Published in final edited form as:
Z Psychol. 2013 April 1; 221(2): 72–78. doi:10.1027/2151-2604/a000137.

Exergaming in Youth: Effects on Physical and Cognitive Health

John R. Best
Washington University School of Medicine in St. Louis

Abstract

Exergaming (a portmanteau of “exercise” and “gaming”) is a relatively new genre of interactive video gaming that stimulates an active, whole-body gaming experience. Exergaming could have a significant positive impact on youth as across the globe youth are living more sedentary lifestyles. Exergaming has the potential to thwart this trend by engaging youth in physical activity (PA). Exergaming is not only physically-engaging but is also cognitively-engaging, and this combination of physical and cognitive engagement may translate into improved cognitive function in youth. The purpose of this review article is to examine the state-of-the-art in exergaming research to address whether exergames are a viable tool to promote PA in youth and benefit cognitive functioning among youth. The research addressing these questions is still quite nascent; therefore, only tentative conclusions can be drawn. However, this review points out promising lines of research and makes suggestions for future research to obtain more firm conclusions.

Exergaming (a portmanteau of “exercise” and “gaming”), also known as active video gaming, refers to a relatively new generation of gaming in which the gamer’s gross motor movements replace the traditional button presses of sedentary gaming. Although exergames have been available since the 1980s, high costs and poor interfaces initially impeded commercial success. This changed somewhat in the late 1990s with the introduction of *Dance Dance Revolution* (DDR), an exergame that has players mimic dance steps presented on the video screen in rhythm with various musical selections (Behrenshausen, 2007). In its original form, DDR appeared in arcades as a stand-alone machine using pressure-sensitive footpads to determine the player’s movements. More recently, advances in wireless and sensor technologies have allowed for low cost interfaces, thus transporting exergaming from the public arcade to people’s private homes (Staiano & Calvert, 2011). In 2006 Nintendo introduced the Wii, which included a wireless remote embedded with accelerometers and optical sensors to measure arm motion and rotation. This allowed the gamer to make gross movements with the arms (e.g., swing, thrust, and rotate) while gaming at home. For example, in Wii Sports boxing, the gamer stands in front of the television holding the remote in one hand and a supplemental remote in the other hand. During the game the gamer makes punching motions to compete in boxing matches against virtual boxers. In late 2010 Microsoft introduced the Kinect, an add-on peripheral for the Xbox360 console, which circumvented an external controller altogether. The Kinect uses optical sensing to track the movement of individuals in three dimensions, thus allowing whole-body movement (e.g.,

Correspondence: John R. Best, Washington University School of Medicine, Department of Psychiatry, 660 South Euclid Avenue, Campus Box 8134, St. Louis, MO, USA 63110; Phone: (314) 286-2070; Fax (314) 286-2091; bestj@psychiatry.wustl.edu.

jumping, squatting, running in place) to be translated into virtual activity. In Kinect Sports, one of the first exergames to be released for the Kinect, gamers compete in six different sports (e.g., track & field, beach volleyball) by performing the real-life movements of the sport (e.g., throwing an imaginary javelin or spiking an imaginary ball). In its first year, Microsoft reported an astounding 18 million sales of the Kinect (Miller & Lamm, 2012), which reflects the substantial popularity of exergaming among youth. Results from a national U.S. survey in 2010 reveal that nearly 40% U.S. high school students (U.S. grades 9–12) play exergames at least 1 day per week (Fulton, Song, Carroll, & Lee, 2012).

With so many young people participating regularly in exergaming, there is great interest in what effects exergaming may have on developing youth. The majority of research has focused on the possibility that exergaming increases energy expenditure, regular physical activity (PA), and physical fitness in youth (e.g., Baranowski et al., 2012; Daley, 2009). A smaller, but growing literature concerns its effects on youth's cognitive function, especially within the realm of executive function (EF) (e.g., Best, 2012; Staiano, Abraham, & Calvert, 2012). The purpose of this article is to review the literature within each of these domains—i.e., the physical and cognitive domains. Others have conducted systematic reviews of research on the effects of exergaming on physical health in youth (Barnett, Cerin, & Baranowski, 2011; Biddiss & Irwin, 2010; Daley, 2009). This review differs from these past ones by bringing attention to the effects on cognitive health and by suggesting possible interconnections between these two domains.

Can exergames be a viable tool to promote PA in youth?

Across the globe, rates of obesity among youth have increased dramatically over the past 3 to 4 decades (Swinburn et al., 2011). Obese youth are at heightened risk for long-term health consequences, such as type 2 diabetes and cardiovascular disease, especially if they remain obese as adults (Juonala et al., 2011). Obesity results from a chronic energy imbalance, in which energy consumption exceeds energy expenditure over time. One culprit of this energy imbalance may be heavy use of electronic media that discourages PA (Baranowski & Frankel, 2012); however, exergaming offers the possibility that electronic media can be turned from foe to friend by providing an appealing interactive platform to increase energy expenditure among youth.

The physiological response during exergaming

In a systematic review, Biddis and Irwin (2010) reviewed 18 studies conducted between 1998 and 2010 on children and youth and concluded that exergaming typically elicits light-to-moderate-intensity activity, which results in energy expenditure greater than sedentary gaming but below the intensity needed to improve aerobic fitness. Importantly, the exercise intensity varies across games, with games involving the lower body eliciting greater energy expenditure than games requiring primarily the upper body. Similar conclusions were drawn from reviews by Daley (2009) and Barnett and colleagues (2011). In a recent study, not included in these reviews, Bailey and McInnis (2011) examined the energy expenditure associated with 6 distinct exergames (3 games played on commercial consoles such as Cybex Trazer and 3 games played on consumer consoles such as Nintendo Wii), compared to rest and treadmill walking, in both lean and overweight children (aged 9 to 13). The researchers found that all six games elicited moderate-to-vigorous intensity activity, with 4- to 8-fold increases in energy expenditure compared to sedentary rest in both lean and overweight children. Moreover, four of the six games elicited greater energy expenditure than did treadmill walking (4.8 km/hour). The researchers note that they selected games (including commercial fitness-oriented games typically found in fitness centers) and difficulty levels within those games to maximize energy expenditure, which was typically not the case in previous studies. In another recent study, Graves and colleagues (2010) examined a popular in-home exergame (Nintendo Wii Fit) in comparison to sedentary gaming, brisk walking, and jogging in lean adolescents. Most Wii Fit games elicited greater energy expenditure and heart rate than did rest or sedentary gaming but a smaller response than brisk walking (5.3 km/h) or treadmill jogging (8.4 km/h). Overall, the evidence suggests that while exergaming does increase energy expenditure beyond that of sedentary gaming, it typically does not achieve the energy expenditure inherent in moderate-to-vigorous PA. That stated, there is significant variation, with exergames oriented to fitness training and requiring total body movement more capable of achieving higher intensity PA.

Enjoyment and motivation to play exergames

One of the great hopes is that exergames will offer a viable substitute for traditional videogames and other sedentary activities (Daley, 2009). Generally, youth engage in activities that they enjoy, and several studies have assessed children’s enjoyment of exergames immediately after playing them. For example, Bailey and McInnis (2011) examined children’s enjoyment across the six exergames described above. Children enjoyed playing all of the exergames, with slight gender differences (e.g., boys enjoyed Wii Boxing more, whereas girls enjoyed DDR more), and with overweight children generally enjoying the games more so than lean children (especially the commercial exergame Sportwall). However, enjoyment of other activities (e.g., sedentary gaming, treadmill walking) was not assessed, thus precluding a comparison of enjoyment between exergaming and other activities. Graves and colleagues (2010) addressed this gap by examining the reported enjoyment of several Wii Fit games in comparison to sedentary gaming, brisk walking, and jogging in lean adolescents. These youth reported greater enjoyment in playing the Wii Fit than in playing the sedentary game or in engaging in treadmill walking or jogging, suggesting that youth may be more inclined to play Wii Fit than these other activities.

To more closely determine whether youth will play exergames rather than other games, researchers have assessed children’s motivation to play exergames by assessing the relative reinforcing value (RRV) of exergaming. RRV is a concept based in behavioral economics, which is the study of how individuals allocate their resources (e.g., time, effort, money) to make choices (Epstein, Salvy, Carr, Dearing, & Bickel, 2010). During the RRV task, individuals choose to work to gain access to one option (e.g., exergaming) or to an alternative (e.g., sedentary gaming); the option for which the individual is motivated to work hardest has the greater RRV. In one study, Epstein and his colleagues (Epstein, Beecher, Graf, & Roemmich, 2007) determined the RRV of an interactive dance game (DDR) and an interactive cycling game (Cateye stationary cycle) relative to playing those games in a sedentary fashion using a handheld controller. The researchers found that children (both lean and overweight 8- to 12-year-olds) were more motivated to play DDR in an active fashion compared to in a sedentary fashion but were not more motivated to play the cycling game in an active fashion compared to in a sedentary fashion. A more recent study (Penko & Barkley, 2010) determined that the RRV of exergaming (Wii Sports boxing) was greater than sedentary gaming (Nintendo PunchOut!) among lean, but not overweight, 8- to 12-years olds. Interestingly, both lean and overweight children liked playing the exergame more so than playing the sedentary game or walking on a treadmill. As the authors note, the neurobiological systems that underpin RRV and liking are distinct, which could simultaneously lead an individual to like a behavior without being highly reinforced by that same behavior. The authors also suggest that RRV may be a better predictor of future behavior (e.g., exergaming) than reports of liking. Thus, to determine whether a particular exergame is a viable substitute for other PA activities, researchers should determine how well it is enjoyed by youth and how motivated those youth are to gain access to that game relative to alternative activities.

Does exergames increase PA over time and improve physical health?

The above evidence suggests that children engage in light to moderate activity during exergaming, and enjoy and are motivated to play exergames. But, does this translate into increased PA over time, and if so, does this positively affect physical health? Reviews of studies occurring before 2010 (Barnett, et al., 2011; Biddiss & Irwin, 2010) concluded that there is only weak evidence that exergaming increases youth's PA while decreasing their sedentary behavior. Typically exergaming declines over time, with maximal use occurring at first receipt of the exergaming consoles and games. Participants often report that boredom and technical problems reduce exergaming over time; however, support from friends and family, and the ability to exergame with others facilitate long-term exergame play. Overall, these past reviews suggest there is little evidence that access to exergaming over time improves body composition or physical fitness. However, the reviewers noted that further investigation is needed, as a number of methodological limitations were identified (e.g., non-randomized designs, insufficient statistical power due to samples typically less than 50 children).

Since these reviews, two randomized controlled trials (RCTs) have been conducted on larger samples of children. In one study (Maddison et al., 2011), 10- to 14-year old children (n = 322; overweight or obese; owners of a Sony Playstation 2 or 3 console but non-owners of exergames) were randomly assigned to receive the Sony EyeToy and 5 games (3 games at baseline and 2 more games at 12 weeks) or to a no treatment control. Importantly, children in the experimental group also received encouragement to increase their PA, whereas children in the control group received no such encouragement. At the end of the study (24 weeks), children in the exergaming group had gained less weight, had improved body composition, reported more time exergaming, and reported marginally less time playing sedentary video games, relative to the control group. However, no differences were observed in average daily time spent in moderate-to-vigorous PA using objective measurements (i.e., accelerometers worn on the hip). In a second study (Baranowski, Abdelsamad, et al., 2012), 9- to 12-year-olds (n = 78; at risk for obesity; non-owners of a Nintendo Wii) were randomly assigned to receive a Wii and their choice of 2 exergames (1 at baseline, 1 at week 7) or to receive a Wii and their choice of 2 sedentary games. In contrast to the Maddison et al. study, no prescriptions to increase PA were made to either group; this was done to increase the ecological validity of the results and to selectively manipulate only the PA component of game play (Baranowski, Baranowski, O'Connor, Lu, & Thompson, 2012). The primary outcome in this study was PA, measured objectively at several time points across the 12-week study using accelerometers. In line with Maddison et al., no differences in physical or sedentary activity following the intervention were observed between the exergame and sedentary game groups. Thus, while there is some evidence that regular exergaming can improve youth's body composition (Maddison, et al., 2011), these recent RCT studies offer no evidence that it increases daily engagement in moderate-to-vigorous PA. It is possible that exergaming substituted for other forms of PA that the children may have typically engaged in, rather than for sedentary activities, leading to no net change in PA. It is also possible that it is not sufficient to provide access to exergaming; specifically, encouragement to increase PA also may be needed.

Summary

At this point, it is unclear whether exergaming is a viable tool to promote PA in youth. During single session studies, exergaming can elicit light- to moderate-intensity PA, depending on the exergame platform and specific game, and is perceived as enjoyable and reinforcing; however, over time, it appears that interest and adherence to moderate-intensity exergaming wane. That said, it should not be concluded that exergaming cannot enhance PA (Baranowski, Baranowski, et al., 2012), and there are several avenues through which future exergaming could be a stronger tool to promote PA. First, as the technology underlying exergaming continues to improve, its ability to capture children's movement accurately will also improve, likely resulting in a more realistic and varied gaming experience. Second, exergames that incorporate immersive narratives will likely result in stronger effects on children's behavior than games without an underlying narrative (e.g., Lu, Thompson, Baranowski, Buday, & Baranowski, 2012). Third, exergames that encourage competition and group play may prove to be more enjoyable and motivating over time, resulting in longer-term use as compared to games played alone (Madsen, Yen, Wlasiuk, Newman, & Lustig, 2007). Finally, it may be insufficient just to provide access to exergames. For example, it may be necessary to train parents to properly "coach" their children to use exergames properly (Errickson, Maloney, Thorpe, Giuliani, & Rosenberg, 2012) or to provide prescriptions to meet daily PA recommendations (Maddison, et al., 2011). Additionally, restriction to sedentary games and activities may need to go hand-in-hand with access to exergames.

Does exergaming benefit cognitive functioning in youth?

A critical challenge to psychological scientists involves determining what sorts of experiences promote cognitive development among children and adolescents. In recent years, interest in two domains of experience has grown significantly. The first domain is PA (Hillman, Erickson, & Kramer, 2008; Tomporowski, Davis, Miller, & Naglieri, 2008). Interest in the importance of PA to cognition has been prompted in part by the recognition that (1) overweight and obese youth, who are typically less physically active than their lean peers, show poorer cognitive function and academic achievement (Y. Li, Dai, Jackson, &

Zhang, 2008; Taras & Potts-Datema, 2005) and (2) there are close interconnections between the biological pathways underlying energy metabolism, motor control, and cognition, suggesting that the human brain may function optimally when the individual engages regularly in physical activity (Diamond, 2000; Vaynman & Gomez-Pinilla, 2006). Experimental research indicates that aerobic exercise (i.e., steady-state PA at a moderate intensity), both in acute and chronic forms, improves children's cognitive function, especially within the realm of executive functioning (EF) (Best, 2010). Also, youth with greater physical fitness show better EF than youth with less fitness (e.g., Hillman, Buck, Themanson, Pontifex, & Castelli, 2009). EF encompasses the cognitive processes necessary to override automatic responses, resolve conflict between goal-oriented and impulsive behavior, keep and manipulate information in mind in order to think and behave in a goal-directed fashion (Banich, 2009). EF is critical in myriad aspects of youth's lives, from competent social interaction (Carlson, 2009) to emotional regulation (Simonds, Kieras, Rueda, & Rothbart, 2007) to effective weight control (Best et al., 2012)

The second domain involves challenging, interactive activities, including video gaming. Experimental research has shown that playing action video games—i.e., sedentary games that are fast paced and have high perceptual, cognitive, and motor demands— enhances multiple aspects of visuo-spatial processing and EF, including attentional control and cognitive flexibility (e.g., Green & Bavelier, 2003; Greenfield, DeWinstanley, Kilpatrick, & Kaye, 1994; R. Li, Polat, Makous, & Bavelier, 2009). In a recent review, Green and Bavelier (2012) provide a unifying theory to explain all these myriad enhancements to cognitive function. They suggest that playing action video games (not to be confused with *active* video games, i.e., exergames) improves individuals' ability to utilize task-relevant information and ignore irrelevant information, which in turns allows individuals to more quickly and efficiently learn from the environment. That is, action video gaming enhances the efficiency with which individuals 'learn to learn,' a concept attributed to the famous psychologist Harry Harlow (1949). It can be argued that efficient 'learning to learn' requires EF, especially the ability to employ adaptive and flexible cognition to learn from a novel situation rather than relying on automatic responses to stimuli (Best, 2010).

Exergaming can combine physical activity and action video gaming and thus has the potential to improve youth's cognitive function, especially within the realm of EF (Staiano & Calvert, 2011). However, to my knowledge, only two studies have tested this possibility in normally developing youth (Best, 2012; Staiano, et al., 2012) and one study has tested this in developmentally disordered youth (Anderson-Hanley, Tureck, & Schneiderman, 2011). All three studies tested the acute effects of exergaming on cognition, i.e., the immediate effects of playing an exergame for a period of time (e.g., 25 minutes) on cognitive function. Together, these studies tentatively suggest that acute exergaming bolsters EF in youth.

In a 2 × 2 design, Best (2012) compared the effects of playing a game that elicited both PA and cognitive engagement (i.e., a Wii exergame with action video game elements) to games that elicited PA or cognitive engagement (but not both) to watching an educational video (neither PA nor cognitive engagement). To measure cognitive function, including EF, participants (primarily lean 6- to 10-year-olds) performed the Attention Network Test for Children (Rueda et al., 2004) immediately after each activity. It was found that playing an exergame selectively enhanced children's EF, regardless of whether the exergame had action video game elements. In a second study, Staiano and colleagues (2012) examined the effects of exergaming in a competitive versus cooperative fashion on EF. Their design rationale was based in part on previous research suggesting that competitive, but not cooperative, behavior elicits activity from brain regions underpinning EF (Decety, Jackson, Sommerville, Chaminade, & Meltzoff, 2004). Primarily overweight or obese adolescents (15- to 19-years olds) were randomly assigned to play Wii EA Sports Active in a cooperative or competitive fashion for 10 weeks or to a no treatment control condition. After the 10-week training period, the participants played the exergame one last time (in either the cooperative or competitive fashion) and then completed an EF assessment. Adolescents in the control condition also completed the EF assessment, but after sitting in a chair for 5 minutes. In line with the main hypothesis, adolescents in the competitive exergame condition showed improved EF on both tasks compared to adolescents in either the cooperative exergame or control conditions. However, contrary to predictions, playing the cooperative exergame did not improve EF as compared to the control condition. The researchers also found that improvements in EF over the 10-week period correlated with weight loss during that same period, but only for children in the competitive condition.

Anderson-Hanley and her colleagues (Anderson-Hanley, et al., 2011) tested whether exergaming could bolster EF and reduce repetitive behaviors in children and adolescents (aged 8 – 21 years) diagnosed with Autism Spectrum Disorder (ASD). One theory within the ASD research field suggests that the repetitive behaviors characteristic of children with ASD may be underpinned by deficits in EF (Turner, 1999). Anderson-Hanley and her colleagues reasoned that given the evidence that PA improves EF and that interactive video games may be therapeutic for children with ASD, exergaming could reduce ASD symptoms via improved EF. Indeed, the researchers demonstrated that playing an exergame for 20 minutes (either DDR or a cybercycle game) reduced participants' repetitive behaviors and improved performance on one EF task relative to watching a video for an equivalent period of time.

Summary

To date, the limited experimental research suggests that exergaming can immediately enhance EF in normally developing youth and youth with ASD. It may be that certain types of exergames (e.g., ones that require competition) have a stronger impact than others; however, much more research is needed. One area of future research should include chronic exergaming studies. Currently, all studies with youth have been acute studies examining the immediate effects of exergaming on EF. (*Note:* Although Staiano and her colleagues had youth play exergames over 10 weeks, their experimental design prohibits teasing apart the chronic from the acute effects.) Whereas acute exergaming is expected to primarily have transient, immediate effects, chronic exergaming may have more robust, enduring benefits to EF. A study with older adults suggests this possibility. In this study (Anderson-Hanley et al., 2012), older adults who participated in 3 months of exergaming (cybercyling) achieved greater benefits to EF than older adults who participated in traditional stationary biking for an equivalent period of time. Moreover, cybercyclists had higher concentrations of plasma brain-derived neurotrophic factor following treatment, which is a protein that promotes neuroplasticity. Remarkably, the fitness gains were similar across the treatment and control groups, perhaps suggesting that the cognitive elements of exergaming confer benefits to EF and to brain health beyond the benefits provided by improved cardiovascular fitness (Best, 2010).

Conclusions

This review sought to address two questions: (1) can exergames be a viable tool to promote PA in youth? And (2) does exergaming benefit cognitive functioning in youth? Currently, it is not possible to answer either question conclusively. Rigorous experimental research on the physical and cognitive effects of exergaming is limited—especially in the realm of cognitive effects. Moreover, exergaming is a broad genre of gaming, and within this genre there is substantial variation in what types of movements are required and in the contents of the game. As noted above, the physical and cognitive effects likely depend on what type of exergame is being played. Finally, exergaming continues to evolve at a rapid pace, with new exergaming consoles and games being introduced all the time. Thus, these questions will continue to be germane and should be addressed with each advancement in exergaming.

These caveats aside, research does suggest that exergaming has the potential to benefit both physical and cognitive health. In fact, these seemingly disparate benefits may be more interrelated that one would think. Figure 1 presents a theoretical model, based on the research presented above, suggesting the mechanisms by which exergaming may benefit youth's physical and cognitive health, and how these domains may be interrelated. First, because exergaming can (but not always) elicit moderate-intensity PA, regular exergaming may increase regular PA, which could improve physical fitness. Engaging in regular PA, both directly and indirectly through increased fitness, may improve youth's EF (Best, 2010). Importantly, this model posits a positive feedback from improved EF back to increased PA. From a behavioral economic perspective (Epstein, et al., 2010), children with improved EF may make more thoughtful, future-oriented decisions based on delayed rewards, rather than immediate gratification. For example, children with high EF may choose to engage in PA, knowing the long-term benefits of doing so, rather than engage in sedentary activities. Second, to play exergames with the highest possible performance, youth need to execute motor movements in a controlled and coordinated fashion. Given the evidence of the close interconnections between the brain regions required for motor control and coordination (cerebellum) and those required for cognitive control (prefrontal cortex), as well as co-development of these regions (Diamond, 2000), this motor skill training may be important to fine motor control development as well as to EF development. Finally, through the action game and social elements—e.g., by requiring rapid decision-making and cognitive flexibility to compete successfully with peers—exergaming may provide cognitive training, which could transfer to EF.

Because exergaming has the potential to benefit physical and cognitive health in youth through multiple pathways, the most exciting exergaming research will involve collaborations amongst developmental and cognitive psychologists, kinesiologists, behavioral medical researchers, and game designers. Such collaborations will result in theoretically based research to determine what types of game elements are needed to positively impact physical and cognitive health, how gains in one domain affect the other, and what factors influence youth's choices between exergaming and engaging in other activities.

References

Anderson-Hanley C, Arciero PJ, Brickman AM, Nimon JP, Okuma N, Westen SC, Zimmerman EA. Exergaming and older adult cognition a cluster randomized clinical trial. American Journal of Preventive Medicine. 2012; 42(2):109–119. [PubMed: 22261206]

Anderson-Hanley C, Tureck Schneiderman. Autism and exergaming: effects on repetitive behaviors and cognition. Psychology Research and Behavior Management. 2011; 129:s24016.

Bailey BW, McInnis K. Energy cost of exergaming: A comparison of the energy cost of 6 forms of exergaming. Archives of Pediatrics and Adolescent Medicine. 2011; 2011:15.

Banich MT. Executive function: The search for an integrated account. Current Directions in Psychological Science. 2009; 18(i2):89–94.

Baranowski T, Abdelsamad D, Baranowski J, O'Connor TM, Thompson D, Barnett A, Chen T. Impact of an active video game on healthy children's physical activity. Pediatrics. 2012; 129:e636–e642. [PubMed: 22371457]

Baranowski T, Baranowski JC, O'Connor T, Lu AS, Thompson D. Is enhanced physical activity possible using active videogames? Games for Health: Research, Development, and Clinical Applications. 2012; 1:228–232.

Baranowski T, Frankel L. Let's get technical!: Gaming and technology for weight control and health promotion in children. Childhood Obesity. 2012; 8(1):34–37. [PubMed: 22799477]

Barnett A, Cerin E, Baranowski T. Active video games for youth: A systematic review. Journal of Physical Activity and Health. 2011; 8:724–737. [PubMed: 21734319]

Behrenshausen BG. Toward a (kin)esthetic of video gaming: The case of Dance Dance Revolution. Games and Culture. 2007; 2(4):335–354.

Best JR. Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. Developmental Review. 2010; 31:331–351. [PubMed: 21818169]

Best JR. Exergaming immediately enhances children's executive function. Developmental Psychology. 2012 *in press*.

Best JR, Theim KR, Gredysa DM, Stein RI, Saelens BE, Welch RR, Wilfley DE. Behavioral economic predictors of overweight children's weight loss. Journal of Consulting and Clinical Psychology. 2012 *in press*.

Biddiss E, Irwin J. Active video games to promote physical activity in children and youth: A systematic review. Archives of Pediatrics & Adolescent Medicine. 2010; 164:664–672. [PubMed: 20603468]

Carlson SM. Social origins of executive function development. New Directions in Child and Adolescent Development. 2009; 123:87–97.

Daley AJ. Can Exergaming contribute to improving physical activity levels and health outcomes in children? Pediatrics. 2009; 124(2):763–771. [PubMed: 19596728]

Decety J, Jackson PL, Sommerville JA, Chaminade T, Meltzoff AN. The neural bases of cooperation and competition: an fMRI investigation. NeuroImage. 2004; 23(2):744–751. [PubMed: 15488424]

Diamond A. Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. Child Development. 2000; 71:44–56. [PubMed: 10836557]

Epstein LH, Beecher MD, Graf JL, Roemmich JN. Choice of interactive dance and bicycle games in overweight and nonoverweight youth. Annals of Behavioral Medicine. 2007; 33:124–131. [PubMed: 17447864]

Epstein LH, Salvy SJ, Carr KA, Dearing KK, Bickel WK. Food reinforcement, delay discounting and obesity. Physiology & Behavior. 2010; 100:438–445. [PubMed: 20435052]

Errickson SP, Maloney AE, Thorpe D, Giuliani C, Rosenberg AM. "Dance Dance Revolution" used by 7- and 8-year-olds to boost physical activity: Is coaching necessary for adherence to an exercise prescription. Games for Health: Research, Development, and Clinical Applications. 2012; 1:45–50.

Fulton JE, Song M, Carroll DD, Lee SM. Active video game participation in U.S. youth: Findings from the National Youth Physical Activity and Nutrition Survey, 2010. Circulation. 2012; 125:AP260.

Graves LEF, Ridgers ND, Williams K, Stratton G, Atkinson G, Cable NT. The physiological cost and enjoyment of Wii Fit in adolescents, young adults, and older adults. Journal of Physical Activity and Health. 2010; 7:393–401. [PubMed: 20551497]

Green CS, Bavelier D. Action video game modifies visual selective attention. Nature. 2003; 423:534–537. [PubMed: 12774121]

Green CS, Bavelier D. Learning, attentional control, and action video games. Current Biology. 2012; 22(6):R197–R206. [PubMed: 22440805]

Greenfield PM, DeWinstanley P, Kilpatrick H, Kaye D. Action video games and informal education: Effects of strategies for dividing visual attention. Journal of Applied Developmental Psychology. 1994; 15:105–123.

Harlow HF. The formation of learning sets. Psychological Review. 1949; 56:51–65. [PubMed: 18124807]

Hillman CH, Buck SM, Themanson JR, Pontifex MB, Castelli DM. Aerobic fitness and cognitive development: Event-related brain potential and task performance indices of executive control in preadolescent children. Developmental Psychology. 2009; 45(1):114–129. [PubMed: 19209995]

Hillman CH, Erickson K, Kramer A. Be smart, exercise your heart: Exercise effects on brain and cognition. Nature Reviews Neuroscience. 2008; 9:58–65.

Juonala M, Magnussen CG, Berenson GS, Venn A, Burns TL, Sabin MA, Raitakari OT. Childhood adiposity, adult adiposity, and cardiovascular risk factors. New England Journal of Medicine. 2011; 365(20):1876–1885. [PubMed: 22087679]

Li R, Polat U, Makous W, Bavelier D. Enhancing the contrast sensitivity function through action video game training. Nature Neuroscience. 2009; 12(5):549–551.

Li Y, Dai Q, Jackson JC, Zhang J. Overweight is associated with decreased cognitive functioning among school-age children and adolescents. Obesity. 2008; 16(8):1809–1815. [PubMed: 18551126]

Lu AS, Thompson D, Baranowski JC, Buday R, Baranowski T. Story immersion in a health videogame for childhood obesity prevention. Games for Health: Research, Development, and Clinical Applications. 2012; 1:37–44.

Maddison R, Foley L, Ni Mhurchu C, Jiang Y, Jull A, Prapavessis H, Rodgers A. Effects of active video games on body composition: a randomized controlled trial. The American Journal of Clinical Nutrition. 2011; 94(1):156–163. [PubMed: 21562081]

Madsen KA, Yen S, Wlasiuk L, Newman TB, Lustig R. Feasibility of a dance videogame to promote weight loss among overweight children and adolescents. Archives of Pediatrics & Adolescent Medicine. 2007; 161:105–107. [PubMed: 17199076]

Miller, B.; Lamm, G. Microsoft Kinect for Xbox sales hit 18 million. TechFlash: Seattle's Technology News Source. 2012. Retrieved from http://www.techflash.com/seattle/2012/01/microsoft-kinect-for-xbox-sales-hit-18m.html

Penko AL, Barkley JE. Motivation and physiologic responses of playing a physically interactive video game relative to a sedentary alternative in children. [Comparative Study]. Annals of behavioral medicine : a publication of the Society of Behavioral Medicine. 2010; 39(2):162–169. [PubMed: 20169428]

Rueda MR, Fan J, McCandliss BD, Halparin JD, Gruber DB, Lercari LP, Posner MI. Development of attentional networks in childhood. Neuropsychologia. 2004; 42(8):1029–1040. [PubMed: 15093142]

Simonds J, Kieras J, Rueda M, Rothbart M. Effortful control, executive attention, and emotional regulation in 7-10-year-old children. Cognitive Development. 2007; 22(4):474–488.

Staiano AE, Abraham AA, Calvert SL. Competitive versus cooperative exergame play for African American adolescents' executive function skills: Short-term effects in a long-term training intervention. Developmental Psychology. 2012; 48(2):337–342. [PubMed: 22369339]

Staiano AE, Calvert SL. Exergames for physical education courses: Physical, social, and cognitive benefits. Child Development Perspectives. 2011; 5:93–98. [PubMed: 22563349]

Swinburn BA, Sacks G, Hall KD, McPherson K, Finegood DT, Moodie ML, Gortmaker SL. The global obesity pandemic: shaped by global drivers and local environments. The Lancet. 2011; 378(9793):804–814.

Taras H, Potts-Datema W. Obesity and student performance at school. Journal of School Health. 2005; 75:291–295. [PubMed: 16179079]

Tomporowski PD, Davis CL, Miller PH, Naglieri JA. Exercise and children's intelligence, cognition, and academic achievement. Educational Psychology Review. 2008; 20(2):111–131. [PubMed: 19777141]

Turner M. Repetive behavior in autism: A review of psychological research. Journal of Child Psychology and Psychiatry. 1999; 40:839–849. [PubMed: 10509879]

Vaynman S, Gomez-Pinilla F. Revenge of the "Sit": How lifestyle impacts neuronal and cognitive health through molecular systems that interface energy metabolism with neuronal plasticity. Journal of Neuroscience Research. 2006; 84(4):699–715. [PubMed: 16862541]

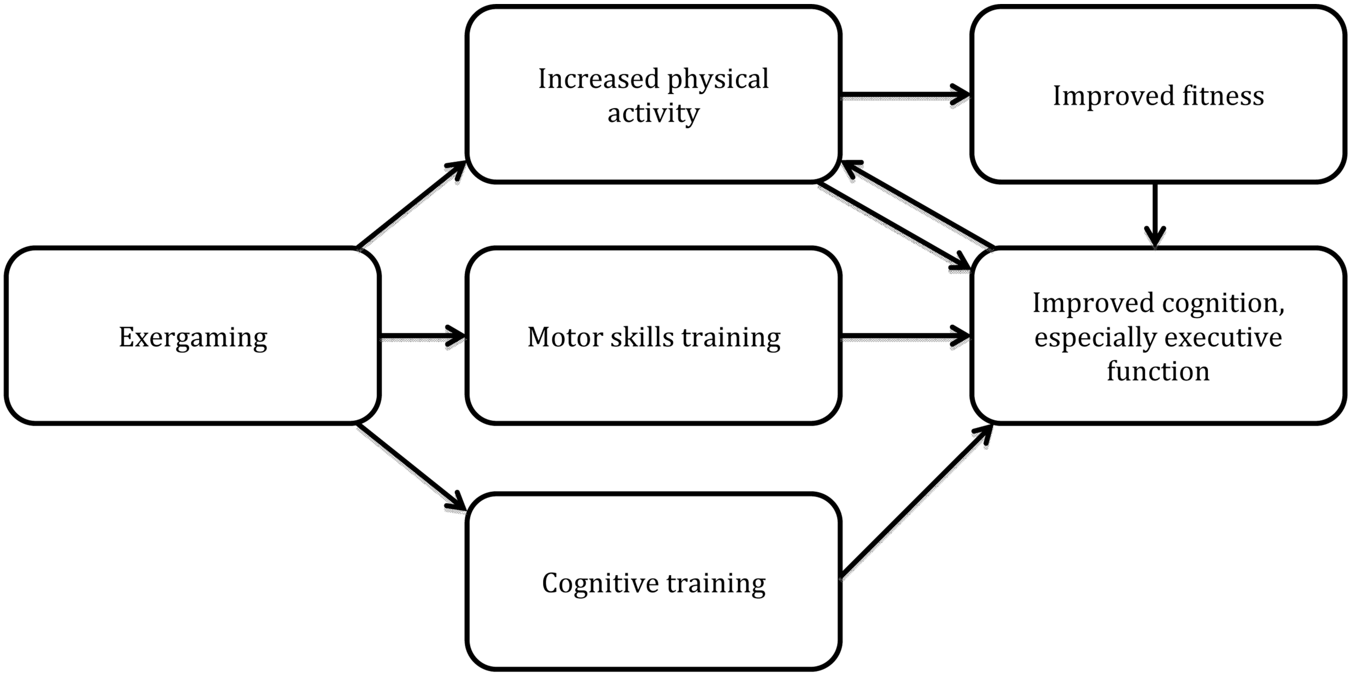

Figure 1.
A theoretical model of the mechanisms by which exergaming may benefit youth's physical and cognitive health.