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The Potential of Using Virtual Reality Technology in Physical Activity Settings

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In recent years, virtual reality technology has been successfully used for learning purposes. The purposes of the article are to examine current research on the role of virtual reality in physical activity settings and discuss potential application of using virtual reality technology to enhance learning in physical education. The article starts with a description of major features in virtual reality technology, then focuses on review and critique of studies on its use in physical activity settings, and concludes with a discussion on future directions of using the virtual reality technology in research of learner conceptual change in physical education. Research evidence cited and reasoning made in the article support the idea that, under certain conditions and with specific learners, virtual reality technology can be a useful tool to enhance learning in physical activity settings by facilitating the conceptual change process.

Keywords Virtual reality, physical activity, conceptual change, physical education

As technology continues to advance in our societies and our lives, people from all walks of life have begun to embrace its impact and explore its present and future potential. Many technology inventions become available every day to help people better connect to the world or better accomplish what they do. One technology, virtual reality (VR), has been used successfully in collaborative learning (Monahan, McArdle, & Bertolotto, 2008) or science (Kartiko, Kavakli, & Cheng, 2010; Lee, Wong, & Fung, 2010). In the field of kinesiology, VR has been adopted in many applications to help train students and professionals as well. There is no doubt that VR applications have changed the way people live, play, and learn in the physical domain. It is helpful and necessary for kinesiology researchers to take a scholarly look at VR technology to further understand and explore its potential. The purposes of the article are to examine current research on the role of virtual reality in physical activity settings and discuss potential application of using virtual reality technology to enhance learning in physical education. The article is organized in three sections to: (a) a description of major features in the current virtual reality technology, (b) a review and critique of studies on VR use in physical activity settings, and (c) a discussion of future directions of using VR technology to enhance learning in physical education by facilitating learner conceptual change.

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Virtual Reality Features and Applications

Sherman and Craig (2003) have defined VR as "a medium composed of interactive computer simulation that senses the participant's position and actions and replaces or augments the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation (a virtual world)" (p. 13). A VR environment is an artificial physical environment created using digital technology. Visual, audial, and other perceptual stimuli are incorporated in the technology in a sequence of manipulated events to which a person is expected to react. A simple VR environment consists of a two-dimensional viewing environment, whereas a complex VR environment can include three-dimensional (3-D) digital objects and human avatars in real-time (i.e., without any time delay in movement between users' and avatars' interactions). Because a 3-D environment provides a condition where individuals are immersed in close-to-reality situations to interact with digital objects and human avatars, three human–VR interaction concepts have been used to help understand applications and their features: immersion, interaction, and presence.

Immersion

Immersion has been originally defined by Slater and Wilbur (1997) "as a technology that describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant" (p. 604). In this environment, "inclusive" denotes that in the technology-created environment, actual external reality is no longer available for perception by the individual; he or she is enclosed in the virtual environment. "Extensive" refers to the range of sensory modalities accommodated in order to operate in the virtual world. "Surrounding" indicates the extent to which the VR environment is panoramic rather than limited to a narrow field. "Vividness," in reference to Steuer (1992), indicates a sensorially rich environment in which responses generated by the individual mimic those that he or she generates in the actual environment.

Individual immersion in a VR environment is actualized through using immersive display devices. One example, as shown in Figure 1, is a head-mounted display. The device has a small optic display/screen in front of each eye in which the user sees a pre-programmed 3-D environment. Another example is the Cave Automatic Virtual Environment (CAVE). Figure 2 shows a CAVE environment of a soccer goal. A CAVE system, when programmed well, can closely represent an environment by highly resembling the real world in full-scale. The system in Figure 2 consists of four planes (the floor and three adjacent walls) on large screens on which the physical environment is displayed. One advantage of using a CAVE system is that it allows the user to move naturally in the space surrounded by digitally created environmental cues.

Interaction

When users are immersed in a VR environment, they can interact in real time with objects and avatars. Zeltzer (1992) has defined *interaction* as "the degree to which virtual environment parameters can be modified at runtime" (p. 128). Designers have used different devices to facilitate interaction. One example of the devices is body motion capture device, as shown in Figure 3. The function of the device is to record human movement in the human-VR environment interaction. A body motion capture device consists of a set of internal sensors attached to the human body by a Lycra® suit that detects, follows, and records

Figure 1. View of a head mounted display (HMD) device.

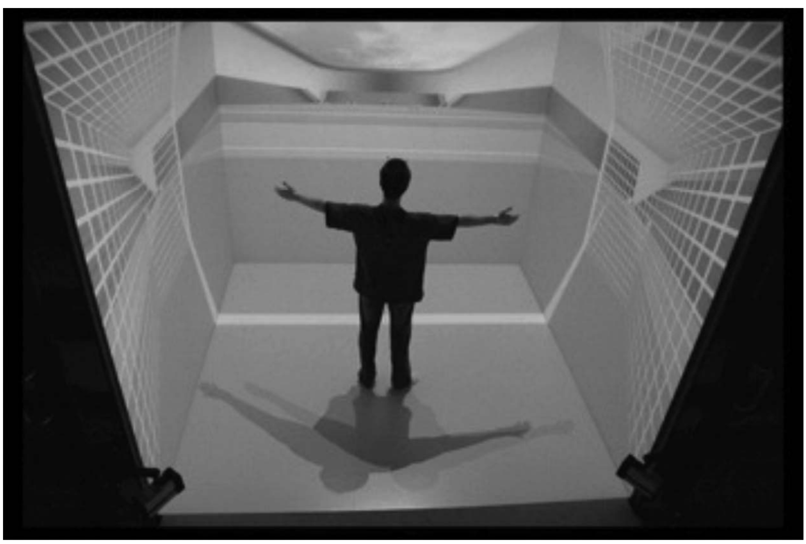

Figure 2. View of a Cave Automatic Virtual Environment (CAVE) consisting of four dimensional planes (the floor and three adjacent walls) on large screens on which the physical environment is displayed.

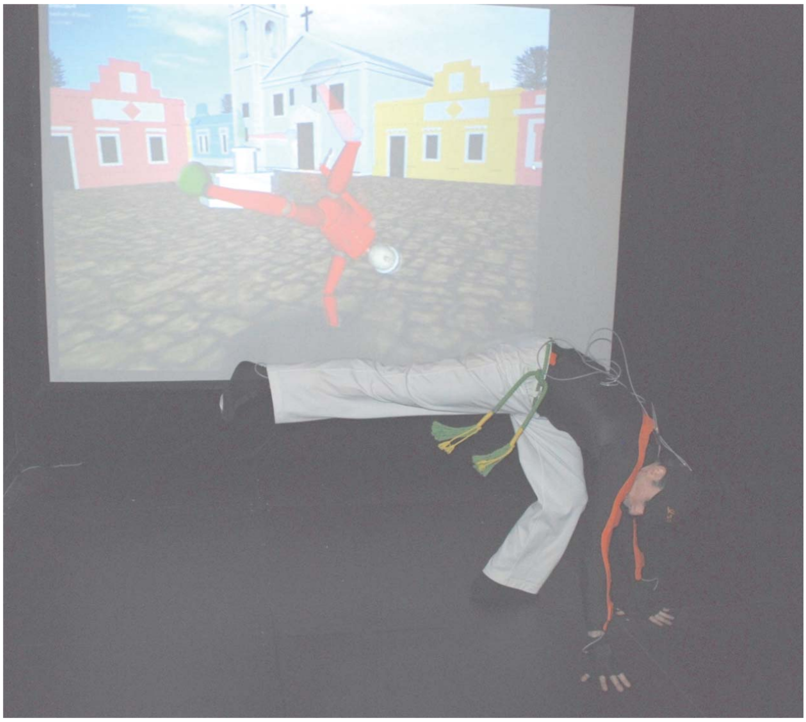

Figure 3. View of interactions between an avatar and a human through a body motion capture device (color figure available online).

movements of the person and conveys body movements to a recognition server to activate an avatar. In turn, the avatar acts as the person in the VR environment. The person–avatar interaction can be used for many purposes, one of which is training.

Another device is the haptic force feedback, as shown in Figure 4. The device is composed of three articulated branches attached in parallel to a grasping tool that gives kinematic feedback on all degrees of all axes. The device incorporates tactile sensors that measure forces exerted by a user. This device is particularly useful in training fine motor skills.

Presence

The concept of *presence* has been defined by Slater and Wilbur (1997) as the subjective feeling of "being in the virtual environment" (p. 607). In other words, it is a psychological sense of "being there" in the VR environment. Human beings may experience different levels of presence in the same digital environment (Bowman & McMahan, 2007). The stronger a person experiences the feeling of being in a VR environment (presence), the more likely he or she will report behaving typical to that in the real world. According to Slater and Steed (2000), *presence* determines the level of immersion a subject experiences; in turn it determines the effect of VR on the purpose of immersion (e.g., learning). For Schuemie, Van Der Straaten, Krijn and Van der Mast (2001), the concept of presence is a key element in research related to VR effectiveness.

An Example of a VR Environment in Soccer

De Loor, Bénard, and Bossard (2008) designed CopeFoot, a VR 3-D environment on the MASCARET virtual reality platform (Buche, Querrec, De Loor, & Chevaillier, 2004) to

Figure 4. View of a haptic force feedback. The device is composed of three articulated branches, attached in parallel to a grasping tool that gives kinematic feedback on all degrees of all axes.

help players learn and practice tactical decisions in soccer. CopeFoot uses a context-based reasoning as the teaching platform in which player activated avatars perceive, decide, and act to create and respond to situations on the soccer field. The avatars in CopeFoot were designed to mimic the process of how elite players make decisions and perform in real contexts. Bossard, Kermarrec, Bénard, De Loor, and Tisseau (2009) and Bossard, Kermarrec, De Keukelaere, Pasco, and Tisseau (2011) demonstrated using avatars to create a VR environment to train soccer players to make tactical decisions. Bossard et al. (2011) asked 12 experienced youth soccer players ($M_{age} = 15.8$ years, $SD = 0.38$) to perform five counter attacks from the middle field with two partners and three opponents. Objective observation data and after-decision interview data were collected to establish decision-making patterns that the experienced players used in solving tactical problems. These patterns were organized into sequential scenarios in CopeFoot that were then used to train the avatars. The avatars in the CopeFoot VR can be used to train a novice soccer player to make tactical decisions by presenting various tactical problems during avatar-player interaction. For example, the avatar can start an attack that requires the player to come up with a counter-attack tactic. In the CopeFoot system, each time avatars encounter a tactical problem, the player will act and interact with them to create a relevant solution. This solution then becomes a case that the opponent avatars will use in the future against the player in training; when the player makes a move that creates the similar tactical problem, the opponent avatar will react to it with the solution to counter, which will create a new tactical problem for the player. Figure 5 below shows a view of a player interacting with an avatar in the CopeFoot environment.

A limitation of the CopeFoot system is that it only requires the player to mimic an action rather than carry-out a soccer movement and/or skill. In other words, the player in training does not act or react as though they were playing soccer. Thus, the effect of training

Figure 5. View of a player interacting with an avatar in the CopeFoot environment.

on connecting cognition (tactical decision making) and kinetic operations (carrying-out a tactical movement) remains unknown. One way to integrate these movements and decisions making will be to develop a similar CopeFoot system on the CAVE platform.

Using VR Technology in Physical Activity Settings: Research Evidence

Students learn best when they interact with real-world events and solve real-world problems (Mayer & Alexander, 2011). But learning in the real-world environment sometimes imposes challenges in access, task progression, and/or safety. The VR technology has been viewed as a solution to these challenges. Its successful use has been reported in facilitating learning in specific content (Mills & De Araujo, 1999; Pan, Cheock, Yang, Zhu, & Shi, 2006; Yang, Chen, & Jeng, 2010), suggesting that a VR learning environment can be used to provide a realistic and safe environment for learners to perform specific tasks.

Most of the VR learning environments available are designed to focus on facilitating cognitive learning. Using VR technology in physical activity settings is new and is considered having great potential. One advantage of using VR is to eliminate the risk of injuries in physical training, for example. Another advantage is to provide learners with information that is not readily visible or available when learning in the real world but that can play an important role in learning (e.g., air circulation, wind direction, the gravity force). With improvement in VR technology, it can be expected that VR will become a major tool to create various conditions to enhance learning experiences. The section that follows illustrates evidence from research studies exploring the possibility of using VR technology to facilitate learning in the physical movement domain.

Motor Skills Learning

Eaves, Breslin, Van Schalk, Robinson, and Spears (2011) studied the issue of using VR technology in motor skills learning. Their study focused on the effects of two variations of real-time VR feedback (full or reduced) on motor learning in dance. Participants (n = 30; 17 men, 13 women; M_{age} = 21 years; age range: 20–29 years) were randomly assigned to three experimental conditions: full feedback, reduced feedback, and no feedback. The full-feedback condition presented learners with a feedback on the difference between 12 of their joint center locations and the expert's movement in a complex motor-skill in dance. The reduced-feedback condition provided feedback only on four distal joint center locations. The no-feedback condition presented no real-time feedback during learning. Differences between learners' movement and experts' movement on each measured joint were used to evaluate learners' performance. Results revealed that learners in both full- and reduced-feedback conditions learned better than those in the control condition. Those in the reduced-feedback condition, however, demonstrated better performances than those in the full-feedback condition. The researchers reasoned that reduced feedback (with information from eight fewer joints to process) allowed the learners to better focus on the feedback that was more task-relevant. Eaves et al. (2011) concluded that with careful design VR technology could be used as a useful platform to teach complex real-world motor skills.

However, it seems that VR utility may rely on the types of skills, specifically whether the skill to be learned is an open or a closed skill. Fink, Foo, and Warren (2009) studied an open skill using VR technology to address the "outfielder problem," which refers to the ability of a baseball outfielder to decide where to run to catch a fly ball. A VR environment in which fly baseballs were projected in 16 patterns was designed to train outfielders' decision making. Experienced college baseball and softball players (n = 12) were asked to catch the fly balls under two conditions: forward direction and backward direction. Success rates were compiled. Results revealed that one half of the balls (50%) were recorded as successful catches. Zaal, Bongers, Fernandez, and Bootsma (2010) have studied the "outfielder problem" using another VR system (CAVE) and found a success rate of 80%. But these results were not representative of the players' real ability. Based on these studies, Zaal and Bootsma (2011) concluded that although VR can be a useful tool for the study of perception–action relationship, it may have very limited influence on real action. The key issue of transferring decisions and open skills learned in a VR environment to real playing fields remains unaddressed. Zaal and Bootsma (2011) were skeptical that a VR environment could be used to recreate and replace the real situation due to many limiting factors in VR, such as large space, object trajectory variations, human movement differences in a confined vs. an open environment). They further concluded that:

> An experiment in which participants run to catch real balls, in a real environment, which has real variablity in conditions (think of effects of wind, lighting, more complex feedback), obviously has more ecological validity than an experiment in even the most advanced VR setup. (p. 100)

But findings on using VR to facilitate learning closed skills suggest a greater potential than learning an open skill illustrated above. Patel, Bailenson, Hack-Jung, Diankov, and Bajcsy (2006) compared participants' performances on several Tai Chi movements in a two-dimensional (2-D) video system and a 3-D immersive environment. Undergraduate students (13 men, 13 women) were randomly assigned to either a 2-D (7 men, 6 women) or a 3-D (7 women, 6 men) condition. The participants then learned Tai Chi movements by mimicking the teacher in the respective systems. Learning outcome performances were video recorded after the learning process and were evaluated through blind, independent rating by two experts using 13 rubric scoring systems (7-point Likert scale for each rubric).

Results showed that the participants in both conditions improved their skills, but those in the 3-D environment achieved better scores than those in the 2-D environment.

These results suggest that within a 3-D VR environment designed for a specific purpose, learners can improve closed motor skills. The finding, however, is inconclusive because the transfer of learned skills from VR to real world still is an issue. Kozak, Hancock, Arthur and Chrysler (1993) compared real-world training against VR training and no-training on a closed skill (pick-and-place) transfer from practice to real-world performance. They found no evidence of transfer from the VR practice to the real-world performance. VR technology, on the other hand, has improved significantly since 1993. It is hopeful that new studies based on new VR technology can help clarify these issues.

Physiological Responses to Physical Activity

Heart rate, ventilation rate, and sweating, are important physiological indicators for the impact of exercise/physical activity on the human body. They are also often used as indicators of whether an individual is exercising at a physical activity level to receive health benefits. Standards based on these indicators, especially on heart rate, are used as platforms on which the effect of physical activity is evaluated for adults and children alike. In recent years, VR technology has been viewed as an opportunity to study and improve physiological responses to exercise in a safe, controlled, and motivational environments.

Chuang, et al. (2003) examined the influence of VR technology on physiological responses of the cardiovascular and ventilatory systems during incremental exercise testing. Twelve healthy subjects (10 men, 2 women; $M_{age} = 74.5$ years, $SD = 4.7$ years) performed exercise tests on a friction-braked cycle ergometer with VR technology (virtual screen that included two bicycle riders: one represented the subject and the other an accompanying rider) and without VR technology (no screen). Physiological response measures included heart rate, blood pressure, rating of perceived exertion, average oxygen uptake, and respiratory parameters. Results revealed that (a) the VR and non-VR systems did not produce different outcomes on submaximal and peak exercise responses and (b) the VR system significantly increased cycling time, distance, and caloric expenditure.

Studies of VR impact on physiological responses are scarce, so the findings cannot be taken as conclusive. But the fact that the VR system resulted in an increase in select behavioral and physiological measures (e.g., exercise time, distance, and caloric expenditure) suggests that this technology can help participants optimize their exercise routines and, as such, increase behavioral and physiological benefits of exercise.

Users' Exercise Experience and Performance

How users experience tasks in a VR environment, including their feelings toward the VR environment (presence), has been identified as a key element that determines success or failure of the VR learning environment (Sun, Tsai, Finger, Chen & Yeh, 2008). Thus, studying presence is an important aspect of inquiry into the impact of VR technology on the human–device interaction. Ijsselsteijn, De Kort, Westerink, De Jager, and Bonants (2006) used Slater and Wilbur's (1997) theoretical immersion–presence framework to study the extent of association between immersion and presence enhanced motivation and presence in a VR environment. Adult workers ($n = 24$; 12 men, 12 women; $M_{age} = 41.3$ years) were asked to exercise on stationary bikes in a high or low immersion VR environment in two conditions:

with or without a virtual coach. It was found that in the high-immersion VR environment, the participants experienced a higher perception of presence, cycled faster, and reported more perceived competence, control, interest, and enjoyment than in the low-immersion condition.

In a study on VR impact on exercise experience, Mestre, Maïano, Dagonneau, and Mercier (2011) assigned 12 college students (6 men, 6 women; $M_{age} = 22.92$; $SD = 1.44$) to either of the two conditions: cycling on stationary bikes with video feedback only or with video feedback while listening to music. Performance variables (heart rate, instantaneous power, and distance) and cognitive/affective variables (gaze behavior, attention focus, commitment, and physical activity enjoyment) were measured. Results revealed a positive effect of video feedback with music condition on participants' commitment to the task and performance. This finding may suggest that music may enhance the feeling of immersion in a VR environment and the combination is likely to enhance exercise performance better than the single-source immersion.

Research evidence presented above appears to support that (a) VR environment should not provide too much feedback, (b) 3-D systems produce better skill learning outcomes than 2-D systems, (c) high-immersion environments may provide a more positive affective responses and motivation to exercise than low-immersion environments, and (d) VR environments may not induce higher physiological responses and may not provide additional benefits above and beyond a simple physiological monitoring system.

Research on VR application in motor skill learning/physical activity is still in its infancy. But the findings have shown both its potential and limitation. It appears that at this time, VR systems built on the current technology platforms cannot replace the real world experience for learning. The real world provides richer learning experiences that involve complex interactions between learners, environment, teachers/coaches, and other stakeholders such as peers that a digital world may not be able to recreate at the present time. Furthermore, as Bossard et al.'s study (2009) showed, novices or beginners may benefit more than experts from using the VR environment. An obvious shortcoming in the studies reviewed is that they all involved individualized learning/training that provided the experiences to one learner or player at a time. Thus, tremendous challenges remain in using VR technology to teach students in groups, such as the case in physical education. With the development of technology, it is hoped that future VR systems can offer a VR learning environment where multiple 3-D high immersion learning stations can be incorporated to enable group learning opportunities where multiple students can learn together but at their individualized paces.

Future Directions

As more studies focus on using VR technology in educational settings to improve students' cognitive, affective and motor learning, Huang, Rauch, and Liaw (2010) argued that, "educators or instructional designers, as they apply a new VR technology to educational settings, need to consider carefully how pedagogy or a learning theory may influence the learning process" (p. 1172). To address this issue, a robust learning theory must be used to form a relevant theoretical platform on which various technologies can be incorporated in designing VR environments that enhance learning. In the following section an attempt is made to explore how conceptual change theory can be applied to design VR learning environments for physical education.

Conceptual Change Theory in Physical Education

Cognitive psychologists have provided important insights into the way learners acquire new knowledge. They define learning as a change "in the way a person thinks, reasons, believes, and processes information, in part, by expanding or altering the individual's existing knowledge base" (Alexander, 2006, p. 123). Learners acquire new knowledge based on their previous knowledge and experience. According to Vosniadou and colleagues (Vosniadou 1994, 2002; Vosniadou & Brewer 1992, 1994), students' prior knowledge should not be considered "mistakes" or "errors" that must be replaced with scientific knowledge, but as naïve theory based on which the learner begins the long journey of learning. Based on the findings from research on student's prior knowledge in physics, Vosniadou (2002) argued that children's naïve knowledge is neither a collection of unstructured knowledge elements nor stable misconceptions that need to be replaced; instead it is "a complex conceptual system that organizes children's perceptual experiences and information they receive from the culture into coherent explanatory frameworks that make it possible for them to function in the physical world" (p. 61). Naïve theories represent the explanations students use to describe a particular phenomenon within a domain. Vosniadou and colleagues have suggested considering learning as a conceptual change process from naïve theory to scientific theory.

In physical education, conceptual change has been observed in elementary school children when they attempted to explain their physiological responses to physical activities. Pasco and Ennis (2013) studied third graders' prior knowledge about energy expenditure during exercise. Students (n = 45) were interviewed during their regular physical education class in order to investigate how they understood energy expenditure during exercise. Results revealed two levels of understanding. At the first level of understanding, the students considered energy expenditure as an on/off process; they believed that when one was tired (out of energy), the body was slowing down and eventually coming to a stop. At the second level, energy expenditure during exercise was understood as a dimmer switch process; the students believed that when one was tired, the body was in the process of becoming stronger and healthier. These prior conceptions might have impacted the children's behavioral responses to the task of running a mile in a physical education class. The students with the first level of understanding were more likely to stop running when they felt tired, whereas the students with the second level of understanding were more likely to keep running by adjusting their pace.

Using Virtual Reality to Promote Conceptual Change in Physical Education

Pasco and Ennis's (2013) study confirms that in physical education students' previous knowledge and experiences may play an important role in students' behavior. Promoting conceptual change through instruction can be difficult (Vosniadou, 2007). When engaging in a physical activity task, it is difficult for students to know their energy level in real time. Thus the role of prior knowledge may not be determined at the task level. In teaching the physical educator should try to identify the initial conceptualization (mental models) in the students, so that their initial naïve conceptual mental models might be targeted for specific pedagogical strategies that facilitate the process of conceptual change. One possibility to make this reconceptualization process effective is to provide them information in real-time about their behavior or physiological responses in movement. Using Pasco and Ennis' (2013) study as an example, students should be given information about their misconceptualized mental models so that they can address the unscientific knowledge by incorporating scientifically correct information in the mental model restructuring process (Vosniadou, 2007). A VR system can help this process by providing the information through a gauge of energy expenditure displayed in either a 2-D or a 3-D environment. When students exercise in this environment, their level of energy will decrease depending of the types of exercises. As they experience energy expenditure in relation to exercise intensity and fatigue, they will see, feel, and, hopefully, believe the relation between changes in energy levels and types of exercises. In the meantime, the concept of pacing can be learned, which can demonstrate restoration of the level of energy without stopping the physical activity. In so doing, the students are more likely to understand the concepts of intensity and pacing in relation to energy expenditure during exercise.

To facilitate conceptual change in skill learning, a VR system, such as the CopeFoot, can be helpful as well. Learners will become immerged in this environment by controlling an avatar. They collaborate with other players (via their avatars) in creating counter attack scenarios and use them repeatedly to find out those most effective. During the process, they learn tactical decision-making by interactively co-constructing mental models to replace those they determine invalid through the trial-and-error processes with their avatars. Useful mental models of effective tactics and skills will form to replace the naïve ones. Because they share same virtual soccer field and attempt to solve same tactical problems, learners can develop a collaborative and dynamical understanding of the situation that leads to a successful conceptual change, which is an essential step toward effective construction of knowledge and skill (Alexander, 2006).

As we move forward using VR technology in physical education there are opportunities in the future to teach key concepts in physical education and increase students' physical activity. For example, learners can use VR technology to learn motor skills in a new way where they can mimic the movement of an expert avatar. In this system they can receive learning cues that are developed simultaneously by a real-time Intelligent Tutoring System (Graesser, Conley & Olney, 2012) based on real-time analysis of learners' prior knowledge, current responses to the environment, their movement solutions in a large array of VR conditions, and application decisions made in the VR environment. These opportunities can lead to new designs of learning experiences in physical education for the twenty-first century.

Conclusion

Effectively using VR technology to promote physical activity is still more of an assumption than a reality (Mohnsen, 2003; Daduo, Rongwei, Zhanfeng, Ji'an & Chao, 2010; Jiankang, 2011). Research evidence presented above supports that, under certain conditions and with specific learners, VR technology can be a useful learning tool in physical activity settings. It seems that the conceptual change theory can be used as an effective theoretical framework to guide the future design, development, implementation, and research of VR-based learning experiences.

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