Epidemiology in Mental Health*, 4(7), 51-61. doi:10.2174/1745017901107010051
- Roberts, D., Wolff, R., Otto, O., & Steed, A. (2003). Constructing a Gazebo: supporting teamwork in a tightly coupled, distributed task in virtual reality. *Presence*, 12(6), 644-657. doi:10.1162/105474603322955932
- Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation,

- social development, and well-being. *American Psychologist*, 55(1), 68-78. doi:10.1037110003-066X.55.1.68
- Scullion, J., Baxter, G., & Stansfield, M. (2015). UNITE: Enhancing students' self-efficacy through the use of a 3D virtual world. *Journal of Universal Computer Science*, 21(12), 1635-1653. doi:10.3217/jucs-021-12-1635
- Schmierbach, M., Limperos, A. M., & Woolley, J. K. (2012). Feeling the need for (personalized) speed: How natural controls and customization contribute to enjoyment of a racing game through enhanced immersion. *Cyberpsychology, Behavior, and Social Networking*, 15(7), 364-369. doi:10.1089/cyber.2012.0025
- Schmidt, B., & Stewart, S. (2010). Implementing the virtual world of Second Life into community nursing theory and clinical courses. *Nurse Educator*, 35(2), 74-78. doi:10.1097/NNE.0b013e3181ced999
- Slater, M., Usoh, M., & Steed, A. (1994). Depth of presence in virtual environments. *Presence: Teleoperators and Virtual Environments*, 3(2), 130-144. doi:10.1162/pres.1994.3.2.130
- So, H. J., & Brush, T. A. (2008). Student perceptions of collaborative learning, social presence and satisfaction in a blended learning environment: Relationships and critical factors. *Computers & Education*, 51(1), 318-336. doi:10.1016/j.compedu.2007.05.009
- Soltani, P. (2018). A SWOT analysis of virtual reality (VR) for seniors. In G. Guazzaroni (Ed.), *Virtual and augmented reality in mental health treatment*. Hershey, PA: IGI Global. doi:10.4018/978-1-5225-7168-1.ch006
- Soltani, P., Figueiredo, P., Fernandes, R. J., & Vilas-Boas, J. P. (2017a). Muscle activation behavior in a swimming exergame: Differences by experience and gaming velocity. *Physiology & Behavior*, 181, 23-28. doi:10.1016/j.physbeh.2017.09.001
- Soltani, P., Figueiredo, P., Ribeiro, J., Fernandes, R. J., & Vilas-Boas, J. P. (2017b). Physiological demands of a swimming-based video game: Influence of gender, swimming background, and exergame experience. *Scientific reports*, 7(1), 5247. doi:10.1038/s41598-017-05583-8
- Soltani, P., Figueiredo, P., Fernandes, R. J., & Vilas-Boas, J. P. (2016). Do player performance, real sport experience, and gender affect movement patterns during equivalent exergame? *Computers in Human Behavior*, 63, 1-8. doi:10.1016/j.chb.2016.05.009
- Susi, T., Johannesson, M., & Backlund, P. (2007). Serious games: An overview. (Technical Report No. HS-IKI-TR-07-001). *Skövde*, Sweden: University of Skövde.
- Tang, J. T., Lan, Y. J., & Chang, K. E. (2012). The influence of an online virtual situated environment on a Chinese learning community. *Knowledge Management & E-Learning: An International Journal (KM&EL)*, 4(1), 51-62.
- Vrellis, I., Avouris, N., & Mikropoulos, T. A. (2016). Learning outcome, presence and satisfaction from a science activity in Second Life. *Australasian Journal of Educational Technology*, 32(1), 59-77. doi:10.14742/ajet.2164
- Webster, R. (2016). Declarative knowledge acquisition in immersive virtual learning environments. *Interactive Learning Environments*, 24(6), 1319-1333. doi:10.1080/10494820.2014.994533
- Whitehead, S., & Biddle, S. (2008). Adolescent girls' perceptions of physical activity: A focus group study. *European Physical Education Review*, 14(2), 243-262. doi:10.1177/1356336X08090708
- Yee, N. (2006). Motivations for play in online games. *CyberPsychology & Behaviour*, 9(6), 772-775. doi:10.1089/cpb.2006.9.772
- Young, M. F., Slota, S., Cutter, A. B., Jalette, G., Mullin, G., Lai, B., Simeoni, Z., Tan, M., & Yukhymenko, M. (2012). Our princess is in another castle: A review of trends in serious gaming for education. *Review of Educational Research*, 82(1), 61-89. doi:10.3102/0034654312436980.

ADDITIONAL READING

- Sun, H. (2013). Impact of exergames on physical activity and motivation in elementary school students: A follow-up study. *Journal of Sport and Health Science*, 2(3), 138-145.
doi:10.1016/j.jshs.2013.02.003
- Peng, W., & Hsieh, G. (2012). The influence of competition, cooperation, and player relationship in a motor performance centered computer game. *Computers in Human Behavior*, 28(6), 2100-2106.
doi:10.1016/j.chb.2012.06.014
- Pasco, D., Roure, C., Kermarrec, G., Pope, Z., & Gao, Z. (2017). The effects of a bike active video game on players' physical activity and motivation. *Journal of Sport and Health Science*, 6(1), 25-32.
doi:10.1016/j.jshs.2016.11.007
- Staiano, A. E., & Calvert, S. L. (2011). Exergames for physical education courses: Physical, social, and cognitive benefits. *Child Development Perspectives*, 5(2), 93-98. doi:10.1111/j.1750-8606.2011.00162.x
- Vernadakis, N., Papastergiou, M., Zetou, E., & Antoniou, P. (2015). The impact of an exergame-based intervention on children's fundamental motor skills. *Computers & Education*, 83, 90-102.
doi:10.1016/j.compedu.2015.01.001
- Finco, M. D., Reategui, E., Zaro, M. A., Sheehan, D. D., & Katz, L. (2015). Exergaming as an alternative for students unmotivated to participate in regular physical education classes. *International Journal of Game-Based Learning (IJGBL)*, 5(3), 1-10. doi:10.4018/IJGBL.2015070101
- Lindberg, R., Seo, J., & Laine, T. H. (2016). Enhancing physical education with exergames and wearable technology. *IEEE Transactions on Learning Technologies*, 9(4), 328-341.
doi:10.1109/TLT.2016.2556671
- Pedersen, S. J., Cooley, P. D., & Cruickshank, V. J. (2017). Caution regarding exergames: A skill acquisition perspective. *Physical Education and Sport Pedagogy*, 22(3), 246-256.
doi:10.1080/17408989.2016.1176131
- Gibbs, B., Quennerstedt, M., & Larsson, H. (2017). Teaching dance in physical education using exergames. *European Physical Education Review*, 23(2), 237-256.
doi:10.1177/1356336X16645611
- Finco, M. D., Reategui, E. B., & Zaro, M. A. (2015). Exergames lab: A complementary space for physical education classes. *Movimento*, 21(3), 687-699.

KEY TERMS AND DEFINITIONS

MUVE: A computer, server-, or internet-based virtual environment that can be accessed by multiple users simultaneously.

Virtual reality: Interactive computer-generated experiences that take place in simulated environments and incorporate audiovisual and sensory feedbacks.

Exergame: A term referred to video games that require some degrees of exercise to operate them.

Collaborative learning: An educational approach to teaching and learning that involves students working together to complete a task or to solve a problem.

Physical education: An educational course related to maintaining the human body through physical exercises.

Biomechanics: This term refers to the study of structure and function of the mechanical aspects of biological systems.

Exercise physiology: The study of the acute responses and chronic adaptations to exercise.