Title: *Efficient and effective change principles in Active Video Games*

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Abstract

Active Video Games have the potential to enhance population levels of physical activity but have not been successful in achieving this aim to date. This paper considers a range of principles which may be important to the design of effective and efficient Active Video Games from diverse discipline areas including: behavioural sciences (health behaviour change, motor learning and serious games), business production (marketing and sales) and technology engineering and design (human-computer interaction/ergonomics and flow). Both direct and indirect pathways to impact on population levels of habitual physical activity are proposed, along with the concept of a game use lifecycle. Examples of current active and sedentary electronic games are used to understand how such principles may be applied. Furthermore, limitations of the current utilisation of theoretical principles are discussed. A suggested list of principles for best practice in Active Video Game design is proposed along with a list of research ideas to inform practice to enhance physical activity.

INTRODUCTION

Sufficient regular physical activity is important for health (1, 2). Screen based media includes television, computers and electronic games. Increased use of screen based media is believed to contribute to increased sedentary time and decreased physical activity, particularly in children and adolescents (3), and is associated with negative health consequences (4, 5). However, electronic games could have a positive impact on habitual physical activity levels via both indirect and direct pathways, as illustrated in Figure 1.

Insert Figure 1 about here

We propose that electronic games, including sedentary electronic games (SEG) – such as those played with mouse and keyboard - could enhance physical activity indirectly by influencing knowledge, attitudes or skills related to being physically active. For example, a health education-focused 'serious game' may educate players about the importance of physical activity for enhanced health and this could encourage greater physical activity participation. Similarly, an electronic game showing highly desirable game characters participating in physical activity could encourage more positive attitudes to physical activity and thus increase likelihood of future participation in physical activity. Further, playing an electronic game could enhance mental or physical skills related to physical activity – for example a football-themed SEG may develop football strategy skills and enhance participation in traditional football activities such as community football leagues; and playing table tennis on a virtual reality active input electronic game may develop motor skills and enhance participation in real world table tennis.

Compared with sedentary games, active video games (AVGs) have additional potential to promote physical activity directly because players have to engage in physical activity to play the game. AVGs that require limb and/or trunk movement input have been identified as a direct

pathway for electronic games to increase habitual physical activity and enable players to experience the fun of electronic games whilst being physically active (6, 7).

What makes an AVG successful can depend on the discipline's perspective. For example, AVG business/production professionals may be aiming for hardware and software which is perceived in the marketplace as highly desirable, is profitable to produce and results in many sales. In contrast, AVG engineers/designers may be aiming for a game that receives critical acclaim for its interface, graphics or narrative. However, health professionals may be aiming for AVGs which result in widespread population increases in physical activity. This paper focuses on how this later aim could be better achieved using improved conceptual models.

To achieve enhanced population physical activity, AVGs need to be accessible and attractive to a large proportion of the population, who need to play the games regularly and for sufficient duration. Thus many individuals within a population need to: be attracted to obtain AVG hardware and software (acquisition), learn how to play the game(s) (learning), regularly play the game(s) for physiologically meaningful exposures each week and maintain regular play for sufficient weeks/months to have a clinically meaningful impact on health and development (habitual use). Further, the AVG must require sufficient movement for successful game play (1), that is, the required movement must be physiologically beneficial and game fidelity must ensure that players can only progress through the game with appropriate movement.

Current experience with successful AVGs suggests players move through a cycle with each AVG; a cycle of acquisition, learning, habitual use and declining use. For example, Erickson (8) found weekly coaching could maintain use, but once coaching ceased, use declined rapidly. Figure 2 represents this "lifecycle" of AVG use. At a given point in time, any player may be playing multiple AVGs, and be at a different point in the lifecycle for each AVG.

Insert Figure 2 about here

Current approaches to enhancing population physical activity levels through the use of AVGs have typically focused on the habitual use stage of the lifecycle, and have adopted the prominent health behaviour theories used in traditional lifestyle change interventions (9). However, there have been suggestions that new, broader theoretical models may be necessary for understanding the unique processes associated with engagement in video game play (10). Given the lifecycle of AVGs, the extent of population involvement is dependent on the game publisher's ability to increase purchase intentions and the probability that a player will purchase the game (11). Further, poor game interface design, usability and inferior graphics are likely to result in users not persisting through the learning phase to become habitual users (12). Thus, principles from areas other than health behaviour change may be useful in enhancing population physical activity levels with AVGs.

The current paper provides an overview of example principles from a sample of discipline areas and theories likely to be important for AVG acquisition, learning and habitual use: health behaviour change, motor skill development, business production, human-computer interaction and flow. Limitations of current theories and research utilising derived principles to examine AVGs are discussed. The paper presents suggestions for the principles which could be applied at each phase of the lifecycle to ensure best practice. Finally, suggestions for research to enhance the success of AVGs in changing population physical activity levels are provided.

BEHAVIOURAL SCIENCE PRINCIPLES

Health Behaviour Change Principles

Processes underpinning behaviour change within the context of AVGs have been understood predominately through the application of the following theories: self-determination theory (13), theory of planned behaviour (14, 15), social cognitive theory (16), and the elaboration likelihood model (17). Components of self-determination theory (as a widely used example) are introduced below, followed by a discussion of methods and outcomes associated with the application of self-determination theory-based behaviour change techniques within the context of AVGs.

Self-determination theory addresses the type of motivation underlying behavioural pursuits (13). Intrinsically (or autonomously) motivated behaviours are performed for enjoyment reasons, whereas extrinsically motivated behaviours are performed for instrumental reasons such as to gain a reward or avoid punishment. Individuals are more likely to be intrinsically motivated when three basic psychological needs are met: autonomy, competence, and relatedness. Autonomy refers to the sense of choice, competence involves feeling able to effectively master optimally challenging tasks, and relatedness refers to feeling a sense of belonging.

Autonomy supportive game features may be provided through flexibility in choices for tasks, movements, characters and rewards (18). Competence may be promoted through the provision of feedback, modeling, and challenging but achievable tasks. For instance, in *Guitar Hero* (Red Octane, Mountain View, USA), players are appropriately matched with their ability level based on previous scores (18). Competence can also be supported by allowing players to watch and refer to representations of themselves in avatar form (9). Multiplayer games have also been posited to create a sense of relatedness through shared play with others either in person or via the internet (18).

Manipulations of autonomy through choice for missions as well as character skills and appearance, and manipulations of competence through graded tasks have been shown in undergraduate students to positively predict enjoyment and motivation for future game play, although no effects were demonstrated on energy expenditure (19). Perceptions of competence in the popular *Dance Dance Revolution* game (*DDR*, Konami) have, however, been shown to be associated with increased energy expenditure (20), and observations of a virtual-self exercising (as compared to watching a virtual-other) have been shown to influence real world exercise behaviour (21). Although the effectiveness of feedback has not been measured specifically in AVGs, findings from the 'serious games' literature suggests that feedback is associated with skill development and enjoyment (22). In response to manipulations of relatedness, Peng and Crouse (23) demonstrated that participants assigned to a relatedness condition (e.g., co-operation in the same space and

competitive in separate spaces), compared to a single player condition, were significantly more motivated to engage in future game play. However, an exploratory study has recently failed to find any association between autonomous motivation and game competence per se and either active or sedentary gaming (Simons et al., 2014).

Motor skill development principles

Other areas of behavioural science, such as motor learning and serious gaming (22, 24), may also supply useful principles to inform enhancing AVG capacity to increase physical activity.

Dynamic systems theory, as it relates to motor development, posits that motor skill development is a coordination of multiple subsystems (e.g., neurological and muscular) and depends on environmental and task constraints. The developmental process is non-linear and constrained by contextual affordances and rate limiters. Affordances encourage skill development and can include motivation, encouragement and positive feedback. Rate limiters that inhibit or delay development may include biological constraints (such as being overweight), environmental constraints (such as limited space) or task constraints (25). Thus for AVGs to promote relevant motor skill development, they should provide appropriate and accurate environmental and task constraints. The movements performed during AVG should be similar to those in real life to promote transfer to real life physical activity skills (26). A qualitative study in 9-10 year old children supports this, with children reporting perceived bidirectional transferability between AVGs and real life in terms of building skill (27). Interestingly, Sheehan et al. (28) showed that playing *DDR* during a physical education class improved balance more effectively than traditional physical education. However, there is limited research of typically developing children in free playing situations to assess whether skill actions (e.g., a tennis strike) performed in the virtual environment resemble those performed in the real world. One observational study of children (mean age of six years) playing the Wii found a strike skill had more semblance to a real life movement than the other two skills observed, which showed little evidence of correct performance (29). Furthermore, a cross-sectional study in pre-school aged children found that more time spent playing AVGs was associated with higher fundamental motor

skill ability, although it was not clear whether the use of AVGs contributed to skill development or whether children with better existing skills were more likely to engage in these games (30). Additionally, AVGs have been developed for older adults that use the variable practice principles of dynamical systems, for example to improve walking and balance ability in stroke rehabilitation patients (31).

PRINCIPLES FROM OTHER PERSPECTIVES

Research on the health-promoting benefits of AVGs has traditionally incorporated just health behaviour change principles. However, to create effective and efficient AVGs, principles from other relevant disciplines could also be considered. The following principles are presented as examples (rather than a definitive list) of potential theories and strategies drawn from business professional and game engineer/designer disciplines. They are presented as a means to advance the multi-disciplinary dialogue necessary to create effective activity-promoting AVGs.

Business/Production Principles

Traditional models of decision making have been cognitively based with reliance on the assumption that humans (buyers) make decisions based on rational, conscious processes, for example the consumer buying decision process (32) and the uses and gratifications theory (33, 34). Rogers' (35) diffusion of innovations theory proposes that the adoption of new technologies depends on five perceived attributes of the innovation: relative advantage (Is the new technology perceived as better than what already exists?), compatibility (Is the new technology matched with user norms, values, needs and expectations?), complexity (Is the new technology easy to use and understand?), trialability (Is it possible to test out the new technology without having to make a large commitment?), and observability (Are the benefits easily seen?).

An analysis of educational computer games found that many do not satisfy these five basic principles (36). This is probably even more the case for activity promoting games. Adolescents perceive the quality of AVGs to be inferior compared to traditional SEGs (12), negatively influencing

relative advantage. AVGs do not always meet players' needs and expectations (reducing capability) (12). Some AVG studies show that technical problems often occur and sensors do not always work properly (12, 37), so complexity might be too high in some cases. Players need to have the skills, knowledge and equipment to use them (AVGs may require additional software and hardware compared to traditional games). This upfront investment in a gaming system may reduce the trialability. Finally, observability might be low because it takes a long time for the health benefits of play to become evident. This implies that selling AVGs as an obesity or cardiovascular disease prevention tool may reduce uptake.

Design/Engineering Principles

Human-computer interaction

Human factors engineering/ergonomics developed in the 20th century with a focus on the interaction between humans and machines to enhance satisfaction and productivity during use and to reduce the negative impact of use on health and wellbeing (38). Much of the research conducted over the last few decades has concentrated on human-computer interaction (39). The discipline aims to design "machine" input controls and output displays to match the capabilities (both mental and physical) of human users. The interaction is viewed as taking place within a systems model, thus taking account of the social and physical environment and the task being performed (40).

According to these principles, input controls for AVGs should be designed to match the user's physical and mental attributes and expectations. For example, a "wand" controller should match the anthropometric dimensions of the intended user's hand and not be so heavy as to fatigue the user quickly. Similarly, output displays should match user expectations – for example the motion of the wand should be faithfully replicated within the AVG virtual world to match the player's cognitive models of how motion should occur. For interaction with an AVG to be maintained, the task being performed should be interesting and desirable to the user. The AVG environment should be socially supportive of play and also enable safe AVG play and be physically suited to the player, such that accidental contact with objects and others is minimised. Human computer interaction

research has mainly evaluated software aspects of the interaction (41) but has also considered physiological responses to games (42) and movement during AVG use (43). However, this traditional view on human-computer interaction emerged out of a desire to enhance productivity processes using computers, and did not initially consider entertainment experiences such as digital play.

Flow

Advanced by Csikszentihalyi (44), flow theory can be used to describe the pleasure and enjoyment arising from immersion in daily activities of work and play. When individuals are in the flow state, they are absorbed in the activity and disengaged from distractions. Applied to AVGs, a flow state would be exhibited for example when a user playing a dance simulation feels fully immersed in the game such that they perceive themselves to be dancing (in contrast to exercising). Elements of game play necessary to promote a flow state include: concentration, challenge, player skills, control, clear goals, feedback, immersion, and social interaction (44). Concentration can be targeted by including high-quality stimuli (i.e. objects are detailed, unique animation, sound, speech, and appearance is used) (45). Challenge can be addressed through matching a player's skills to the level of difficulty and by presenting a range of different challenges. Users feel a sense of control when they have freedom to choose game options, strategies, and character-related features. Clear goals are established when the user is presented with specific and achievable goals that require them to continue playing to reach the set target. Alongside goals, continuous feedback can be provided on progress by presenting status reports during game play, summary tables at the conclusion of play, and a guide on how to reach the next goal. Elements of game play that may contribute to immersion include graphics, sound, animation, fluidity of game play and intricate details that allow the user to feel excited and emotionally involved in the game. Social immersion is encouraged by game features that support competition and cooperation between players such as online multiplayer games that match players based on ability, and provide a mechanism for tracking the progress of friends.

Ratings of flow and enjoyment following game play on commonly-used consoles has shown that AVG cycling games are perceived as more enjoyable and offer more elements of flow than traditional cycling (46). *DDR* users who trained for a minimum of 20 hours reported experiencing immersive game flow when playing at the advanced level (47). Investigations of the relationship between game flow and energy expenditure in response to five commonly played AVGs revealed that varying levels of flow were experienced in relation to each game, and that the level of flow experienced was positively correlated with energy expenditure (48). Lyons et al. (49) showed that more engaging AVGs may produce greater intensity activity. In an exploration of dance games, Thin, Brown, and Meenan (50) found that whilst the level of physical exertion was similar across three gaming consoles, the enjoyment and difficulty ratings varied between consoles. However, game enjoyment may still impact on total energy expenditure through an influence on the intensity and duration of game play. Lyons et al. (51) showed that less active games were perceived as more enjoyable than the more active games, suggesting that the more active (but less enjoyable) games may be less likely to be played over time. One recent study found that AVG game engagement was only weakly correlated with active gaming (Simons et al., 2014). However, based on this exploratory study, it is not known whether game engagement refers to a trait (in the sense that some people become more easily immersed when gaming) or a state (in the sense that some games have stronger immersive qualities) or a mix of trait and state qualities.

PRINCIPLES CURRENTLY IDENTIFIABLE IN ELECTRONIC GAMES

To examine the extent to which principles from various disciplines are identifiable in current commercial electronic games, an evaluation was conducted of two exemplar games: a leading AVG game and a leading SEG. The AVG selected was the table tennis game in *Sports Champions* (SCE, San Diego, USA) played on the PlayStation 3 Move. The game is a simulation of real life table tennis with options for one or two players to compete against virtual opponents in free play or in a structured championship. Industry data suggest over 3.6 million copies have been sold. The SEG selected was *League of Legends* (Riot Games, Santa Monica, USA). The game is a multiplayer online battle game

typically played with teams of 5 people against other human or artificial intelligence teams. Industry data suggests there are over 67 million users each month.

The extent to which various principles were identifiable in these games was assessed by a panel of AVG professionals attending the Games for Increasing Physical Activity: Mechanisms for Change Conference in Houston, Texas, USA in May 2014. The panel of 11 represented a range of professional backgrounds (health promotion, public health, physiotherapy, ergonomics, motor skill development, communication, media psychology, health behaviour change, human computer interaction, game design) and electronic game experience (epidemiological studies, field trials of AVGs with activity and motor skill outcomes, laboratory studies of muscle activity, energy expenditure of AVGs, qualitative studies of perceptions about AVGs, game content analysis, game development including mobile app based games).

Panel members worked in small groups to discuss the extent to which the 25 selected principles were identifiable in each game. Each principle was rated for identifiability as either low, medium or high. Further information was gathered from two experienced players following the conference. Ratings and comments were sent around paper authors in two iterative processes. The ratings and explanatory comments are shown in Table 1. Overall, the principles were identifiable in both games, though often to differing extents, which may, at least in part, explain differences between the games in terms of popularity and usage. For example, there were more aspects of *League of Legends* which supported autonomy in terms of a sense of choice and concentration.

Insert Table 1 about here

LIMITATIONS IN THEORIES CURRENTLY APPLIED TO ACTIVE VIDEO GAMING

The brief overview of selected theories and the identification of selected principles identifiable in the two exemplar electronic games presented above highlights the multitude of factors likely to be important in determining the success of an AVG in terms of its capacity to

enhance population levels of physical activity. A number of other potentially important factors have been identified and the lack of inclusion of these factors in currently applied theories can be seen as a limitation of those theories. A sample of these factors and how they may be related to AVG use are briefly presented below.

Demographic Factors

There is considerable evidence that various demographic factors are related to electronic game use. For instance, boys are consistently shown to spend more time engaging in SEG than girls (52-54). Older adolescents spend more time on gaming than younger adolescents (52, 54). African Americans have also been shown to engage in SEG more than Caucasian and Asian American counterparts (55). In addition, parents' education and household income level (56) have been shown to negatively predict time spent in SEG. Preferences for game genre, such as action, sports or fantasy, have also been shown to be predicted by gender (57), race (58) and socioeconomic status (59).

Although explored to a lesser extent in regard to AVGs, recent evidence has emerged suggesting demographic characteristics play a role in predicting length of engagement, genre preferences, and outcomes associated with gameplay. In contrast to SEG, adolescent AVG players are more likely to be female (60), and adolescent females report spending a greater amount of time playing AVGs than adolescent males (61). Game play exceeding one hour/week is also more likely to be demonstrated by adolescents with lower education levels (52). Enjoyment and genre preferences have further been shown to be predicted by both gender and age (62, 63). Finally, age (6), gender (64), and weight status (20, 51) have been shown to predict energy expenditure during AVG use.

Personality Traits

Similar to demographic characteristics, personality traits have been associated with differential engagement and preferences in SEG. Extraversion, for instance, has been shown to predict preferences for more casual (e.g., party, music), role-playing, and real-time strategy games, whereas conscientiousness has been associated with sport genres, and openness has been

associated with action adventure (65). Game enjoyment has also been demonstrated to be a function of personality traits, such that the same game may be perceived as more or less enjoyable by different users (18). Traits such as novelty seeking are also positively associated with engagement time (66).

Among the limited studies addressing the influence of personality traits on AVG use, more positive attitudes toward AVGs and less positive attitudes toward SEGs have been shown to be associated with greater AVG play (67). Personality traits have also been shown to be associated with preferences for certain motivational phrases during game play (68).

Habit Formation

Habit formation is a key determinant of sustained behaviour change (69). While theories of consumer buying decision processes (32) aim to influence intentions, habits have been shown to override intentions (70). Physical activity behaviour from AVG use could become habitual regular use under stable circumstances that continually satisfy the users' needs. Habit strength is a correlate of both AVG play and SEG play, indicating that both types of gaming are habitual behaviours (67). The fact that AVG playing can become habitual is positive, because this increases the chance of sustained use of AVGs. However, as SEG play is also habitual, it may be hard to exchange AVG play for SEG play.

Focus on console based games

A limitation of the current application of principles to AVGs is that research has tended to focus on AVGs that are commercially available for console electronic games. However, these are constrained to an indoor environment limiting physical activity opportunities. Considerable potential exists for AVGs designed for mobile technologies. Personal mobile devices (e.g. smartphones) can potentially be used to play app-based mobile activity games anywhere, anytime. In-built sensors within mobile devices allow real time feedback, and progress can be shared instantly via social media apps. Game updates can be downloaded to promote sustained interest and global positioning system tagging of real locations can encourage users to move around the physical world to unlock

digital content at different locations. All these features could be combined to offer a flexible, engaging, evolving game which has potential to retain users' interests over a sustained period (71).

BEST PRACTICE PRINCIPLES FOR ENHANCING POPULATION PHYSICAL ACTIVITY USING AVGS

Whilst a single theory may be unrealistic, a set of principles likely to be important for the design of AVGs which can make a useful contribution to the promotion of habitual physical activity, may encourage cross-discipline collaborations and support advancement of the field. Therefore the panel of conference participants developed a list of principles to be considered at each phase in the AVG lifecycle to maximise the potential for changes in population physical activity. The list was based on the available literature on potentially relevant theories plus the experience of panel participants, including direct experience in designing games (72-75) (Table 2).

Insert Table 2 about here

RESEARCH IDEAS FOR ENHANCING POPULATION PHYSICAL ACTIVITY USING AVGS

Based on an understanding of the current state of research and practice, the conference workshop participants also developed a list of research ideas to enhance knowledge to support more effective and efficient AVGs. Table 3 presents the panel's list of research ideas.

Insert Table 3 about here

CONCLUSION

This paper introduced the ideas of multiple potential pathways for electronic games to have a positive impact on population habitual physical activity, the different discipline perspectives on what constitutes a successful AVG and the lifecycle of AVG use. Examples of relevant principles from behavioural sciences (health behaviour change, motor skill learning), business production (marketing and sales) and technology engineering and design (human-computer interaction/ergonomics and

flow) were outlined, along with a discussion of some factors likely to be important to habitual AVG use not explicit in the selected theories. An example of how a successful AVG and SEG have adhered to these principles was presented. This process demonstrated that for AVG use to be sustained, these games may need to incorporate the sophistication that to this point is typically only found in SEG. Future game development and research may benefit from infrastructure and capacity to support multidisciplinary collaboration to apply the principles for best practice targeting each phase of the AVG lifecycle, and explore the research ideas suggested.

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