A Systematic Review on the Potential of Motion-Based Gaming for Learning

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Abstract: With the inclusion of motion-based technologies such as the Wii-mote, Microsoft's Kinect or the PlayStation Move, the possibilities for using video games for serious purposes have multiplied. The purpose of this article is to explore the state of the research related to the use of video games employing motion-based technology for purposes other than entertainment. After systematically searching digital databases and online journals, 33 relevant articles were included in the study. We found that motion-based technologies have been beneficial when applied to physical and health education, training, therapy, and learning in the classroom, however, it has been noted that virtual environments might not be able to replace a real environment. Moreover, it is not clear in which situations these technologies can have a more substantial benefit. Overall there is a need for the proposal of new hypotheses and more in-depth research.

Introduction

Studies show that traditional video games, meaning games which are mediated through a personal computer or console, provide engaging experiences that help users develop practical, cognitive, social, and decision-making skills (Foster & Mishra, 2009; Ma, Williams, Prejean, & Richard, 2007; Susi, Johannesson, & Backlund, 2007). Other studies indicate that playing video games can lead to aggressive behaviors and can be a factor in a number of potentially dangerous health issues such as obesity (Dipietro, Ferdig, Boyer, & Black, 2007; Foster & Mishra, 2009). Given that video games are often seen as having significant effects on players, it is not surprising that there is an increasing interest in the use of video games for non-entertainment purposes. Video games are used successfully in several fields such as in military training, health care training, and for instructional interventions in the classroom (L. A. Annetta, Murray, Laird, Bohr, & Park, 2006; Katrin Becker, 2010; Michael & Chen, 2006; Susi, et al., 2007).

Motion-based gaming, an activity in which players interact with a digital game environment primarily through physical movements and gestures in three-dimensional space, has added a new dimension to the gaming experience. Commercial devices such as Microsoft's Kinect for the Xbox 360 and Nintendo's Wii have opened up a number of opportunities for using video games for non-entertainment purposes. Through a systematic review we are aiming to answer the following research questions: What is the state of the research related to using motion-based gaming technologies for learning, and what are the opportunities, challenges and limitations when using motion-based gaming technologies for serious purposes as described in the literature?

Methodology

This review was conducted over a period of 6 months. Articles were reviewed according to the type of research, research design, and the main topics representing current trends in the literature. Articles were retrieved from the following databases: EBSCO Host, ProQuest, Web of Science, Engeneering Village, JSTOR and PubMed. The search strategy was tailored slightly for each database; however the common search query was: "video games" or "digital games" or "computer games" AND earning AND gestur* or physi* or haptic or wii or kinect or (motion and playstation). All articles were restricted to peer-reviewed scholarly publications ranging between the years 2005 and 2011.

In total, 112 articles where found. An initial review of the literature was conducted based on the title and the keywords of the author. Articles unrelated to the research questions, and those without an abstract were excluded. A second review of the remaining articles was done based on their abstracts. Similarly, unrelated articles were excluded. From the remaining set of results, a more detailed review was done; articles were included when the following conditions were fulfilled: (1) Articles must be related to the research questions; (2) The article should be fully available online; (3) Empirical articles should include enough information related to the type of research, research design and methodologies. Additionally, related articles from peer-reviewed journals in game studies such as Game Studies and Eludamos were added. As a result, we included a set of 33 articles.

In order to answer the first research question, the final set of articles were coded according to the type of research, goal of the article, results, limitations and future research, and type of technology described in the article. The type of research was classified into empirical and non-empirical. Empirical-research-based articles, which represent 62% of the articles that were included, were also coded according to the number of participants, type of participants and research design. Articles in this category were predominantly quantitative, representing 34% of the total number of articles. Even though qualitative articles represent just 6% of the articles, many articles combined both types of research. Articles with mixed methodology represent 21% of the articles. Non-empirical articles, which include literature reviews, descriptions of projects, and theoretical articles, represent 39% of the total. Without discarding the importance of these quantitative, mixed and non-empirical articles; it is evident that there is a need of more qualitative research. New hypotheses and more large-scale, comprehensive studies are also needed.

In addition, we also found that the most researched technology was the Nintendo Wii; commonly used games were *Wii Sports* and *Wii Fit*. Technologies that were moderately used were video-capture, dance pads, the Nintendo DS, and haptic gloves. These types of technologies have been more influential since the release of the Wii in 2006. Considering that this review ranges from 2005-2011, the popularity of the Wii is not surprising. Technologies such as Microsoft's Kinect or Playstation Move are relatively new and have been commercially successful, and it is expected that in the following years they will be the most widely researched.

In order to map out the opportunities, challenges, and limitations when using motion-based gaming technologies for serious purposes, we generated our own keywords (codes) for each article based on the abstract, goals and results. As a result, a list of 43 unique codes was generated. Afterwards, these codes were grouped into themes. We found two main themes: effects when introducing augmented movement to video games and application of motion-based games. For the first theme, 8 articles were included. These articles examined topics such as learning capacity and cognition, development of motor skills, social learning, and engagement and motivation. For the second theme—application of motion-based games—a total of 21 articles were considered, which were classified into: health/physical activities/sports, in the classroom, for entertainment, and for training.

Results

Research regarding the effects when using video games with traditional controls show that video games can motivate players to continue gaming while developing cognitive, social and decision-making skills (Foster and Mishra, 2009). However, increased movement—one of the main characteristics of motion-based games—adds an extra dimension to the possible effects when playing video games. In this stream of the literature three topics that are researched are the relationship between adding augmented movement to video games and engagement, motivation, and learning.

Yannakakis et al. (2008) point out that there is a relationship between physical activity and engagement using video games. In a quantitative study, data was collected from physiological signals captured from 58 children from 8 to 10 years old when using two games developed especially for kids: Bug Smasher and an adapted version of Space Invaders. Kids interacted with the game while playing in a digital playground which captured the movement of the players. From the results, the authors demonstrate that when children are having "fun" during physical play they are engaged more; this was reflected through increased physical activity. In addition, Levac et al. (2010) conducted a study about the motivational effects when playing games that involve movement. Data was collected from 28 participants aged between 7 and 12 years while playing *Wii Fit*. Results show that movement in video games also contributes to motivating players to succeed in the game. However, results also indicate that there are differences between the quantity and quality of movement across different games, depending on the age and the experience of the participants. Children with previous experience using Wii demonstrate greater quantity of movement; however, there is no difference between the quality of movements.

In similar research, Dale et al. (2008) study the role of motor execution and longer-timescale cognitive processes, such as learning. The authors conducted two experiments exploring match-to-sample paired-associate learning, in which participants learned randomized pairs of unfamiliar symbols. During the experiments, their hand movements were continuously tracked using the Nintendo Wiimote. Both experiments showed that the dynamic characteristics of action reflect ongoing learning in a cognitive task. The first experiment showed that features of action dynamics grow more confident over a learning task, and can mark the performance of the participant, indicating whether or not they had acquired particular knowledge. The second experiment revealed that these characteristics generally index learning, not just motor familiarity with the device.

From this section it is possible to conclude that integrating movement and games can motivate players to continue playing, engaging them in the activity, which can in turn foster learning across different tasks. However, most of these studies were conducted on children and using a limited number of video games. It is hard to generalize these results for all types of video games. However, these studies present evidence that there is a relationship between movement and engagement, motivation and learning with video games. This shows the potential of this type of technology when used for purposes beyond entertainment.

Applications in Physical and Health Education

Most of the research that falls into this category supports the hypothesis that motion-based gaming can help to encourage players to engage in physical activities, promoting a healthier lifestyle. This technology can be integrated into a game specifically to promote physical activity or for entertainment purposes. Rhodes et al. (2009) evaluate the effect of videobike gaming versus traditional indoor cycling on the constructs of the theory of planned behavior, which studies the relation between attitudes and behavior, and adherence in sports. During the study, 32 male college students were instructed to exercise at moderate intensity for 30 minutes, three times per week, for 6 weeks. Results showed that affective attitude and adherence across the 6 weeks significantly favored the videobike condition over the comparison condition. However results might change if videobike gaming was to be compared to outdoor exercise. In a similar study, Warburton et al. (2007) reported that the attendance of the interactive video game group was significantly higher (78%) than that of the traditional training group (48%), resulting in a greater improvement in physical fitness. Both studies provide evidence of the positive impact when using these types of games for preventing obesity and motivating physical activity. However, other studies indicate that a virtual environment might not be able to replace a real environment. Baumeister et al. (2010) studied the difference between real and virtual environments through cortical analyses when individuals were playing golf. Overall participants performed with a significantly better score in the real condition. However, differences might arise if the experimental conditions are changed or if the experiment focuses on specific goals.

A common term for describing a way of combining physical activity and video gaming, often for entertainment purposes, is “exergaming.” A number of authors have suggested that exergames are appealing to children, adolescents, and young adults, and can motivate youth to increase their engagement in physical activity (Hicks and Higgins 2011; Papastergiou 2009; Paez 2008). Exergames also provide immediate feedback about the user's performance. One of the most popular examples of this type of game is *Dance Dance Revolution* (DDR), which can be used to teach dance-related skills such as rhythm, tempo, and choreography, although Hicks et al. (2011) argue that the most important benefit is the potential to promote a healthier lifestyle. However, in 2008 Baranowski et al. conducted a literature review which found that studies involving DDR have reported mixed results, with some noting no change in physical fitness and a gradual loss of interest in the game among participants. Results from a series of studies that investigate the viability of DDR for increasing physical activity in the home environment indicate that both initial and sustained participation are influenced by a number of factors, including social interactions and the presence of other video games (Paez, 2008). Additional research is thus needed to explore the effects of these factors.

Applications in Training

Motion-based gaming technologies have also been used successfully to train users in the use of other complex technologies such as surgical simulators or sophisticated haptic gloves systems. A study conducted by Boyle et al. (2011) investigates whether or not structured surgical training using the Nintendo Wii can improve the performance of laparoscopic tasks. Medical students with no prior laparoscopic or video game experience were divided into two groups. One group played four different games on the Wii, each of which required skills relevant to laparoscopic surgery, such as depth perception. The control group received no extra training. Results showed that all participants improved significantly from the first session to the second. While practice on the Wii was associated with a trend toward better performance, there were no significant differences between the groups for either the physical tasks (bead transfer and glove cutting) or the virtual laparoscopic tasks using the ProMIS surgical simulator.

Similarly, Bargerhuff et al. (2010) introduced a system that captures participants' perceptions when being trained to use a haptic glove system through a custom video game. There were a total of 5 participants, each of whom played for 60 minutes. A mixed methodology was followed and data sources included computer generated results (level attained, navigation speed, and efficiency), questionnaire responses (engagement perceptions), video-recordings, and detailed notes. Results suggest that the participants improved the skills associated with use of the haptic glove and active engagement with the game. Participants also demonstrated an ability to attain higher game levels with additional practice time, although this improvement varied among them. However, the study provided less evidence for the use of the haptic glove as an embodied skill. Participants continued to view the glove as a tool that required effort.

Applications in Therapy

Another stream of the literature focuses on the use of motion-based technologies for therapeutical purposes for people with intellectual or physical disabilities and for the elderly. Through a literature review, Burstin and Brown (2010) explore the clinical applications of virtual reality technologies, and also discuss how consoles, such as the Nintendo Wii, can be integrated into different types of therapy and rehabilitation interventions. According to the authors, virtual reality technologies can raise the motivation level of patients performing repetitive rehabilitation tasks, and can be used to improve balance, posture, movements, and cognition through practicing different motor-learning tasks. Additionally, the authors point out that in contrast to some virtual reality systems, commercial gaming systems are relatively inexpensive and simple to set up, and may provide an effective alternative. However they may not be adequate for tracking patients' performance and cannot always adapt to the patients' abilities.

Regarding to the use of these type of technologies as therapeutical intervention for people with intellectual disabilities, Wang Y. et al. (2011) used Wii sports for supporting rehabilitation therapies for children with Down Syndrome. This quantitative study compares the effectiveness of using Wii Sports versus standard occupational therapies. Data was collected from 160 children with Down Syndrome aged between 7 and 12 years old. Participants used the assigned intervention on sessions of 1-2 hours, 2 days per week for 24 weeks. Results show that both therapies are effective in improving sensorimotor function as compared to children with no therapy; the virtual therapy improved motor proficiency, visual-integrative abilities, and sensory integrative functions for children with Down Syndrome; and there was an increase in motor, emotions and behavior skill subsets following both types of therapies.

In another study, Fenney and Lee (2010) probe the capacity of persons with dementia to learn motor tasks when using *Wii Sports* (bowling) as a recreational activity. Participants were 68, 79, and 90 years old males. Quantitative and qualitative data was gathered during 9 weeks followed by a 5-6 month retention test. Results present evidence that Wii environments are engaging. Participants improved and maintained performance for 5 months and completed motor tasks regardless of the conditions. Similarly, Yalon-Chamovitz (2008) studied the perceptions and effects of a video-capture game-based intervention for individuals with severe physical and intellectual disabilities when used as a leisure activity. Participants in this experiment were 33 young adults with a mean age of 28 years old. Data was collected using observations, and questionnaires. Participants were divided in two groups, the control group used traditional activities such as discussions and outings; participants in the experimental group used the virtual intervention. The activity took place for 12 weeks, 2 or 3 times per week, 30 minutes per session. Results show that even though there was a high interest in using the video game, participants were attracted to more active and physically demanding leisure activity and there were no changes in self-esteem.

Regarding to the use of motion-based video games for physical therapies, Bursting et al.'s (2010) literature review points to one of the main problems in physical therapies: patients receive a small amount of therapy time during rehabilitation. Virtual reality can deal with this problem providing assistance, immediate feedback, and real-time interactive experience. In this review, the author notes that through this type of therapy, patients tend to forget their limitations. Virtual reality encourages them to reach their goals and helps them to continue the therapy without feelings of fatigue or boredom. With the inclusion of new consoles, virtual reality can be cheap, and it is perceived by both patients and therapist as something positive. Additionally, in another study Eng et al. (2007) propose a motor neurorehabilitation system for stroke patients with upper limb paresis. The system is a custom application where the patient controls a first-person view of virtual arms in tasks varying from simple tasks such as hitting objects to complex task such as grasping and moving objects. Usability results show that user acceptance of the system was high; most patients expressed a desire to use the system on an ongoing basis. Pilot study results show that therapy has not prevented patients' progress of disease, and suggest that it might add to the efficacy of traditional physiotherapy. Patients generally accept the therapy system and are motivated to use it. This system is promising for providing effective rehabilitation based on validated neuroscientific hypotheses. The system may provide improved efficacy of rehabilitation by enhancing patient concentration through the use of the goal-oriented tasks. Additionally, it can also be used as both a therapy and assessment tool. However, more work is needed in defining and calibrating standard tests using the game infrastructure to ensure reproducible results.

Lastly, motion-based technologies are also used as a therapeutical intervention for the elderly. De Bruin et al. (2010), in a literature review, have explored the potential of dance-pad-based training protocols for aged people. The main idea of this type of environment is to combine physical game-like exercises with sensory and cognitive challenges in a virtual environment. The most common reason for loss in functional capabilities in the aged is inactivity or immobility. Physical exercise helps to restore postural balance and walking function. However, physical exercise is sometimes challenging; people can be afraid or it can be painful. Gaming elements can be used to take patients attention away from any pain. Dance pads offer a potential alternative for training stepping ability in older adults, although it still is necessary to conduct further research in order to implement and evaluate virtual-reality based exercises. Results in an experiment conducted with older adult women showed that Wii-play did not have substantial physical effects, however, participants perceived an improved sense of physical, social and psychological wellbeing. Overall the experience was empowering and motivating for participants (Wollersheim et al., 2010).

Applications in the Classroom

Research related to the uses of motion-based video games as a learning intervention in the classroom is scant. It is important to note that in this section we are not including physical education or sports courses, as they were included in previous sections. Yang et al. (2010) have developed a custom environment called the Physically Interactive Learning Environment (PILE), which is intended to integrate motion-capture technology into English as a second language classes at an elementary school level. The system allows students to carry out various English learning activities using physical movements and speech. Results from a study comparing the English abilities of a group using the PILE system to a group using traditional teaching using slides indicated that the PILE system had a beneficial effect on students' long-term learning. In addition, the system was easy to operate and enhanced the students' motivation to learn. These conclusions were based on observations of the students' behavior during the class, collecting data from pre-tests and post-tests, and through questionnaires and teacher interviews. Even though it seems that the PILE system is capable of attracting students' attention, the duration of the study, three weeks, one class per week, was insufficient to determine whether or not this effect would persist and for how long. Additionally, in a exploratory review, Maldonado (2010) explores the potential of using the Nintendo Wii in the classroom. The author concludes that even though the Wii may provide a number of benefits in areas such as vocabulary building, cognitive development, and participation, it is necessary to consider the following factors: there is a limited number of players that can participate at one time, movement is mostly focused on the arms and legs, loud sounds can be disruptive for children pursuing other activities, and cost.

Conclusions

In the present work, we conducted a systematic review in order to explore the state of the research related to the use of video games employing motion-based technology for purposes other than entertainment. The research questions explored in this review were: What is the state of the research related to using motion-based gaming technologies for learning, and what are the opportunities, challenges and limitations when using motion-based gaming technologies for serious purposes as described in the literature?

For the first research question, we found that research has been rigorous in presenting empirical evidence that support the results. Most of the evidence relies on quantitative data and mixed methodologies. However, there is a need for more qualitative research in order to increase the depth of the research and propose new hypotheses. Additionally we found that, in the previous years, these technologies were expensive and were mostly in laboratories or other types of institutions. However, now with the development and release of commercial devices such as the Wii and the PlayStation Move, costs have been reduced, and motion-based technologies are beginning to be introduced into more environments. The most researched technology at the moment is the Nintendo Wii, however, there is a trend to explore new console-based technologies such as Microsoft Kinect.

For the second research question, we found that, similar to other types of video games, motion-based video games motivate players to be immersed in the gaming experience while developing cognitive, social and decision-making skills. We also found that there is a connection between physical activity and engagement in video games fostering learning in different types of tasks, however a more precise definition of engagement would be helpful. Additionally, we found that motion-based technologies have been successfully applied in physical and health education, training, therapies, and in the classroom. Furthermore it has been noted that virtual environments might not be able to replace a real environment; there is no clear evidence as to whether these technologies can support a constant change in physical fitness or in which situations they can have a more substantial benefit.

As for future work, in order to achieve a deeper understanding of the potential of motion-based technologies for serious purposes, it is necessary to conduct more empirical research, create new hypotheses, and continue developing a deeper and more comprehensive understanding of the use of these technologies. Both types of research, quantitative and qualitative, could help to elicit different types of information that will be helpful in reaching more detailed conclusions.

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