Developmental Psychology
2012, Vol. 48, No. 2, 337–342

0012-1649/12/$12.00 DOI: 10.1037/a0026938

Competitive Versus Cooperative Exergame Play for African American Adolescents' Executive Function Skills: Short-Term Effects in a Long-Term Training Intervention

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Exergames are videogames that require gross motor activity, thereby combining gaming with physical activity. This study examined the role of competitive versus cooperative exergame play on short-term changes in executive function skills, following a 10-week exergame training intervention. Fifty-four low-income overweight and obese African American adolescents were randomly assigned to a competitive exergame condition, a cooperative exergame condition, or a no-play control group. Youths in the competitive exergame condition improved in executive function skills more than did those in the cooperative exergame condition and the no-play control group. Weight loss during the intervention was also significantly positively correlated with improved executive function skills. The findings link competitive exergame play to beneficial cognitive outcomes for at-risk ethnic minority adolescents.

Keywords: exergame, physical activity, executive function skills, competition, adolescents

U.S. children underperform academically on global standardized tests of mathematics and science (Miller, Sen, Malley, & Burns, 2009). Poor academic achievement is particularly prevalent for obese (Taras & Potts-Datema, 2005) and low-income African American youths (National Center for Education Statistics, 2007), and these youths are heavy consumers of media, including video games (Rideout, Foehr, & Roberts, 2010). Our purpose was to examine the short-term effects of playing exergames, which are video games that require gross motor activity (Staiano & Calvert, 2011), on overweight and obese adolescents' executive function skills within the context of a long-term intervention program.

Executive function skills include action inhibition and initiation, cognitive flexibility, and attention and sensory processing, thereby providing the building block for higher order thinking (Gazzaniga, Ivry, & Mangun, 2002). Executive function skills provide an important cognitive foundation for strong performance in mathematics and science (Latzman, Elkovitch, Young, & Clark, 2007). Unlike other cognitive abilities that mature in early childhood, executive function skills develop throughout adolescence (see Best & Miller, 2010). Experiences that improve adolescent executive function skills include traditional video game play (Greenfield, deWinstanley, Kilpatrick, & Kaye, 1994), physical activity (Hillman, Buck, Themanson, Pontifex, & Castelli, 2009), and competition (Decety, Jackson, Sommerville, Chaminade, & Meltzoff, 2004). We extend these findings by assessing if exergame play can improve at-risk overweight African American adolescents' short-term executive function skills after competitive or cooperative gaming experiences within the context of a longer term intervention program.

Greenfield (1984) was the first scholar to suggest that cognitive skills could be improved by video game play. Numerous subsequent studies, particularly training studies that compare action to nonaction games (e.g., Green & Bavelier, 2003), have demonstrated that playing video games improves spatial processing skills (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Subrahmanyam & Greenfield, 1994), visualization and acuity (Green & Bavelier, 2007; Okagaki & Frensch, 1994), and deployment of attention (Castel, Pratt, & Drummond, 2005; Green & Bavelier, 2003; Greenfield et al., 1994). Benefits in cognitive flexibility are also produced from video game play, including task-switching skills (Green & Bavelier, 2006), perceptual speed (Subrahmanyam & Greenfield, 1994), cognitive mapping (McClurg & Chaille, 1987), and three-dimensional rotation skills (Greenfield, Brannon, & Lohr, 1994; Okagaki & Frensch, 1994).

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We gratefully acknowledge Robert Wood Johnson Foundation Grant #66723 for its support of this research. We thank Amanda Terry, Kimberly Watson, and Patrick Scanlon for data collection and entry; Rusan Chen for his statistical guidance; and Coleen Lucas, Kirsten Hawkins, and the staff of the Wellness Clinic at H. D. Woodson High School in Washington, DC, for participant recruitment and data collection efforts.

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Gender differences in spatial skills have been linked to video game expertise (Greenfield et al., 1994). Training studies have demonstrated that both male and female participants improve in cognitive performance (Feng, Spence, & Pratt, 2007; McClurg & Chaille, 1987), with gender differences emerging primarily in complex mental rotation tasks (Okagaki & Frensch, 1994). One study found that female participants increased in mental rotation skills more than male participants did after a 4-week traditional video game training experience, but this may be because females began at a lower level of baseline performance (Feng et al., 2007). Even a brief 2¼-hr maze-based video-game intervention improved spatial skills among fifth-grade students, particularly the students who initially scored lower on these skills, who were also more likely to be girls (Subrahmanyam & Greenfield, 1994).

Aerobic activity, including training programs that require intense motor activity, also improves adolescents' executive function skills (Davis et al., 2007). For example, concentrated short-term aerobic activity increased executive function skills in preadolescent children, in part due to enhanced skills to regulate attentional control (Hillman, Pontiflex, Raine, Hall, & Kramer, 2009). Similarly, adolescents' cognitive skills of attention and concentration improved after 10 min of hand–eye motor coordination exercises (Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008).

Very little published evidence currently exists about the cognitive effects of exergame play on platforms such as Xbox Kinect or Nintendo Wii, or after playing movement-oriented exergames such as Dance Dance Revolution. One study found no effects of 20 min of aerobic exergaming on cognitive control measured by a modified flanker task (O'Leary, Pontifex, Scudder, Brown, & Hillman, 2011). Yet these new platforms and their games combine physical activity with video game experiences, thereby providing potential to improve executive function skills (Staiano & Calvert, 2011). Exergames do increase heart rates to levels of cardiorespiratory fitness and optimal aerobic exercise in adolescents and young adults (Höysniemi, Aula, Auvinen, Hönnikäinen, & Hämäläinen, 2004), including overweight adolescents (Unnithan, Houser, & Fernhall, 2006). Exergame play also produces caloric expenditure that meets standards for moderate intensity activity in adolescents and young adults (Graf, Pratt, Hester, & Short, 2009; Graves, Stratton, Ridgers, & Cable, 2007). Because exergames are very popular with youths (Rideout et al., 2010), they have unexplored potential to improve cognitive skills.

Gaming can involve competition and/or cooperation. Competition demands higher levels of executive function skills than cooperation does. For instance, the medial prefrontal cortex of young adults is activated by competition, but not by cooperation (Decety et al., 2004). Mentalizing the self and other within competitive game play, including predicting an opponent's actions, places demands on executive function skills (Decety et al., 2004). Cooperative actions are also slower and more carefully produced than competitive actions. For instance, the reach-to-grasp movement occurs faster when participants compete to place an object on a surface than when they cooperate to join two objects together (Georgiou, Becchio, Glover, & Castiello, 2007).

This study examined the short-term effects of playing the Nintendo Wii EA Sports Active exergame in competitive, cooperative, or no-play control conditions on the executive function skills of low-income African American overweight and obese students, following a 10-week exergame training intervention. Our hypotheses were as follows:

> *Hypothesis 1:* On the basis of the literature on videogame play (Greenfield et al., 1994) and aerobic exercise (Hillman, Pontiflex et al., 2009), we predicted that exergame play would improve executive function skills when compared with baseline scores and with the no-play control group.

> *Hypothesis 2:* On the basis of demands to mentalize the self and others and to predict others' actions to maximize the chances of winning (Decety et al., 2004), we predicted that competitive more so than cooperative exergame play would improve players' executive function skills over and beyond aerobic activity influences.

> *Hypothesis 3:* On the basis of improved cognitive outcomes from physical activity interventions (Davis et al., 2007), we predicted that weight loss during the exergame training intervention program would be significantly positively correlated with increases in executive function skills.

Method

Participants

Participants were 54 African American 15- to 19-year-old adolescents (*M* age = 16.46 years, 31 females), most of whom were overweight and obese. At baseline, participants had a mean weight of 95.64 kg, a mean body mass index (BMI) of 33.10, and a mean BMI percentile of 94.61. At Week 10 of training, participants had a mean weight of 95.02 kg, a mean BMI of 32.92, and a mean BMI percentile of 93.94. This study was part of a larger intervention program to treat obesity at a high school, located in a low-income inner city neighborhood in Washington, DC. We targeted obese, low-income African American youths because they are at risk for poor academic achievement (National Center for Education Statistics, 2007; Taras & Potts-Datema, 2005) and obesity (Ogden, Carroll, Curtin, Lamb, & Flegal, 2010), and spend large amounts of time playing video games (Rideout et al., 2010).

Participants were recruited from the school-based wellness center, by flyers posted at the school, and by word of mouth via teachers and peers. Within each gender group, students were randomly assigned to one of three conditions: competitive exergame play, cooperative exergame play, or a no-play control group.

Nintendo Wii EA Sports Active Exergame Treatment Conditions

The Nintendo Wii EA Sports Active exergame, marketed as an innovative fitness video game that helps players get in shape, involves routines of cardio, upper and lower body strength training, and sports games. Players must correctly position their legs and arms to successfully control their on-screen character. Controllers are held in the hand or placed in a leg strap to communicate player movement to the sensor bar placed beside the television screen. A resistance band is used in strength exercises. Players track progress by earning points and expending calories, in our case by competing individually against another player or by cooperating as a two-person team.

Measures

Delis–Kaplan Executive Function System (D–KEFS). The D–KEFS is a paper-and-pencil measure consisting of nine subscales that assesses performance of the frontal system of the brain, which controls executive function skills (Delis, Kaplan, & Kramer, 2001). The D–KEFS has been validated against other gold standard cognitive tests, including the Wisconsin Card Sorting Test, and its test–retest reliability ranges from .62 to .80 (Homack, Lee, & Riccio, 2005).

Because of the kinds of cognitive skills that have improved after traditional video game play (e.g., visual–spatial skills, visual acuity, visualization, task switching, perceptual speed), we administered the two D–KEFS subscales of Design Fluency and Trail Making. The Design Fluency and Trail-Making subscales measure visual–spatial skills, response inhibition, motor planning, visual scanning, speed, and cognitive flexibility. In the Design Fluency subscale, the participant connects dots to design as many novel shapes as possible. Each subtest contains 35 boxes that are filled with dots. The participant is asked to connect four lines and draw a different design in each box. For example, the Switching subtest, which measures design fluency, visual scanning, and cognitive flexibility, involves squares with 10 dots (five filled dots and five empty dots). The participant must connect the dots, alternating between empty and filled. The Design Fluency score is the total number of novel designs drawn. In the Trail Making subscale, the participant connects letters or numbers in five random arrays. For example, the Number–Letter Switching subtest, which is a key measure of executive function skills, asks the participant to draw a line to connect the numbers numerically and the letters alphabetically, switching each time from a number to a letter (e.g., 1–A–2–B). Design Fluency and Trail-Making subscores were summed to create a total D–KEFS score.

In this study, two research assistants coded the cognitive tests. A third research assistant double-coded all tests. Interrater reliability, calculated as Cronbach's alpha, was $\alpha = .971$ at baseline and $\alpha = .965$ at treatment for Design Fluency scores, and $\alpha = .949$ at baseline and $\alpha = .978$ at treatment for Trail-Making scores.

Procedure

At baseline, each participant completed the D–KEFS cognitive tests in a group setting. One of three trained experimenters read the directions aloud and timed each subtest. A practice trial preceded each subtest. Each participant then had 30 s to complete the visual scanning subtest and 60 s to complete each of the other subtests. Participants were instructed to work as quickly and accurately as possible.

After baseline measures were collected, participants in the Nintendo Wii EA Sports Active exergame training conditions played in competitive or cooperative conditions for an average of 10 weeks to examine the potential of exergame play for weight loss. Each session lasted approximately 30 min and occurred either after school or during part of the lunch break. Sessions were available every school day (i.e., up to 5 days per week) throughout the intervention program. On average, exergame condition participants attended 10.6 (SD = 5.1) sessions during the 10-week training program, which averages one exergame play session per week.

During training, both treatment groups participated in the same Wii EA Sports Active exergame routines. Youths typically played with a peer, with the pair structure varied over time. Youths in the competitive condition were encouraged to win by earning the top score and by expending the most calories each time they played. Those in the cooperative condition were encouraged to play with their teammate to earn the highest possible score and to expend the most calories as a pair. Players in the competitive condition were told to compare their fitness progress with others, whereas those in the cooperative condition were told to work together to progress as teams. Youths in the no-play control group continued their typical activities.

After 10 weeks of training, we assessed short-term exergame effects on cognitive skills. Students in the Wii treatment conditions first played an exergame circuit workout routine of cardio and sports games in their respective cooperative or competitive conditions. Caloric expenditure, which was recorded by a triaxial accelerometer integrated into the Nintendo Wii system, averaged 100.90 kCal (range = 52.00 kCal to 259.80 kCal). Duration of play, which averaged 15.50 min, was also recorded by the Wii system.

We tested participants on the D–KEFS immediately after treatment because aerobic activity should have its greatest impact on cognitive skills when students are most likely to be aroused and alert. For the no-play control group, the D–KEFS was administered after adolescents had been seated for approximately 5 min, as is typically done in a school testing situation. Cognitive tests took approximately 15 min to complete for all participants at both baseline and treatment assessments.

Results

Delis–Kaplan Executive Function System (D–KEFS) Scores

To assess any potential executive function differences at baseline, we conducted a 3 (condition) × 2 (gender) analysis of variance (ANOVA) with the baseline total D–KEFS executive function score as the dependent variable. There were no significant baseline condition ($p = .202$) or gender ($p = .817$) differences.

Difference scores were created by subtracting the total D–KEFS scores at baseline from the short-term total D–KEFS scores after 10 weeks of treatment. These difference scores were examined using a 3 (condition: competitive exergame, cooperative exergame, or no-play control group) × 2 (gender) ANOVA with treatment and gender as between-subjects independent variables and the difference scores as the dependent measure.

The two-factor ANOVA computed on total D–KEFS difference scores yielded a significant main effect of condition, $F(1, 48) = 4.137$, $p = .022$, partial $\eta^2 = .147$. Simple planned contrasts revealed that youths in the competitive exergame condition improved in D–KEFS total scores significantly more than did those in either the cooperative exergame condition, $F(1, 35) = 5.956$, $p = .020$, partial $\eta^2 = .145$, or the no-play control group, $F(1, 35) = 6.122$, $p = .018$, partial $\eta^2 = .149$. There was no significant difference in total D–KEFS difference scores for youths in the cooperative exergame condition and the no-play control group ($p = .429$). Youths in the competitive exergame condition improved their total D–KEFS scores by an average of 15.40 points ($SD = 12.21$), versus 6.59 points ($SD = 9.23$) for those in the cooperative exergame condition, and 2.41 points ($SD = 19.42$) for those in the no-play control group.

Long-Term Weight Change and Executive Function Skills

To determine whether there was a longer term effect of weight loss on executive function skill improvement, Pearson product–moment correlations were computed between weight loss over 10 weeks and improvement in D–KEFS scores. For the competitive group, there was a significant positive correlation between weight loss and improvements in D–KEFS total scores ($r = .479$, $p = .038$). For the cooperative and no-play control groups, there were no significant correlations between weight loss and changes in D–KEFS scores.

Discussion

This study examined the short-term effects of competitive versus cooperative exergame play on overweight and obese African American adolescents' executive function skills, following a 10-week exergame training intervention. These executive function skills included task switching, speed of visual search, attention, visual–motor function, temporal sequencing, and mental flexibility.

Our first hypothesis was that youths in the competitive and cooperative exergame conditions would increase in executive function skills more than would the no-play control group due to aerobic activity immediately before treatment tests occurred. This prediction was partially supported. As predicted, youths who played the exergames competitively for 15 min improved in executive function skills more than did those in the no-play control group. When compared with baseline scores, adolescents in the competitive condition increased their total D–KEFS scores 7 times more than did the no-play control group. Contrary to prediction, however, participants in the cooperative condition did not perform significantly better than did those in the no-play control group for the executive function test.

Our second hypothesis was that youths in the competitive exergame condition would perform better than those in the cooperative exergame condition because of increased demands of competition on the prefrontal cortex to mentalize the self and other in order to win (Decety et al., 2004). That prediction was fully supported. Youths in the competitive condition scored twice as well on executive functioning as those in the cooperative condition when compared with their baseline scores. The much stronger effects of competition versus cooperation for improved executive function skills suggest that competition may be a key factor for improved skills.

Our third hypothesis was that adolescents who lost weight during the exergame intervention would increase in executive function skills. As expected, those in the competitive group demonstrated a long-term relationship between weight loss and improved executive function skills. However, this finding did not emerge for those in the cooperative exergame condition. This beneficial finding for competitive exergame play is particularly encouraging because many overweight and obese youth underperform academically (Taras & Potts-Datema, 2005).

Most prior video game studies that yielded improvements in executive function skills compared action games, such as first-person shooter games in which peripheral attention skills are activated to kill targets and to avoid being killed, to less violent nonaction games (see Feng et al., 2007; Green & Bavelier, 2003, 2006); therefore, the gaming content was not similar across conditions. Moreover, action games typically involve violent content, a risk factor for antisocial behavior (Calvert, 1999). A major strength of our study is that executive function skills in at-risk overweight African American adolescents increased when the same nonviolent content was used in both exergame conditions on the cognitive assessment day and throughout the intervention program. Specifically, the content involved simulated sports games that required participants to inhibit and initiate actions, attend to the screen, and process sensory information, which directly relate to executive function skills. Adolescents' executive function skills improved just by playing the games competitively. Playing competitive exergames, therefore, may provide a way to develop executive function skills for adolescents who may be less interested in more traditional school-based approaches to cognitive skill development.

Both male and female adolescents benefited from competitive exergame play for the total D–KEFS scores. Males generally perform better on visual–spatial and cognitive flexibility tasks (Linn & Petersen, 1985) particularly during adolescence (Liben, 2006), participate in competitive sports more than female adolescents do (Centers for Disease Control and Prevention, 2010), and prefer competition, whereas female adolescents prefer cooperation (Ahlgren & Johnson, 1979; Gill, 1988). Therefore, our results hold promise for minority female adolescents to keep up with their male peers during a critical time when executive function skills are developing and maturing (Best & Miller, 2010).

A major limitation of this study is that executive function skills at Week 10 were assessed immediately following exergame play for the competitive and cooperative participants, so it is impossible to know whether the executive function skill improvements were from the most recent exergaming session or from the accumulation of training and physical activity during the 10-week training period, or from both. The correlation with longer term weight loss and exergame play in the competitive condition suggests that there may be long-term influences as well as short-term ones. Even so, documenting short-term effects within the longer term training program sets the stage for future research that can separate these two possible areas of influence. An additional limitation is the lack of neural imaging data that could link prefrontal cortex brain activity to competitive versus cooperative exergame play. Our results also may not generalize beyond overweight, low-income, African American youth, though this group is clearly at risk for scholastic underperformance (National Center for Education Statistics, 2007). Future research should examine these issues as well as explore whether these findings for the Nintendo Wii EA Sports Active game generalize to exergames on other platforms, such as the Xbox Kinect.

In conclusion, Greenfield (1984) first proposed that video games provide an informal context for learning in which youths can develop important cognitive skills. Because exergame play is a popular activity that combines physical movement and competition, rich potential exists for adolescents to inadvertently develop essential executive function skills that are crucial for academic success.

References

Ahlgren, A., & Johnson, D. W. (1979). Sex differences in cooperative and competitive attitudes from the 2nd through the 12th grades. *Developmental Psychology, 15,* 45–49. doi:10.1037/h0078076

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81,* 1641–1660. doi:10.1111/j.1467-8624.2010.01499.x

Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M., & Gratton, G. (2008). The effects of video game playing on attention, memory, and executive control. *Acta Psychologica, 129,* 387–398. doi:10.1016/j.actpsy.2008.09.005

Budde, H., Voelcker-Rehage, C., Pietrabyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience Letters, 441,* 219–223. doi:10.1016/j.neulet.2008.06.024

Calvert, S. L. (1999). *Children's journeys through the information highway.* Boston, MA: McGraw Hill.

Castel, A. D., Pratt, J., & Drummond, E. (2005). The effects of video game experience on the time course of inhibition of return and the efficiency of visual search. *Acta Psychologica, 119,* 217–230. doi:10.1016/j.actpsy.2005.02.004

Centers for Disease Control and Prevention. (2010, June 4). Youth risk behavior surveillance—United States, 2009. *MMWR: Morbidity and Mortality Weekly Report, 59*(SS-5). Atlanta, GA: U.S. Department of Health and Human Services.

Davis, C. L., Tomporowski, P. D., Boyle, C. A., Waller, J. L., Miller, P. H., Naglieri, J. A., & Gregoski, M. (2007). Effects of aerobic exercise on overweight children's cognitive functioning: A randomized controlled trial. *Research Quarterly for Exercise and Sport, 78,* 510–519.

Decety, J., Jackson, P. L., Sommerville, J. A., Chaminade, T., & Meltzoff, A. N. (2004). The neural bases of cooperation and competition: An fMRI investigation. *NeuroImage, 23,* 744–751. doi:10.1016/j.neuroimage.2004.05.025

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis–Kaplan Executive Function System examiner's manual.* San Antonio, TX: Pearson.

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological Science, 18,* 850–855. doi:10.1111/j.1467-9280.2007.01990.x

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2002). *Cognitive neuroscience: The biology of the mind* (2nd ed.). New York, NY: Norton.

Georgiou, I., Becchio, C., Glover, S., & Castiello, U. (2007). Different action patterns for cooperative and competitive behavior. *Cognition, 102,* 415–433. doi:10.1016/j.cognition.2006.01.008

Gill, D. L. (1988). Gender differences in competitive orientation and sport participation. *International Journal of Sport Psychology, 19,* 145–159.

Graf, D. L., Pratt, L. V., Hester, C. N., & Short, K. R. (2009). Playing active video games increases energy expenditure in children. *Pediatrics, 124,* 534–540. doi:10.1542/peds.2008-2851

Graves, L., Stratton, G., Ridgers, N. D., & Cable, N. T. (2007). Comparison of energy expenditure in adolescents when playing new generation and sedentary computer games: Cross-sectional study. *British Medical Journal, 335,* 1282–1284. doi:10.1136/bmj.39415.632951.80

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423,* 534–537. doi:10.1038/nature01647

Green, C. S., & Bavelier, D. (2006). Effect of action video games on the spatial distribution of visuospatial attention. *Journal of Experimental Psychology: Human Perception and Performance, 32,* 1465–1478. doi:10.1037/0096-1523.32.6.1465

Green, C. S., & Bavelier, D. (2007). Action video game experience alters the spatial resolution of vision. *Psychological Science, 18,* 88–94. doi:10.1111/j.1467-9280.2007.01853.x

Greenfield, P. M. (1984). *Mind and media: The effects of television, video games, and computers.* Cambridge, MA: Harvard University Press.

Greenfield, P. M., Brannon, C., & Lohr, D. (1994). Two-dimensional representation of movement through three-dimensional space: The role of video game expertise. *Journal of Applied Developmental Psychology, 15,* 87–103. doi:10.1016/0193-3973(94)90007-8

Greenfield, P. M., deWinstanley, P., Kilpatrick, H., & Kaye, D. (1994). Action video games and informal education: Effects on strategies for dividing visual attention. *Journal of Applied Developmental Psychology, 15,* 105–123. doi:10.1016/0193-3973(94)90008-6

Hillman, C. H., Buck, S. M., Themanson, J. R., Pontifex, M. B., & Castelli, D. M. (2009). Aerobic fitness and cognitive development: Event-related brain potential and task performance indices of executive control in preadolescent children. *Developmental Psychology, 45,* 114–129. doi:10.1037/a0014437

Hillman, C. H., Pontifex, L. B., Raine, D. M., Hall, E. E., & Kramer, A. F. (2009). The effect of short-term treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience, 159,* 1044–1054. doi:10.1016/j.neuroscience.2009.01.057

Homack, S., Lee, D., & Riccio, C. A. (2005). Test review: Delis–Kaplan Executive Function System. *Journal of Clinical and Experimental Neuropsychology, 27,* 599–609. doi:10.1080/13803390490918444

Höysniemi, J., Aula, A., Auvinen, P., Hönniköinen, J., & Hömölöinen, P. (2004). Shadow boxer: A physically interactive fitness game. *Nordic Conference on Human–Computer Interaction, 82,* 389–392. doi:10.1145/1028014.1028077

Latzman, R. D., Elkovitch, N., Young, J., & Clark, L. A. (2010). The contribution of executive functioning to academic achievement among male adolescents. *Journal of Clinical and Experimental Neuropsychology, 32,* 455–462. doi:10.1080/13803390903164363

Liben, L. S. (2006). Education for spatial thinking. In W. Damon & R. M. Lerner (Eds.), *Handbook of child psychology: Child psychology in practice* (pp. 197–247). Hoboken, NJ: Wiley. doi:10.1002/9780470147658.chpsy0406

Linn, M. C., & Petersen, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development, 56,* 1479–1498. doi:10.2307/1130467 doi:10.2307/1130467

McClurg, P. A., & Chaille, C. (1987). Computer games: Environments for developing spatial cognition? *Journal of Educational Computing Research, 3,* 95–111.

Miller, D. C., Sen, A., Malley, L. B., & Burns, S. D. (2009). *Comparative indicators of education in the United States and other G-8 countries: 2009*. Washington, DC: National Center for Education Statistics (NCES Publication No. 2009–039).

National Center for Education Statistics. (2007). *Digest of education statistics: 2006.* Washington, DC: Author. Retrieved July 14, 2010, from http://nces.ed.gov/programs/digest/d06/tables/dt06_131.asp?referrer=list

Ogden, C. L., Carroll, M. D., Curtin, L. R., Lamb, M. M., & Flegal, K. M. (2010). Prevalence of high body mass index in U.S. children and adolescents, 2007–2008. *JAMA: Journal of the American Medical Association, 303,* 242–249. doi:10.1001/jama.2009.2012

Okagaki, L., & Frensch, P. A. (1994). Effects of video game playing on measures of spatial performance: Gender effects in late adolescence. *Journal of Applied Developmental Psychology, 15,* 33–58. doi:10.1016/0193-3973(94)90005-1

O'Leary, K. C., Pontifex, M. B., Scudder, M. R., Brown, M. L., & Hillman, C. H. (2011). The effects of single bouts of aerobic exercise, exergaming, and video-game play on cognitive control. *Clinical Neurophysiology, 122,* 1518–1525. doi:10.1016/j.clinph.2011.01.049

Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). *Generation M2: Media in the lives of 8- to 18-year-olds:* Report from the Kaiser Family Foundation. Retrieved July 14, 2010, from http://www.kff.org/entmedia/upload/8010.pdf

Staiano, A. E., & Calvert, S. L. (2011). Exergames for physical education courses: Physical, social, and cognitive benefits. *Child Development Perspectives, 5,* 93–98. doi:10.1111/j.1750-8606.2011.00162.x

Subrahmanyam, K., & Greenfield, P. M. (1994). Effect of video game practice on spatial skills in girls and boys. *Journal of Applied Developmental Psychology, 15,* 13–32. doi:10.1016/0193-3973(94)90004-3

Taras, H., & Potts-Datema, W. (2005). Obesity and student performance at school. *Journal of School Health, 75,* 291–295. doi:10.1111/j.1746-1561.2005.tb07346.x

Unnithan, V. B., Houser, W., & Fernhall, B. (2006). Evaluation of the energy cost of playing a dance simulation video game in overweight and non-overweight children and adolescents. *International Journal of Sports Medicine, 27,* 804–809. doi:10.1055/s-2005-872964

Received July 27, 2010
Revision received September 27, 2011
Accepted November 14, 2011 ■