

Building a Better Mousetrap (Exergame) to Increase Youth Physical Activity

Tom Baranowski, PhD,¹ Ralph Maddison, PhD,² Ann Maloney, MD,³
Ernie Medina, Jr., DrPH,⁴ and Monique Simons, PhD⁵⁻⁷

Abstract

Although exergames have been demonstrated to induce moderate levels of physical activity (PA) if played as designed, there is conflicting evidence on use of exergaming leading to increased habitual PA. Exergames have increased PA in some home and school studies, but not others. Exergames have been used in community centers to good effect, but this has not generally been validated with research. PA from exergames may be enhanced by innovative use of sensors, “fun”-enhancing procedures, tailored messaging, message framing, story or narrative, goal setting, feedback, and values-based messaging. Research is needed on PA-enhancing procedures used within exergames for youth to provide a firmer foundation for the design and use of exergames in the future.

Introduction

GAMING IS AN INCREASINGLY popular form of entertainment throughout the world. Exergaming has been used to increase physical activity (PA), but not always. There are two general types of exergames. One type requires physical body movement to enable gameplay (e.g., “Dance Dance Revolution” [Konami Digital Entertainment, El Segundo, CA] [DDR], Wii™ [Nintendo®, Kyoto, Japan] and Kinect™ [Microsoft™, Redmond, WA] games)¹; the other type targets PA change but does not require body movement to progress the gameplay.² The latter tends to incorporate story or narrative into game mechanics, whereas the former tends not to do so.³ Both, or in combination, may be important components of a strategy to increase youth PA. This article briefly reviews what’s known about exergames increasing PA in general, at school, at home, and in community settings and then explores how exergames could be restructured to increase child PA.

What Is Known About Exergames Increasing PA Among Youth?

Without exception, and by definition, videogames that require body movement increase PA. Much of the research to

date has focused on investigating the effect of playing console-based games (e.g., Sony® [Tokyo, Japan] EyeToy® and Move, Xbox™ [Microsoft] Kinect, Nintendo Wii, DDR, XaviX® [San Diego, CA], GameBike™ [Hudson Fitness LLC, Forney, TX]) on both short- and long-term PA. Several systematic reviews exist reporting on the impact of exergames on PA⁴⁻⁶; thus, here we provide a brief summary of the evidence.

The strongest evidence is for the short-term effect of exergames on increasing PA-related energy expenditure (EE) while playing exergames for short periods of time.^{6,7} Data from 12 observational studies and two randomized controlled trials compared exergames with rest, non-exergame play, or both, to determine the short-term effects on EE or physiological parameters such as heart rate or blood pressure.⁷ All studies showed increased EE when playing exergames compared with rest (expressed at 1 metabolic equivalent [MET]). All studies showed increased EE compared with non-exergames, with the greatest levels of EE in games that incorporated the greatest amount of body movement (whole body). Overall, the range of EE values from exergames was 3–7 METs, but most were 3–5 METs, equivalent to light- to moderate-intensity PA. Although there has been abundant research in this area, the collective

¹USDA/ARS Children’s Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas.

²National Institute for Health Innovation, University of Auckland, Auckland, New Zealand.

³University of Massachusetts, Worcester, Massachusetts.

⁴Center for Nutrition, Healthy Lifestyles, and Disease Prevention, School of Public Health, Loma Linda University, Loma Linda, California.

⁵Department of Health Science and EMGO Institute for Health and Care Research, Faculty of Earth and Life Sciences, VU University, Amsterdam, The Netherlands.

⁶Body@Work, Research Center Physical Activity, Work and Health, TNO-VU/VUmc, VU University Medical Center, Amsterdam, The Netherlands.

⁷TNO, Expertise Centre Life Style, Leiden, The Netherlands.

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findings are not surprising because, by definition, PA refers to any muscular movement and results in increased EE. Thus, compared with rest or playing non-exergames, standing up and moving one's arms, body, and legs will result in greater EE. However, the effect of exergames on sustained PA levels is less conclusive.

Data from 11 randomized controlled trials and five observational studies indicated an exergame intervention had no effect on time spent engaging in total PA,^{8–11} moderate to vigorous PA (MVPA),^{9,12} or physical fitness.¹³ However, higher levels of total PA were reported at 6 weeks with a Sony EyeToy intervention group compared with a non-exergame control group, but not at 12 weeks.¹² A DDR intervention resulted in increased self-reported, but not objectively measured, PA.^{9,14} Moreover, increases in weekly MVPA¹⁵ and vigorous PA¹⁴ were found in the intervention group after a 10-week DDR intervention. An increase in aerobic fitness (peak oxygen uptake, a proxy of PA) was reported in participants following a 12-week DDR intervention.¹⁶ School-based studies show some promise, as youth in that setting may choose exergames, as they are a more captive audience.¹⁷

Data from observational studies were equally inconclusive. Although increased aerobic fitness (maximum oxygen uptake) was found after a 30-week DDR intervention,¹⁸ others found no change in aerobic or muscular fitness after 3 months of "Wii Fit" use.¹⁹ Some studies have compared exergame play with more traditional activities, with conflicting results. One study reported levels of PA among those playing exergames compared with physical education (PE) class ($n=4$).²⁰ Alternatively, students spent more time in MVPA during PE and playing football than when playing DDR.²¹

Collectively, these studies suggest that when children and young people play exergames as designed, EE is increased; however, the effect of videogame play on total PA or different intensities of PA is not so clear. Exergames do not appear to have a substantial effect on increasing habitual PA levels in children; however, evidence indicated these games may reduce sedentary time (the most common category of child activity-related behavior). Playing exergames is better than sitting or more traditional videogame play because it results in greater EE. Moreover, two trials showed displacement of non-exergames with active videogame time on the order of 10 minutes/day.^{12,13}

The potential of exergames to increase PA remains. Research to date has been limited by a lack of long-term trials of sufficient duration and sample size. Furthermore, measurements of PA, sedentary behavior, and videogame play have hampered research, with an overreliance on self-report. It is not clear how sensitive objective measures of PA (e.g., accelerometers or pedometers) are to the contribution of exergaming on total PA and sedentary time. There is a dearth of evidence using objective measures on the influence of games for health on PA and sedentary behavior. Given the ubiquitous use of mobile devices, there is also a lack of evidence regarding mobile games (apps) on behaviors such as PA. Given the pervasive use of mobile technologies, the potential impact of mobile exergames is enormous.

How Exergames Could Be Used to Increase PA

As highlighted above, simply providing exergames has not led to sustained increased PA among youth.⁷ The lack of

long-term effectiveness is especially evident when no instruction for minimal use was provided or when there was no program structured around it.^{1,4,22,23} Providing instruction or embedding exergames in a more structured program, for example, a family-, school-, or fitness center-based program, seems more promising.

Home setting/ involving families

The home environment, both physical and social, is of great importance in influencing children's physical activity and sedentary behavior. Parents often decide, especially for younger children, which devices will be in the home and make rules for using the devices,²⁴ including consoles and videogames.²⁵ In addition, the behavior of parents and siblings likely influences the child's behavior.²⁴

Videogames are most often played at home,²⁵ mainly in the living room,²⁶ and most videogames have multiplayer modalities, allowing play by the family. This multiplayer option may be important because children find exergames fun to play with others²⁷ and because playing with others improved adherence.²³ Parents had a positive attitude toward exergames, preferred active games over non-active games, and were willing to buy them. Parental rules did not hinder exergame play at home.²⁸ So, requirements for exergames to increase PA in the home appear to be present.

Parents were important in children's initial participation in exergames,²⁹ whereas brothers and sisters were more important for sustained participation.²⁹ A large randomized controlled trial is currently underway to determine the effects of a family-based exergame intervention,³⁰ which will provide important new information on whether exergames provided to the whole family and encouraging social play is effective for preventing excessive weight gain.

School setting

Children spend up to a third of their weekdays at school, making this an important setting to promote PA and implement exergame intervention. School use of exergames has not been prevalent and may present a missed opportunity to introduce children to an alternative form of PA.³¹

Exergames in PE classes had a positive influence on PA and its determinants.^{5,32–34} Exergaming enhanced students' interest and competence in PA³³ and improved balance more effectively than traditional PE, but not as effectively as a specific balance program.³² Alternatively, exergame play during PE was not sufficiently intense because it did not exceed the moderate intensity cut-point (3 METs). Exergames may present a trigger for interest and motivation for student PA. Future studies should assess how game technology should be implemented in PE to optimize beneficial effects.

Recess¹⁰ and afterschool may also be times for bouts of exergaming in school. During afterschool hours, adolescents spent much of their time in sedentary activities, especially technology-based activities.³⁵ An exergame program could make this time more active. An exergame program, called "E-sportszone," was offered over a 1-year period in a pre-vocational school, the lowest educational level for secondary school in The Netherlands.³⁶ Three hundred students (12–18 years of age) were exposed to the exergame program. Prevalence of overweight, high level of sedentary behavior, and

lack of PA characterized these students. Students could use the exergame room between lessons (1:15–2:15 p.m. and/or 2:15–3:15 p.m.), during recess (12:50–1:15 p.m.), and after school hours (2:15–3:15 p.m. and 3:15–4:15 p.m.). Forty-two percent of the students attended the “E-sportszone” at least once over the 1-year period. Attendance varied from 1 through 114 days (median, 3 days), with a peak during the “E-sportszone marathon,” an event during which the “E-sportszone” was open for 24 hours. Boys used the “E-sportszone” more than girls (odds ratio [OR]=2.8), and older students were less likely to be users than younger students (OR=0.4). Students with a more positive attitude toward PA (OR=1.5) or with higher intention to use the “E-sportszone” (OR=1.5) were more likely to engage in exergaming. Although this study illustrates the potential of exergames to reach at-risk students in school, the frequency of usage was low, and long-term use is challenging.

Exergames may also be used in the classroom. An E-fitbike, an advanced home trainer connected to a computer game, was tested in primary school classes to increase PA and decrease sedentary school time. With the E-fitbike, the player could cycle along tracks and compete with other players.³⁷ Intervention schools received two E-fitbikes for 8 weeks, whereas the control schools were waitlisted to use the E-fitbikes once the study was completed. Although no effects were found on physical fitness (shuttle run test), self-reported PA, and sedentary behavior, students and teachers were very positive about the E-fitbikes. Students wanted to play more often and longer on the E-fitbike, but time was an often-mentioned barrier for using the E-fitbike in class.

A promising strategy for exergame programs to increase frequency of usage and adherence might be to include cooperative activities. Cooperative activities increased group cohesion and resulted in more social support and self-esteem.^{38,39} Group or social play encouraged sustained use^{23,29} and optimized EE.⁴⁰ Cooperative play appeared to be more effective than competitive exergame play for weight loss and increased self-efficacy in overweight and obese children.³⁸

Simply providing exergames in the school setting has not been enough to encourage habitual PA in the long term; therefore future studies should focus on strategies to increase frequency of usage and adherence, such as embedding exergames in a more structured program, organizing booster activities to periodically revive short term interest,³⁶ stimulating cooperative play,³⁸ combining school setting with home setting using social media,⁴¹ and organizing active gaming contests between schools. Studies should investigate the best way to implement exergames in school classes and whether it can increase PA and decrease sedentary time without impairing the quality of the school lessons. Exergames could be integrated with educational purposes. Students might learn more effectively if they moved their body at the same time (i.e., “Embodied Learning” [e.g., a smartphone app taught students math skills while they walked around the schoolyard]).¹⁷

Community settings

PA practitioners have used exergames to promote PA in pediatric obesity programs such as the Family Fit program (Beaver Medical Group in Redlands, CA). Anecdotally, overweight and obese children wanted to play the active

videogames more, even when they were perspiring profusely. Parents commented that they had never seen their kids want to exercise so much and were interested in getting the games for home use. Although the continued use of exergames in these contexts indicates exergames do promote PA, little research has been reported on these uses. Active videogames have also been used in community and clinical settings to establish fitness levels when traditional fitness testing like the 1-mile run or PACER shuttle test was impractical to perform. One study compared fitness scores among middle school students doing the standard 1-mile run and PACER test with that for the 5-minute “Jackie Chan Run” game on the XaviX.⁴² Significant positive correlations were detected between fitness scores and game score. Research is needed on the extent to which each of these (and other community practices) increases the incidence, prevalence, duration, and maintenance of PA.

How Might the Effects of Exergames Be Enhanced?

We initially searched for sound evidence-based procedures to increase PA among children in exergames. Because little to no such research has been conducted within exergames, we attempted to adapt evidence-based procedures in other areas to exergames for children.

Sensors

The exergaming experience is only as good as its sensors: Accurate, reliable, easy to use, and affordable sensors provide feedback necessary to motivate users. Early exergame releases in the 1980s (e.g., “Foot Craze” released for the Atari 2600⁴³) demanded active user interaction and relied on simple pressure sensors; users would watch and listen to a video and “dance” on a foot pad that fed back foot location to the game console. Today, sensor technology is more sophisticated and comes in two types: Nintendo’s Wii games rely on a gyroscope, accelerometers, and a hand-held motion sensor to determine a player’s movements; Xbox Kinect and PlayStation® (Sony) games use a camera to detect the player’s movements in three-dimensional space, translate those movements onto a two-dimensional screen,⁴⁴ and allow the user to become the creator of his or her own onscreen content.⁴⁵ A drawback to the Wii sensors is that players must hold onto a remote while playing, and Wii remotes (Wiimotes) are often dropped or inadvertently thrown across the room during gameplay. A virtual trainer (avatar), more like a cheerleader, whose gender can be changed to suit the players’ preference, offers positive reinforcement but little in the way of constructive criticism. Performance data measured by Wii sensors include caloric or MET expenditure, body mass index, and improvement in balance, but these are not normed for children’s age or adjusted for gender and thereby can be misleading. It is easy to “cheat” a Wiimote, flailing one’s wrist to dupe the sensor into believing one is actually engaging energetically in the activity. Like the inertial sensors, game camera systems do not use high-end equipment (likely because of added cost) and therefore do not provide the resolution and sample frequency necessary to provide consistently accurate data, although they are more accurate than the Wiimotes.⁴ As with the Wii, performance data such as heart rate (in “EA Sports Active” [Electronic Arts, Redwood City, CA] only), body measurements, and other

metrics are not adjusted for pediatric use. Improvements in the accuracy of the sensors should improve the gaming experience because more accurate feedback improves players' ability to set and meet PA goals.

"Wearable" sensors that are actually attached to players, such as caps, bracelets, and gloves, improve data accuracy. These types of sensors were a highlight at the 2014 Consumer Electronics Show in Las Vegas, NV: Observers described a great deal of promise, as the data they record can easily be integrated into a game or athletic regimen. Coaches use these technologies to determine players' level of fatigue, kicking or running power, and other information critical to improving performance. As vendors demonstrated at the Consumer Electronics Show, the accuracy, user-friendliness, and interactivity of sensor technology are developing rapidly. Applications and wearable sensors designed for use with smartphones and other mobile devices also represent potentially powerful, affordable tools for providing players and athletes with accurate real-time feedback. With the increased competition in this sector, manufacturers are finding creative ways to offer incentives to fitness game participants to increase brand loyalty. For example, "Kinect Training" teamed up with Nike (Beaverton, OR) to provide full-body workouts that claim to measure improvements in cardio health, muscle growth, and stamina measured in "Nike-Fuel™ points," a comprehensive unit of measurement developed and trademarked by Nike for use with their fitness devices (e.g., Sportswatch, Nike+ for iPod® [Apple, Cupertino, CA], etc.).⁴⁶ This more comprehensive approach could make fitness games more appealing. Social media could be leveraged to provide real coaching in ways that are developmentally appropriate to the age and objectives of the players, based on sensor data sent electronically to a dedicated Web site. Data could also be shared electronically with healthcare providers, who could monitor progress, regress, and make recommendations for diet and level of activity to their patients. Tangible rewards, such as small toys, could be provided as children engage in more MVPA, as HopeLab has done with "Zamzee."⁴⁷ Google's new contact lenses for diabetics measure the wearer's glucose level, which perhaps could be combined with exergaming.

Game fun or enjoyment

Game enjoyment identifies the factors that likely engage players and thereby enables or facilitates their exposure to any messages or change procedures embedded in the games. Self-determination theory can be used to understand how body movement exergames influence having fun and behavior,^{2,3} whereas diverse social cognitive and communication theories have been combined and sometimes integrated to understand how the story-based exergames influence having fun and behavior.^{48,49} One study systematically varied self-determination theory constructs in a narrative-driven game using a factorial design and found that their autonomy manipulations (i.e., several types of choice versus none) and competence manipulations (difficulty increasing with player skill, feedback on performance, achievement badges versus none) influenced the corresponding need satisfaction and gameplay enjoyment.² This study provides strong support for a self-determination theory approach to understanding exergame enjoyment, but these findings need to be

replicated and extended to exergames. Other aspects of exergame engagement and enjoyment⁵⁰ need to be tested with children.

Values

Self-determination theory proposes that intrinsic motivation leads to increased and longer maintained activity because one enjoys the activity and not because of external factors.^{51,52} Exergames can seek to develop intrinsic motivation by enhancing competence, providing choice, and connecting goals to personal values. A process evaluation of a videogame for healthy diet and physical activity showed that getting good grades, not missing school, obtaining energy to do homework, being healthy and fit, and being a healthy weight were values often mentioned by children.⁵³ Integrating messages about these values in exergame programs might increase intrinsic motivation and thereby maintenance of exergame play.

Persuasive messaging/tailoring

Persuasive messaging has been one approach to promoting PA change. Tailored messaging has influenced PA in more studies than not.^{54,55} Tailored messaging involves measuring some aspect of a player's behavior and/or beliefs about that behavior and then providing messages appropriate to what was measured. Virtually all the tailored messaging for PA has been predicated on the transtheoretical model,^{54,55} measuring the stages of change, and providing messages addressing the player's self-efficacy for being physically active, the pros and cons of PA, and the mechanisms of behavior change specific to each stage. Some transtheoretical model-based studies had no effect on PA, and the effects, when obtained, tended to be very small.⁵⁴ The lack of recent articles on the transtheoretical model indicates that it has gone out of favor. Tailored messaging has been predicated on other theoretical frameworks when targeting other behaviors,⁵⁶ which offers promise for PA. It is possible that variability in the influence of message tailoring on behavior has been due to variability in the quality of implementing tailored messages, but no criteria for quality have been propounded for quality control of tailored messages. Tailored messaging needs to be tested within the context of exergames (e.g., avatars providing tailored messages based on answers to questions early in, or just prior to, gameplay) with children. Developmental considerations will need to be applied to messages for children of different ages. Some of the exergames display images of females in more provocative wear, which can be offensive and inappropriate in certain settings. The ESRB ratings tend to make exergames "E" rated, but depiction of sex-role stereotypes and other cultural bias that enters into the game can be off-putting for certain audiences.

Message framing

Message framing has also been used to increase PA.^{57,58} Messages have been generated either as gain-framed (i.e., indicating the benefits that can be attained from doing a behavior) or loss-framed (i.e., indicating the costs that can be avoided from not doing the behavior). Gain-framed messages have generally worked for preventive behaviors

(including PA), and loss-framed messages have worked for compliance with disease regimens.^{57,58} Message framing needs to be tested in exergames with children, again perhaps by having avatars make statements at strategic points in gameplay. Developmental considerations need to be applied, and, if shown to be effective, quality criteria need to be generated and validated to enhance consistency and quality in using message framing. Diverse ideas for consideration in the design of persuasive messages have been proposed⁵⁹ and should be tried in exergames.

Message tailoring and framing are single aspects of message design, which are important for research to clarify what works and what does not. More comprehensive approaches may be appropriate for practice including both tailoring and framing, but also attention attraction, distinctive branding, and theory-based design.⁶⁰

Story

Story or narrative has been shown to influence behavior⁶¹ and been used in diverse videogames.⁶² Immersion in a storyline focuses a player's attention on the messages and/or procedures embedded in the game and can influence diverse aspects of behavior-related constructs.⁶¹ When players identify with story characters, they are more likely to be immersed.⁶³ Characters in the game cutscenes can model the PA and overcome barriers to doing those activities,⁶² thereby enhancing player learning. In the typical story arc, a character starts out not doing the desired behavior (e.g., PA), and over the course of the build-up to the crisis (usually involving not doing the behavior), the character learns to value the behavior. This arc can result in emotional attachment to and appreciation of doing the behavior.⁶² One study is currently testing wrapping a story around doing PA in an exergame with children (A.S. Lu, personal communication). More such research needs to be conducted in diverse exergames with children of diverse ages to understand developmental factors in story's influences.

Goal setting

Goal setting has been one of the most commonly used behavior change procedures among adults for diverse behaviors⁶⁴ and has been proposed as a mechanism to implement in real life what was learned in a game.⁶⁵ Process evaluation assessment of goals attained within games by children has led to inconclusive outcomes.^{64,66,67} Action implementation intentions (a very specific form of goal setting) enabled children to change diet behavior in an interactive media experience but not coping implementation intentions (a form of problem solving) (D. Thompson, personal communication). Research is needed on implementation intentions with children in exergames.

Feedback

Virtually all exergames have provided some form of feedback.⁶⁸ A concern has been the optimal design of feedback to inform a player of a poor choice or of other inadequate or negative performance. The medical education literature suggests "oreo" feedback (i.e., sandwiching a negative message between two positive messages) may minimize resistance to the message. Among adults, "oreo"

feedback was preferred by lower income participants, but a straight negative message was preferred by middle income participants.⁶⁹ Research is needed on optimal feedback design for children in exergames and on whether turning OFF the audible BOO on DDR, to make it less annoying/insulting, influences what is learned.

Conclusions

We are in the earliest stages of understanding how exergames can be used and/or redesigned to enhance PA among children. The large commercial sales of exergames indicates the extensive reach and child enjoyment of this technology. This article has indicated several paths for further development to capitalize on this reach and enjoyment to increase child PA.

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Address correspondence to:
Tom Baranowski, PhD

USDA/ARS Children's Nutrition Research Center
Department of Pediatrics
Baylor College of Medicine
1100 Bates Street
Houston, TX 77030-2600

E-mail: tbaranow@bcm.edu