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Efficient and Effective Change Principles in Active Videogames

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Abstract

Active videogames have the potential to enhance population levels of physical activity but have not been successful in achieving this aim to date. This article considers a range of principles that may be important to the design of effective and efficient active videogames from diverse discipline areas, including behavioral sciences (health behavior 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 usage of theoretical principles are discussed. A suggested list of principles for best practice in active videogame design is proposed along with suggested research ideas to inform practice to enhance physical activity.

Introduction

This discussion article proposes two models to help understand active videogame (AVG) use: A multiple pathways of effect model and a lifecycle model. It then examines how theories and principles from multiple disciplines could help explain the impact of AVG use throughout the lifecycle. To help elucidate the potential utility of the selected principles, the observability of these principles in an example of a leading AVG is compared with a far more widely used sedentary electronic game (SEG). Finally, ideas for future research and best practice are provided.

Sufficient regular physical activity is important for health.[1,2] Increased use of screen-based media, including television, computers, and electronic games, is believed to contribute to increased sedentary time and decreased physical activity[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.

We propose that electronic games, including SEGs (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 the likelihood of future participation in physical activity. Furthermore, playing an electronic game could enhance mental or physical skills related to physical activity—for example, a football-themed SEG may

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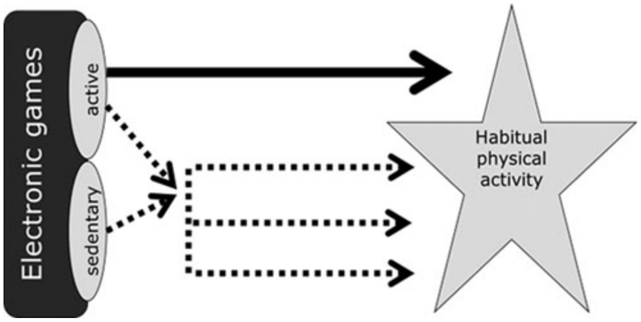

FIG. 1. Pathways for electronic games to enhance physical activity.

develop football strategy skills and enhance participation in traditional football activities such as community football leagues, and playing AVG table tennis may develop motor skills and enhance participation in real world table tennis.

AVGs are electronic games that require limb and/or trunk movement input and therefore have additional potential to directly promote physical activity because players have to engage in physical activity to play the game. To achieve enhanced population physical activity across all age groups, 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 (1) to be attracted to obtain AVG hardware and software (acquisition), (2) to learn how to play the game(s) (learning), (3) to regularly play the game(s) for physiologically meaningful exposures each week and to maintain regular play for sufficient weeks/months to have a clinically meaningful impact on health and development (habitual use), and, in addition, (4) to be exposed to AVGs that require sufficient movement for successful gameplay, which is physiologically beneficial and ensures players can only progress through the game with appropriate movement.

These phases of AVG use (acquisition, learning, and habitual use) are similar to those of the product lifecycle model described in business literature.[6] Figure 2 represents a hypothesized ''lifecycle'' of AVG use where users go through different stages of engagement and disengagement with AVGs. 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. Conceptualizing use of AVGs in this way may help to better understand their use, although further research to explore the validity of this conceptualization is needed.

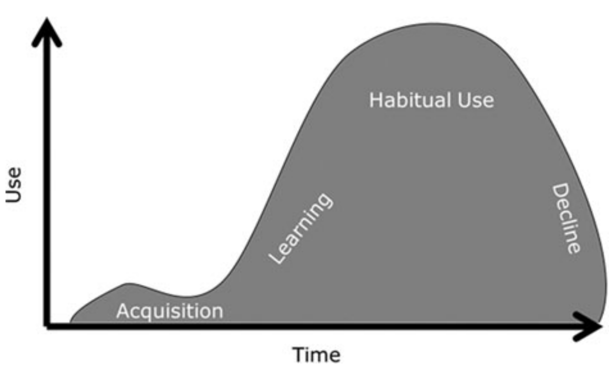

FIG. 2. The lifecycle of active videogame use.

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 behavior theories used in traditional lifestyle change interventions.[7] Unfortunately, recent field studies with AVGs suggest a decline in engagement and use of AVGs over time,[2 8,9] and thus current approaches have not resulted in positive changes to overall population physical activity levels.[2,8–10] However, there have been suggestions that new, broader theoretical models may be necessary for understanding the unique processes associated with the cycle of engagement in videogame play.[11] For example, given the lifecycle of AVGs, the business literature suggests that the extent of population involvement is dependent on the game publisher's ability to increase purchase intentions.[12] Furthermore, poor game interface design, usability, and inferior graphics are likely to result in users not persisting through the learning phase to become habitual users,[13] a key issue in human–computer interaction (HCI). Thus, principles from areas other than health behavior change may be useful in enhancing population physical activity levels with AVGs.

The present article provides an overview of example principles and theories from different discipline areas likely to be important for AVG acquisition, learning, and habitual use: Health behavior change, motor skill development, business production, HCI, and flow. The theories were selected to potentially help explain engagement with AVGs throughout the stages of the lifecycle. To illustrate how these principles can be applied and may influence the acquisition, learning, and habitual use of an AVG, a panel of AVG professionals then rated a popular AVG based on these example principles. A very widely used SEG was also rated according to these example principles, in order to attempt to understand the successes of many SEGs in relation to population reach and engagement. This article presents practical suggestions for the principles that could be applied at each phase of the AVG lifecycle to ensure best practice. Finally, suggestions for research to enhance the success of AVGs in changing population physical activity levels are provided.

Behavorial Science Principles

Health behavior change principles

The processes underpinning behavior change, particularly within the context of the habitual use phase of the AVG lifecycle model, have been understood predominately through the application of the following theories: Self-Determination Theory,[14] Theory of Planned Behavior,[15,16] Social Cognitive Theory,[17] and the Elaboration Likelihood Model.[18] 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 behavior change techniques within the context of AVGs.

Self-Determination Theory addresses the type of motivation underlying behavioral pursuits.[14] Intrinsically (or autonomously) motivated behaviors are performed for their inherent enjoyment, as opposed to gaining a reward or avoiding 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, whereby individuals feel a sense of volition in their behavior, rather than being controlled by external agencies.[14] Competence involves feeling able to effectively master optimally challenging tasks and occurs when individuals succeed in achieving desired outcomes.[19] Relatedness refers to feeling a sense of belonging, which occurs when individuals are provided the opportunity to interact and connect with others.[11]

Autonomy-supportive game features may be provided through flexibility in choices for tasks, movements, characters, and rewards.[19] Competence may be promoted through the provision of positive feedback, opportunities for new ability or skill acquisition, modeling, intuitive game controls that allow for mastery, and challenging but achievable tasks.[19] For instance, in ''Guitar Hero'' (Red Octane, Mountain View, CA), players are appropriately matched with their ability level based on previous scores.[19] Competence can also be supported by allowing players to watch and refer to representations of themselves in avatar form.[7] Finally, multiplayer games have been posited to create a sense of relatedness through shared play with others either in person or via the Internet.[19] Research studies that have manipulated support for autonomy,[20,21] competence,[22] or relatedness[23–25] in AVGs have had positive effects on motivation and engagement but more conflicting effects on physical activity and energy expenditure.

Motor skill development principles

Other areas of behavioral science, including motor learning and serious gaming,[26,27] may also supply useful principles to inform enhancing AVG capacity to increase physical activity, particularly during the learning phase of the lifecycle.

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 nonlinear 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 (such as movements required).[28] Thus for AVGs to promote relevant motor skill development, they should provide appropriate and accurate environmental and task constraints.

The movements performed during AVGs should be similar to those in real life to promote transfer to real life physical activity skills.[29] A qualitative study in 9–10-year-old children supports this principle, with children reporting perceived bidirectional transferability between AVGs and real life sport and physical activity in terms of skill acquisition.[30] It is interesting that Sheehan and Katz[31] showed that playing ''Dance Dance Revolution'' (Konami, Tokyo, Japan) during a physical education class improved balance more effectively than traditional physical education. However, there is limited research in free-playing situations to assess how closely 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 6 years) playing the Wii™ (Nintendo, Kyoto, Japan) found a strike skill had more semblance to a real life movement than the other skills observed, which showed little evidence of correct performance.[32] Furthermore, a cross-sectional study in preschool-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.[33] Additionally, AVGs have been developed for older adults that use the variable practice principles of dynamic systems, for example, to improve walking and balance ability in stroke rehabilitation patients.[34]

Principles from Other Perspectives

Research on the health-promoting benefits of AVGs has traditionally focused on health behavior 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 multidisciplinary dialogue necessary to create effective activity-promoting AVGs.

Business production principles

The acquisition phase of the AVG lifecycle model can be considered using consumer decision-making models, which have traditionally been cognitively based with reliance on the assumption that humans (buyers) make decisions based on rational, conscious processes. Examples include the Consumer Buying Decision Process Model,[35] the Uses and Gratifications Theory,[36,37] and the Diffusion of Innovations Theory.[38] The Diffusion of Innovations Theory proposes that the adoption of a new technology 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?).

Evidence suggests AVGs may be failing to adequately satisfy these five basic business principles. For example, adolescents perceive the quality of AVGs to be inferior compared with traditional SEGs,[13] negatively influencing relative advantage. AVGs do not always meet players' needs and expectations (reducing capability).[13] Furthermore, some AVG studies show that technical problems often occur and sensors do not always work properly,[13,39] so complexity might be too high in some cases. Players need to have the skills, knowledge, and equipment to use the games, and AVGs may require additional software and hardware compared with 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. Observability can, however, be assisted through viewing gameplay videos, blog posts describing weight loss associated with specific AVGs, and game reviews.

Table 1. Ratings of Identifiability of Selected Theoretical Principles in "Sports Champions Table Tennis" and "League of Legends" Electronic Games

Principles	*TT (SEG)*	*LOL (AVG)*	*Comments*
Behavior change: Self-Determination Theory			
Autonomy—sense of choice	L	H	LOL has more choice because each character's individual abilities and gameplay are fundamentally different. In TT, characters may appear to be different, but they have the same specifications, and the user plays in the same way with each character.
Competence—able to master challenging tasks	M	H	TT is rated lower because there are limited numbers of tasks in which to achieve competence (e.g., striking a ball). In contrast, the battle strategy in LOL requires the user to analyze his or her character in relation to both the other characters and the broader situation/scenario. This is in addition to achieving competence in the basic skills the user needs to control his or her character.
Relatedness—feeling a sense of belonging	L	M	LOL is rated as M because although the team may provide a sense of belonging, teams formed at the start of the game may be disbanded instantly at the end, and if users are unskilled, their teammates (as well as other teams) can be insulting. In TT the option of single player (compared with the requirement of multiplayer in LOL) suggests any benefits of attaining a sense of belonging are likely to require additional external efforts (e.g., future discussion with friends or sharing of videogame play) in comparison with the immediacy experienced in LOL.
Motor learning: Dynamic Systems Theory			
Individual constraints—motor competence, fitness	M	M	TT provides an opportunity for gross motor skill practice but requires a higher level of movement ability than LOL.
Task constraints—real life fidelity	M	L	TT is rated higher than LOL because on-screen movement simulates real life movement rather than the disconnect between minimal user input and high on-screen movement demonstrated in LOL. Higher game movement fidelity would result in an even higher rating for TT.
Environmental constraints—supportive social, safe physical	M	L	LOL is rated lower than TT because it is played in an online community, which, by its nature, is unpredictable in terms of support and safety.
Marketing: Diffusion of Innovations			
Relative advantage—better than alternatives	L	H	LOL is rated higher than TT because its reach in terms of user base indicates it is perceived as better than alternatives by many.
Compatibility—matched to user expectations	M	H	LOL is rated higher because TT may not truly reflect the real life game experience that the user might expect. As LOL is fantasy, actions and consequences are determined by the fantasy world rules, for which the user may have few expectations.
Complexity—easy to use and understand	H	L	TT is rated higher as it is easy to learn with a simple task objective. LOL is more complex because users are required to analyze situations and compare players' abilities, and different knowledge is required on the different types of game components.
Trialability—easy to test	M	L	Both require equipment, but TT is easier to test.
Observability—benefits easily seen	H	H	The games are rated similarly high, as benefits such as enjoyment can be readily seen by the user in both games.
Technology engineering/design: Human–computer interaction/ergonomics			
Input—controls match user mental/physical attributes	H	M	For TT, input movement maps reasonably well with virtual bat movement. For LOL, both keyboard and mouse actions need to be learned to control the game.
Output—display match user mental/physical attributes	M	M	Both games were rated M as there is good input–output mapping.

(*continued*)

Table 1. (Continued)

Principles	TT (SEG)	LOL (AVG)	Comments
Task—interesting, desirable	L	H	The depth and variety of LOL have potential to engage users over long periods of time, whereas the TT task has little progression.
Environment—safe, supportive social/physical	M	L	LOL is rated lower because it is a game played in an online community, which by its nature is unpredictable.
Satisfaction—satisfying to use	L	H	The complexity of LOL engenders a greater sense of achievement and therefore satisfaction among users than the more simplistic TT.
Productive—efficiently performs function	H	H	Both efficiently enable gameplay.
Well-being—use has positive impact on mental/ physical health	H	M	TT has more potential as it not only could be enjoyable but also could encourage movement for physical health benefits.
Technology engineering/design: Flow Theory			
Concentration—focused attention	M	H	The complexity of LOL focuses users' attention more than the relatively ''straightforward'' TT.
Challenge—matched to user skills	L	H	TT may be frustrating as the game fidelity is not perfect. LOL has feedback that is matched to a player's mental skill ability.
Control—sense of control, freedom of choice	L	H	LOL provides more user choice because each character's individual abilities and gameplay are fundamentally different. In TT, characters may appear different, but they have the same specifications and play in the same way.
Clear goals—specific and achievable goals	H	M	The goals in TT are obvious, whereas in LOL there are different pathways with different interim goals.
Feedback—continuous, summative	H	H	Both games provide feedback, both interim and at the end of the game.
Immersion—feeling excited and emotionally involved	L–M	H	The complexity and social engagement of LOL increase the potential for immersion.
Social interaction—competition, cooperation	M	H	Although both games have elements of competition and cooperation, LOL has higher levels of cooperation as team members need to work together in order to win.

AVG, active videogame; H, high; L, low; LOL, ''League of Legends''; M, medium; SEG, sedentary electronic game; TT, ''Sports Champions'' Table Tennis.

Design/engineering principles

HCI. 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 well-being.[40] Much of the research conducted over the last few decades has concentrated on HCI.[41] The HCI discipline aims to design ''machine'' input controls and output displays to match the capabilities (both mental and physical) of human users, which is important for both learning and habitual use phases of the lifecycle model of AVG use. HCI is viewed as taking place within a systems model, thus taking account of the social and physical environment and the task being performed.[42]

According to HCI 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, enable safe play, and be physically suited to the player, such that accidental contact with objects and others is minimized. HCI research has mainly evaluated software aspects of the interaction,[43] but some studies have also considered physiological responses to games[44] and movement during AVG use.[45] However, this traditional view on HCI emerged out of a desire to enhance productivity processes using computers and did not initially consider entertainment experiences such as digital play.

Flow theory. Advanced by Csikszentihalyi,[46] flow theory can be used to describe the pleasure and enjoyment arising from immersion in daily activities of work and play. Consideration of flow within game design is imperative because individuals in a flow state are considered to be absorbed in the activity and disengaged from distractions, which may increase the likelihood of habitual use. Applied to AVGs, a flow state would be exhibited, for example, when users playing a dance simulation game feel fully immersed in the game such that they perceive themselves to be dancing (in contrast to exercising). Elements of gameplay necessary to promote a flow state include concentration, challenge, player skills, control, clear goals, feedback, immersion, and social interaction.[46]

In AVGs, concentration can be supported by including high-quality stimuli (i.e., objects are detailed, and unique animation, sound, speech, and appearance are used).[47] 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 him or her to continue playing to reach the set target. Alongside goals, continuous feedback can be provided on progress by presenting status reports during gameplay and summary tables both during and at the conclusion of play. Elements of gameplay that may contribute to immersion include graphics, sound, animation, fluidity of gameplay, 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 constructive 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 following gameplay on commonly used consoles have shown that AVG users experience flow when engaged in more advanced levels of gameplay and that higher flow results in greater energy expenditure.[48,49] Although flow states transverse all age groups, the design content used to achieve flow states must be age-appropriate such that components (i.e., sound and animation) are appropriately matched to the target age demographic.[50]

Principles Currently Identifiable in Electronic Games

To examine the extent to which principles from the disciplines described above are identifiable in current commercial electronic games, an evaluation was conducted of two exemplar games: A leading AVG game and a leading SEG. Principles were selected according to their hypothesized influence on the multiple phases of the AVG lifecycle and their ability to be observed through inspection of a game. The AVG selected was the table tennis game in ''Sports Champions'' (SCE, San Diego, CA) played on the PlayStation®3 Move (Sony Corp., Tokyo, Japan), which 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,[51] making it an example of a very successful AVG, in terms of sales. However, many SEGs have been far more successful in terms of player reach and engagement, and examining whether a very successful SEG demonstrates more favorable ratings of observable principles would provide some evidence that these principles have potential to enhance game reach and use. The SEG selected was ''League of Legends'' (Riot Games, Santa Monica, CA), which is a multiplayer online battle game typically played with teams of five people against other human or artificial intelligence teams. Industry data suggest there are over 67 million users each month.[52]

The extent to which the various selected 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, TX in May 2014. The panel of 11 individuals represented a range of professional backgrounds (health promotion, public health, physiotherapy, ergonomics, motor skill development, communication, media psychology, health behavior change,

Table 2. Suggested Best Practice Principles for Enhancing Population Physical Activity Using Active Videogames

Phase	*Principles*
Acquisition	• Understand the intended market segment anticipated for AVG sales • Tailor marketing strategies for specific demographic and personality characteristics • Identify and use key decision-making processes in AVG buying • Maximize relative advantage in the commercial market • Market using immediate observable benefits of AVG use • Enable easy ''try before buy,'' for example, by providing free trial versions • Minimize barriers to acquisition, for example, using hardware already owned by users, such as smartphone and Internet software downloads
Learning	• Ensure game interaction ease of use such that input and outputs match expectations • Provide an easy initial experience of at least partly successful gameplay • Ensure high fidelity of AVGs to real world skills • Enable an appropriate level of challenge using graded tasks to support an early sense of mastery and achievement, for both motor skill and physical activity intensity • Provide specific, immediate, and tailored feedback • Allow for continual and progressive feedback as skill level and fitness increase • Use input sensor technology for accurate feedback
Habitual use	• Ensure an optimal level of challenge • Support a sense of achievement • Facilitate social interaction, including constructive competition and collaboration • Enable evolution of the game to keep interest • When creating the game, use the actual movement sensors during early development, rather than sitting at a keyboard • Ensure exertion and movement are essential and integral for game progression

AVG, active videogame.

HCI, game design) and electronic game research and development 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 application [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 low, medium, or high. Further information was gathered from two experienced gameplayers following the conference. Ratings and comments were revised by panel members in two iterative processes. The ratings and explanatory comments are shown in Table 1.

Overall, the principles listed in Table 1 were identifiable in both games, although 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'' that supported autonomy in terms of a sense of choice and concentration. Thus using principles such as those listed in future AVG design may enable more efficient and effective physical activity behavior change.

Limitations in Theories Currently Applied to Active Videogaming

The brief overview of selected theories and the identification of selected principles identifiable in the two exemplar electronic games presented above highlight the multitude of

Table 3. Suggested Research Questions for Enhancing Population Physical Activity Using Active Videogames

Phase	*Questions*
Acquisition	• What are the decision processes in choosing to purchase or initially play AVGs? • What are the needs of potential AVG consumers when making purchase/acquisition choices, and how can the compatibility among these needs and AVGs be increased? • How can game design and marketing strategies from SEGs be incorporated into AVGs to increase their relative advantage in the commercial market? • Does increasing consumer skills, knowledge, and access to equipment increase the uptake of AVGs? • What effect can celebrity modeling have on AVG acquisition intentions? • Can free download of smartphone activity-promoting applications at primary care clinics enhance participation in physical activity?
Learning	• What is the movement fidelity of AVGs (i.e., how similar are movement patterns during AVG play compared with real world play)? • What movement skills can be acquired in AVG play? • What type of AVG is more conducive to movement skill acquisition (e.g., hands free, as in Xbox Kinect, or use of a wand, as in Playstation Move)? • What elements of AVG design enhance transfer of learning from virtual to real environments? • What innovative technology can provide accurate, prompt, and meaningful feedback? • What sort of feedback best promotes learning in different groups (e.g., boys/girls, less/more skilled, normal weight/overweight)? • How can social networks be used as an effective means for feedback? • Are there appropriate challenge trade-offs between being easy to learn and sustained game interest?
Habitual use	• Can AVG play enhance self-perceptions of movement competence? • Do AVG-enhanced self-perceptions support sustained physical activity? • How can autonomous motivation for physical activity be promoted by AVG play? • How can the transferability of AVG-supported increases in physical activity to other real life situations be enhanced? • What features of highly successful SEGs can be used by AVGs to enhance habitual use? • How does component *X* of theory *Y* affect habitual use when manipulated in field studies? • What are user preferences for integration of principles *X*, *Y*, *Z* into AVGs? • What is the optimal use of principles in AVGs to promote sustained use? • What are the roles of complexity, narrative, and reward in promoting sustained AVG use? • What AVG design features support optimal challenge levels? • What are the roles of novelty and social interaction in promoting sustained AVG use? • What are important characteristics of avatars that can increase sustained use of AVGs? • Can machine learning be used to provide highly personalized, real-time feedback? • Is provision of multiple platforms/games/applications more successful in promoting sustained physical activity than a single platform/game/application? • What causes individuals to continue/stop playing AVGs? • What factors influence maintenance of AVG play? • How does context (e.g., home, school) facilitate AVG use? • Are AVGs more effective as a stand-alone intervention or embedded in a broader, multicomponent intervention?

AVG, active videogame; SEG, sedentary electronic game.

factors likely to be important in determining the success of an AVG in terms of its capacity to enhance population levels of physical activity. Several other potentially important factors have been identified, including demographic factors,[53–57] personality traits,[19,58] and habit formations.[59] For example, preferences for SEG genre (i.e., action, sports, or fantasy) have been shown to be predicted by gender,[53] race,[54] and socioeconomic status,[55] and in AVGs, girls tend to enjoy more dance-related and boys more sport-related games.[56,57] In addition, although theories of consumer buying decision processes[35] focus on intentions, habits have often been shown to override intentions.[59] When considered in conjunction with the reviewed theoretical principles, these factors may strengthen the effectiveness of the application of these theories in the context of AVG.

The current application of principles to AVGs has tended to focus on AVGs that are commercially available for console electronic games. However, these are constrained to the 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. Built-in 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.[60,61] Highly discounted initial pricing with future in-game purchases or free-to-play game implementation typically inherent in app-based mobile games also allows for mass trialability. Safety risks and the potential vulnerability of players do, however, need to be considered in relation to the collection of spatial positioning data within app-based mobile activity games.

Consideration of these limitations of past research may help AVG developers offer accessible, flexible, engaging, and evolving games with the potential to engage user interests over a sustained period.

Best Practice Principles for Enhancing Population Physical Activity Using AVGs

Although developing a single universal theory may be unrealistic, development of an interdisciplinary set of principles to inform the design of AVGs to promote habitual physical activity (similar to the example principles outlined in this article) may encourage cross-discipline collaborations and support advancement of the field. Therefore the panel of conference participants developed a list of principles for consideration at each phase in the AVG lifecycle to maximize the potential impact on population physical activity. The list was based on the available literature on potentially relevant theories plus the experience of panel members, including direct experience in designing games[62–65] (Table 2).

Research Ideas for Enhancing Population Physical Activity Using AVGs

Based on an understanding of the current state of research and practice, the panel members also developed a list of research ideas to enhance knowledge to support more effective and efficient AVGs (Table 3).

Conclusions

This article introduced the ideas of multiple potential pathways through which AVGs could produce a sustained positive impact on population physical activity and examined different disciplinary perspectives on what constitutes a successful AVG and the lifecycle of AVG use. Examples of relevant theoretical principles from behavioral sciences (health behavior change, motor skill learning, and serious games), business production (marketing and sales), and technology engineering and design (HCI/ergonomics and flow) were outlined. Some of the factors likely to be important to habitual AVG use that are not explicit in the selected theories were then discussed. These example principles were then applied to ratings of a successful AVG and SEG. This process demonstrated that for AVG use to be sustained similarly to successful SEG use, these games may need to incorporate features more aligned to relevant principles as found in SEG. Future AVG development and research may benefit from infrastructure and capacity to support multidisciplinary collaboration to further develop and apply a comprehensive set of principles for best practice across each phase of the AVG lifecycle and to explore the research ideas suggested.

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