Active Video Games – An Opportunity for Enhanced Learning and Positive Health Effects?

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Active video games are an emerging genre of electronic games that provide engaging exercise experiences by combining physical exertion with interactive game play. As such they have attracted increased interest from health promotion professionals to reduce sedentary behavior, increase physical activity, and improve health outcomes such as body composition. However their potential for enhancing the educational experience has not been extensively explored. This paper provides a brief overview of active video game research to date and outlines opportunities for future research. Specifically, we highlight the need to develop a conceptual framework to better understand the determinants, mediators, moderators, and consequences of active video gaming and integrate learning and health outcomes. We propose that active video games can be a key part of a wider "digital" supportive environment where education and health researchers and professionals work with, rather than against, video game technologies to promote learning and health.

KEYWORDS: Exergaming, Video Games, Sedentary, Physical Activity, Virtual Reality

INTRODUCTION

Active video games (AVG) are a growing genre of electronic games, which require physical exertion in order to play them. As a result, AVGs have attracted increased interest by health promotion professionals over the past 10 years due to their potential for encouraging regular physical activity. The gross body movement component replaces the largely sedentary handheld controller of traditional video games where a joypad and/or buttons are used to control the game (Figure 1). Players interact using arm, leg, or whole-body movement with images onscreen in a variety of sporting (e.g., football, martial arts) and game play activities (e.g., dancing, washing windows, spinning plates). A player's body movement is captured through a variety of low cost motion sensors, with examples including cameras (Sony EyeToy®, Microsoft Kinect), infrared sensors (Nintendo Wii and XaviX), accelerometers and gyroscopes

Figure 1. **Example of active video game play.**

(Nintendo Wii remote Plus, Sony Move), pressure-sensitive mats and tables (Dance Dance Revolution, XaviX J-mat and ApartGame, Wii Balance Board), modified ergometers (Xerbike, GameCycle) and laser beams (Lasersquash). There are also other forms of active gaming that don't strictly fall under the above definition. These include a system (Gamercize) that requires sustained physical exertion on an ergometer in order to facilitate the operation of traditional handheld controllers and games, as well as pedometer-based games (e.g., Horsepower Challenge) where accumulated step counts translate into game play credits. The advent of AVGs provides a novel strategy to displace the sedentary forms of video game play with a level of physical exertion that could improve health and wellbeing. AVGs may also provide benefits for educational games—potentially through enhancing the learning experience and also by helping children be more active and be less sedentary.

Video game play in general has grown to become one of the most popular entertainment mediums in the world. The Generation M: Media in the Lives of 8-18 Year Olds survey examined self-reported media use among a nationally representative sample of more than 2,000 (Rideout, Roberts, & Foehr, 2005). Data from this survey showed that 87% of children in the US in 2009 had access to a video game console at home and spent an average of 49 minutes each day playing video games (Rideout, et al., 2005). Such widespread familiarity and appeal of video games makes them an attractive proposition for a range of health promotion interventions including educating patients about the importance of compliance with cancer drug treatment (Beale, Kato, Marin-Bowling, Guthrie, & Cole, 2007) and management of chronic conditions including diabetes (DeShazo, Harris, & Pratt, 2010). The appeal of digital technologies in general is that they are readily distributable and have realistic potential to reach large population groupings, and are a highly engaging media (Williams, 2005).

AVGs offer researchers the opportunity to work with technology to improve health, while preserving the context of the activity (Timperio, Salmon, & Ball, 2004). This is important, as it may be easier to encourage people, particularly children and adolescents to displace sedentary video game play with the more active version, rather than coercing them into another activity in which they are not interested (Marshall, Biddle, Sallis, McKenzie, & Conway, 2002). Current learning is often an almost exclusively sedentary activity. School learning for children and occupational learning for adults typically starts with the instruction for learners to sit still. In an evolutionary context this may not be the most appropriate method of learning, and may be particularly ill suited to some individuals.

The proposition is that AVGs can potentially a) increase physical activity by the very nature of playing them; b) displace the typical sedentary versions of video games and other sedentary learning experiences; c) improve body composition due to the increased activity and decreased sedentary time; d) act as a gateway to conventional exercise and sporting activities and e) enhance the learning experience. The purpose of this paper is to provide a brief overview of current AVG research findings, with a focus on children and young people and to offer suggestions for future research. We will argue that AVGs offer a viable opportunity to augment existing options for children to be active and learn more effectively.

A number of systematic reviews (Biddiss & Irwin, 2010; Daley, 2009; Foley & Maddison, 2010) of AVG research exist, which have focused on quantifying the energy expenditure required to play AVGs and examining the effect of AVG play on physical activity, sedentary behaviors, and body composition. Emerging research is investigating the nature of the game play experience including acceptability of AVGs, however there appears to be very limited research on AVG and learning. A brief overview of the established literature is provided prior to suggestions for future research.

Energy expenditure of active video game play

For AVGs to be a viable physical activity option they must be able to increase activity-related energy expenditure. Much of the research to date has focused on quantifying the energy cost of playing AVGs and comparing this to traditional video game play, TV watching and traditional forms of physical activity (walking, jogging etc.). Energy expenditure is measured in metabolic equivalents (METs), where 1.0 MET is equivalent to energy expended at rest. Overall, research in this area has shown that playing AVGs results in greater energy expenditure than levels observed during passive video game play or other sedentary activities in children and adolescents (see Biddiss & Irwin, 2010; Foley & Maddison, 2010 for a review). Generally AVG play was found to elicit energy expenditure at light or moderate levels (2.0 to 5.0 METs), which is similar to traditional activities, including brisk walking, stair climbing, and skipping. Few studies showed sustained vigorous activity (> 6 METs) during video game play.
Various AVGs have been examined, including Dance Dance Revolution (DDR) (Lanningham-Foster et al.,

2006; Thin & Poole, 2010), Sony PlayStation™ EyeToy® (Lanningham-Foster, et al., 2006; Maddison et al., 2007; Straker & Abbott, 2007; Thin, Howey, Murdoch, & Crozier, 2007), Nintendo Wii (Graves, 2007), and digital exerbikes (Annesi & Mazas, 1997; Warburton et al., 2007; Warburton, Sarkany, Johnson, & et al, 2009), XaviX bowling and XaviX J-Mat (Mellecker & McManus, 2008) with results showing the greatest energy was expended in games requiring both upper and lower limb movement (Daley, 2009; Foley & Maddison, 2010). Furthermore, studies with Nintendo Wii have demonstrated smaller effects on energy expenditure compared to those with EyeToy® or dance mat technologies (Biddiss & Irwin, 2010).

In addition, AVG have been found to increase muscle activation and require more limb and trunk movement (Straker et al., 2009)—which may have additional benefits other than simply expending energy. Indeed AVG are being trialed as interventions to assist people to learn to move as part of rehabilitation (Sveistrup, 2004) and to encourage children with poor motor coordination to be more active and thus learn better motor control (Straker et al., 2011).

Effect of active video game play on physical activity, sedentary behaviors and body composition

While there is a dearth of epidemiological research linking AVG play with physical activity participation, a number of studies have been conducted to determine the effect of AVGs on physical activity behavior. Evidence to date suggests that playing AVGs in the home can provide some moderate increase in physical activity or decrease in sedentary behavior (Biddiss & Irwin, 2010). Despite this, most studies have been short-term (10 to 28 weeks). Most recent evidence from a large (n=322) randomized controlled trial (Maddison et al., 2011), which examined the effect of an EyeToy® video game intervention on physical activity, did not find a significant treatment effect for difference in change for average daily time spent in moderate to vigorous physical activity measured by accelerometer, or self-report at 24 weeks. However the intervention group showed a significant reduction in non-AVGs and increased AVGs, compared to control participants.

Given that sedentary behavior has been linked to overweight and obesity, AVGs have the potential to displace the more sedentary form of video game play, thereby increasing energy expenditure and thus improving body composition. However, while cross sectional studies have shown that traditional video game play is independently associated with being overweight (McMurray et al., 2000; Mendoza, Zimmerman, & Christakis, 2007) there are no epidemiological studies linking AVGs and reduced body fat percentage. Despite this, there have been a small number of studies that have examined the effect of AVG on body composition. A short-term trial (Murphy, 2007) of DDR versus no AVGs showed that weight gained during the 12 weeks of the study, was significantly less in the DDR group. A second study (Madsen, Yen, Wlasluk, Newman, & Lustig, 2007), which examined the effect of a DDR intervention on body mass index (BMI—a crude estimate of being overweight, calculated as weight divided by squared height) of 30 overweight children over six months showed no difference on BMI at either three or six months. This study did not have a control group for comparison and likely lacked statistical power to detect a small but clinically meaningful effect on BMI.

More definitive results are available from a large (n=322) RCT (Maddison, et al., 2011). Participants were overweight children aged 10-14 years who were randomized to receive an active video upgrade of EyeToy® games and camera to their existing PlayStation. Results showed a statistically significant but small treatment effect for change from baseline in BMI (-0.2 kg/m^2 using intention to treat analysis, or -0.3 kg/m^2 using per protocol analysis) and age-standardized BMI (-0.06) at the end of 24-week intervention period. The findings favored the AVG group. There was also significant treatment effect for change from baseline in percentage body fat (-1.5 %) favoring the AVG group.

Nature and acceptability of active video game play experience

We know that children participate in activities they enjoy and feel competent in (Bungum, Dowda, Weston, Trost, & Pate, 2000; DiLorenzo, Stucky-Ropp, Vander Wal, & Gotham, 1998). These emotions have been observed among youth who play sedentary video games (Ryan, Rigby, & Przybylski, 2006), and it is therefore plausible that AVG can fulfill these criteria. Marshall et al. have suggested that interventions to reduce sedentary behavior should preserve the context of the activity (Marshall, Biddle, Gorley, Cameron, & Murdey, 2004). This notion is particularly salient for AVG interventions and is central to whether these games can be effective at increasing physical activity and displacing sedentary behavior. Recent qualitative research has shown that this technology is acceptable to children and adolescents, and their parents, but this acceptance is conditional. For example, a qualitative study in New Zealand (Dixon, Maddison, NiMhurchu, Meagher-Lundberg, & Widdowson, 2010) conducted seven focus groups with children (n=37) and four with adults (n=27) and found parents were generally concerned that playing electronic games was often at the expense of participation in outdoor activities. Despite this, parents acknowledged that this technology was a fact of modern-day life and therefore active over non-AVG playing was endorsed.

Children in the focus groups reported that they enjoyed AVGs, and both children and parents could see that they offered a way to increase activity, improve fitness, and positively alter body shape. In particular, girls saw these types of games as contributing to weight reduction and control, while boys saw them as having the potential to increase body size and strength. Barriers to engagement from the children's perspective included a perception that AVGs would not be something one would engage with in adolescence. For parents the cost of purchasing the games and the lack of space in the home to play the games were seen as barriers. Other research has highlighted that specific components of AVG interventions enhance participation, including group involvement, competitions, peer or family support and variety in music (for dance games) (Chin A Paw, Jacobs, Vaessen, Titze, & vanMechelen, 2008; Madsen, et al., 2007; Paez, Maloney, Kelsey, Wiesen, & Rosenberg, 2009). Interviews conducted with children after a school-based one-week Sony EyeToy® intervention during lunchtime, have also revealed that children reported enjoying the games and felt they would continue to play them if given the opportunity (McDougall & Duncan, 2008).

Qualitative research (Hansen, 2009) with 10-11 year old students (n=6) in the USA who participated in AVG during physical education classes identified an important construct related to video game play, namely a "persistence to game". This was defined as a natural characteristic of children to voluntarily engage and remain engaged in active gaming. Each student was consistently motivated to game play and remained engaged in physical activity while gaming during physical education. Persistence to game was comprised of seven key attributes: 1) fun, 2) opportunities for choice, 3) peer interaction, 4) peer and independent learning, 5) perpetual movement to be engaged, 6) unremitting interest, and 7) video game play motivation (Figure 2).

This research also showed that students participating in active gaming during physical education class demonstrated behavior that was consistent with being in the 'zone' or 'flow state' (Csikszentmihalyi, 1990), which is typically described in sporting performance. Taken together, these findings suggest that children and

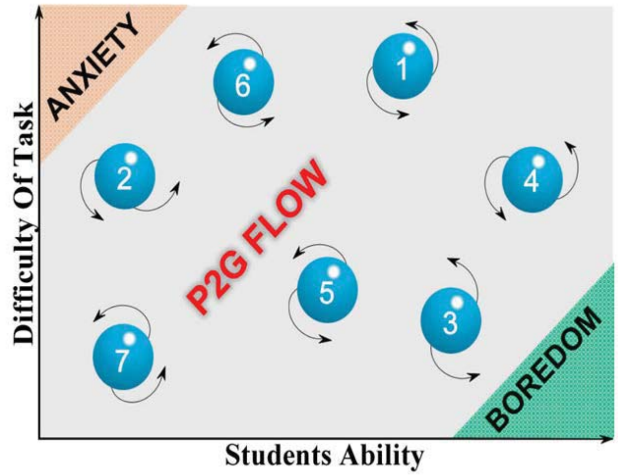

Figure 2. **Schematic diagram of the components of Persistence to Game.**

young people enjoy AVGs, they are not only motivated to participate in active gaming but desire to voluntarily engage in active gaming inside and outside of school hours because they enjoy these contemporary activities.

Active video games and learning

Aside from conference proceedings (Kearney, 2007; Pivec, 2008), we were unable to find any studies specifically examining the potential for enhanced learning by utilizing an AVG rather than a sedentary video game. However, prior evidence suggests that learning can be enhanced if people are active whilst learning.

It has long been known that physical activity can enhance brain development in rats (Fordyce & Wehner, 1993; Neeper, Gómez-Pinilla, Choi, & Cotman, 1996) and that long term physical activity is associated with maintenance of cognitive capacity in older adults (Ratey & Loehr, 2011; Weuve et al., 2004). Additionally, physical activity in digitally augmented spaces has been suggested as an option to assist in some aspects of learning (Price & Rogers, 2004). Further, activity theory has been suggested as a framework for designing learning environments (Jonassen & Rohrer-Murphy, 1999), following a long tradition of promoting 'active' learning (Kieren, 1969).

More recently schools have attempted to enhance physical activity at school to assist with child health (Naylor, Macdonald, Zebedee, Reed, & McKay, 2006) and to have classrooms more active to improve academic performance for children with attention deficit hyperactivity disorder (Mulrine, Prater, & Jenkins, 2008). Further, a short bout of exercise has been found to enhance subsequent attention and academic performance in children (Hillman et al., 2009) and cognitive performance appears to be enhanced whilst exercising (Brisswalter, Collardeau, & René, 2002). Thus the available evidence suggests there is an opportunity to not only enhance the learning of children and others by using a AVG framework rather than a sedentary game framework, but that AVG learning may also result in broader positive health benefits—enabling people to learn and be more active simultaneously.

In summary, AVGs represent an emerging area of research interest. AVGs offer a viable approach to displace a typically sedentary behavior with a more active one, while still retaining the context and enjoyment of the activity. The active forms of video games can increase energy expenditure and seem to have some effect on physical activity, sedentary behavior, and on body weight and body composition. Despite this, research to date has focused primarily on children and young people and less so on adult populations. Research has also relied primarily on self-report to measure behavior and determine exposure. The self-report approach is limited due to the biases associated with recall. Few interventions have examined whether AVG play is a sustainable behavior and whether sustained play has positive effects on outcomes such as weight loss. Only one trial (Maddison, et al., 2011) monitored adverse events and showed that AVG play was not associated with any harm. Finally, there has been a lack of a shared conceptual framework to understand AVG play and the interaction between the technology, the environment, and the individual. Future research needs to address these issues and therefore we finish this paper by providing a roadmap for future AVG research.

Opportunities for active video game research

One of the most important future directions for AVG research is the need to develop a conceptual framework to better understand the determinants, mediators, moderators, and consequences of AVG. Current models envision a comprehensive framework comprising both external and biological predictors for health behavior (Glass & McAtee, 2006). A key concept of models should be risk regulators, which represent a sum of a particular patch of the social and built environment, imposing constraints that shape, channel, motivate, and induce individual behavior. We propose that AVGs could act as a risk regulator to promote physical activity, translating the macro social processes related to video gaming and physical activity to the individual decision making sphere. Therefore, these games provide an opportunity to express the intrinsic dynamics of one's physicality (Hagger & Chatzisarantis, 2007) and enhance well-being, which should provide an instant utility situation (Kahneman, 1999) leading to the maintenance of the AVG behavior. Adding to these mechanisms/mediators by which AVGs should exert their influence on behavior, are the immersive experiences they provide (Bailenson & Yee, 2005; Csikszentmihalyi, 1990), the embodiment of these new means to express one's physical-self (Clark, 2003), the opportunity to constitute avatars (Bailenson & Yee, 2005), and the fun and enjoyment they afford (Kahneman, 1999; Ryan, et al., 2006).

Palmeira and Thin (2010) recently proposed a cyber-ecological approach, which included a hierarchy of "digital" influences on health behavior. Their model incorporated the individual and their digital representation(s) (avatars), which sit at the confluence of two hierarchies of influences on health behavior arising from their physical and digital worlds, respectively (see Figure 3).

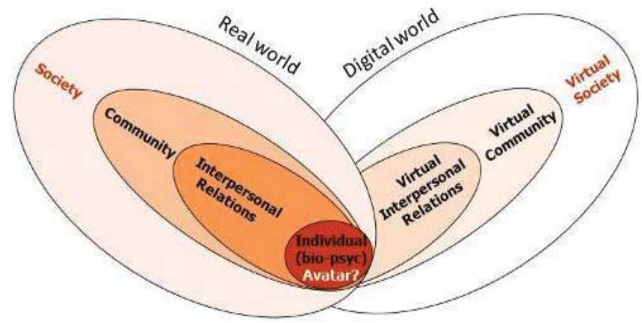

***Figure 3.* Cyber-ecological approach to understanding the interaction between the real and digital worlds.**

The model also includes two intersecting ecological frameworks: the traditional real world paradigm, and a corresponding digital one. Similar to the varying levels of influence exerted by agents in the real world, digital agents also vary in the influence they exert. In the real world, the influences on a person that predominate are top-down, and by and large an accident of birth. In contrast, in digital realms individuals sign-up to digital worlds, social networks and services by choice and have greater levels of control and higher expectations. The fictional interactive environments of video games may allow players to engage cognitively by experimenting with different behaviors and problem-solving techniques in a safe environment (McDaniel & Vick, 2010b). The level of interactivity that digital environments offer is often far greater than in the real world and with greater immediacy. In this cyber-ecological approach AVGs are one form of digital agent with significant positive influence, whereby physical activity is an emergent behavior of the game play experience.

Currently there appears to be a lack of linkage between cognitive models of learning and the health behavior models involving AVGs. As technology continues to develop, understanding how the digital agents and world influence people's lives is a crucial challenge for research aiming to enhance learning and health in the 21st century.

Research findings often lag behind the development of new technologies. To address this, researchers should consider working alongside AVG developers to ensure research is relevant and timely (Thin & Poole, 2010). For example, researchers could work with AVG developers to ensure that newly developed games are effective at enhancing both learning and health. Researchers should also assist game developers to know what types of physical activities are health promoting and in like manner what types of interaction promote learning. To assess learning and verify the claims made by game manufacturers, researchers can incorporate existing cognitive science research design and methodologies to determine changes in knowledge acquisition, memory, and retention of relevant learning outcomes (McDaniel & Vick, 2010a).

While most AVG research has been conducted with children and young people, recent research using Nintendo Wii showed positive effects on balance in older people (Saposnik et al., 2010). AVG offer a potentially more natural interaction style than other forms of computer assisted learning and may thus be more acceptable to older, less technologically engaged populations.

Read and Shortell (2011) recently highlighted the potential of video games as a tool to promote behavior change and improve health outcomes in clinical populations, such as type 1 diabetes and adherence to chemotherapy for people with cancer. Thus patients may be able to gain a learning benefit whilst gaining a physical activity benefit if using AVGs. In other clinical settings, where people are confined to bed or have limited access due to treatment, specific forms of AVGs could potentially both provide ways to increase physical activity, alleviate boredom due to prolonged inpatient stay, and enhance learning about their health condition or other topics of interest.

AVG play appears to offer an engaging and enjoyable experience in both children (Hansen, 2009) and young adults (Thin & Poole, 2010). This is in contrast to the general perception of exercise as being something of a chore and the very term "workout" is associated with negative connotations, and not something one would want to do in their leisure time (Maguire, 2007). AVGs by their very nature can be tailored to the individual player's skill and ability by selecting an appropriate level of difficulty and the game can also be designed to dynamically adjust the difficulty level in response to a player's success/failure in order to maintain a meaningful challenge. This makes them particularly attractive to individuals with low self-efficacy for whom conventional sports and activities are perceived to have significant potential risk for social embarrassment due to poor performance. In fact the competitive challenge aspect of AVGs may engender an experience that is more "sport-like" (Thin, Hansen, & McEachen, 2011) rather than simply technology enhanced physical-activity. But the key point is that the competition that they offer is "safe" and under user control.

Along similar lines, AVG may be able to offer a more engaging and enjoyable learning experience—in contrast to negative perceptions about traditional sedentary classroom learning. Early attempts to improve classroom furniture to enhance learning are now being surpassed by attempts to make school learning more active to achieve health benefits (Lanningham-Foster et al., 2008). Research has shown sedentary video games offer opportunities to develop and assess cognitive processes such as attention, decision making, inductive reasoning, and memory (McDaniel & Vick, 2010b), and there is no reason AVG couldn't achieve similar or even better results. Evidence based guidelines for the wise use of computers by children have recommended active input devices, akin to AVG (Straker, Maslen, Burgess-Limerick, Johnson, & Dennerlein, 2010). This could involve adaptation of existing platforms as demonstrated by Berkovsky et al. (2010) who modified a sedentary computer game (*Neverball,* http://www.neverball.org) to motivate players to perform physical activity. Players were equipped with an accelerometer configured to recognize jump events, such that for every captured jump, they gained additional time to accomplish game tasks. The game was also modified by reducing the time allocated to accomplish tasks and offering players time-based rewards for performing physical activity.

It has been proposed that AVGs could be introduced within both work and school environments to promote health and performance (Shasek, 2010; Straker, Levine,

& Campbell, 2009). For example, physical activity in the classroom is being utilized to assist some children perform better at school (Mulrine, et al., 2008). There is some preliminary evidence that AVGs and related computer technology can be introduced as a seamless way to deliver activity breaks with the classroom setting without over-burdening busy teachers. More research is needed to determine the impact of AVGs within such settings using robust research design and methods.

CONCLUSIONS

This overview has outlined the available evidence to support the role of AVGs to enhance health through physical activity to improve energy expenditure and body composition and enhance learning. The gap in understanding the potential impact of AVG on learning has also been outlined. The nature of the AVG play experience is more than simply technology enhanced exercise and warrants further research in order to inform future game design. Researchers need to work with this technology rather than against it if they are to positively impact future population health and learning.

AUTHOR NOTES

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