

Original article

Impact of an active educational video game on children's motivation, science knowledge, and physical activity

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Abstract

Background: Active educational video games (AVGs) appear to have a positive effect on elementary school students' motivation leading to enhanced learning outcomes. The purpose of this study was to identify the effectiveness of an AVG on elementary school students' science knowledge learning, physical activity (PA) level, and interest-based motivation.

Methods: In this randomized controlled study, 53 elementary school students were assigned to an experimental condition or a comparison condition. The experimental condition provided an AVG learning environment, whereas the comparison condition was based on sedentary educational video games.

Results: The results of repeated measures analysis of variance (ANOVA) on the knowledge test showed that students in both groups performed better on the post-test than they did on the pre-test ($p < 0.001$, $\eta^2 = 0.486$), and their post-test scores did not differ significantly. The experimental condition provided a more active environment since the students' average heart rates (HRs) were in the Target-Heart-Rate-Zone (HR = 134 bpm), which was significantly higher than the average HR (103 bpm) from the comparison condition ($t = 7.212$, $p < 0.001$). Students in the experimental condition perceived a higher level of situational interest than their counterparts in the comparison group ($p < 0.01$, and $\eta^2 = 0.301$).

Conclusion: These results suggest that AVGs benefit children more in terms of PA and motivation than traditional video games by providing an enjoyable learning experience and sufficient PA.

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Keywords: Educational video game; Exergame; Heart rate; Intensity; Interest

1. Introduction

The guidelines for physical activity (PA) for children aged 5–12 by the U.S. National Association for Sport and Physical Education (NASPE) recommend that American children should accumulate at least 60 min daily, on all or most days of the week, in several bouts of PA lasting 15 min or more each day.¹ However, research has indicated that many children are not meeting the recommended guidelines for PA.^{2,3} The rising rates of obesity and the decrease in PA levels affect youth across the nation. It is estimated that the obesity rate has

tripled since 1980 among youth aged 6–11.⁴ Childhood obesity has detrimental long-term effects, since 40%–70% of obese children will grow into obese adults.⁵ Many factors (e.g., excess caloric intake, inadequate amount of PA, or sedentary lifestyles) have been implicated as contributors to this obesity crisis.

School has been regarded as a unique venue for promoting PA in youth, since more than 55 million children attend public or private schools and spend approximately 6–7 h at school every day.⁶ Although school can be an ideal setting for providing opportunities for children to participate and enjoy PA, physical education (PE) classes, recess, and other PA breaks have decreased because many schools are increasing the instructional time for science, mathematics, and reading in order to improve students' standards-based test scores. In this

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regard, schools have become a place where sedentary activities are inevitable.⁷ Given the important role of school, a growing body of research focusing on the association between PA and academic achievement has also singled out schools as a key setting where PA interventions can be structured to benefit cognitive functioning.⁸ A recent systematic literature review conducted by the Centers for Disease Control and Prevention (CDC) summarizing 23 years of research on the associations between PA and academic achievement⁸ indicates an overwhelmingly positive PA-achievement association among elementary children. Among the studies reviewed, 43% reported a positive PA-achievement association, 56% were neutral, and only 1% were negative. This pattern of association is also supported by other published reviews.^{9,10} For example, a recent review of 125 studies suggested that an overwhelming majority of studies reported positive associations between PA and cognition, executive functions, and academic achievement.⁹ However, it has to be pointed out that this evidence was mostly based on correlational studies. Thus, the causative effects of PA on academic achievement can be challenged. Therefore, it is necessary to examine the effect of PA on achievement/learning using rigorous and robust research designs, such as randomized, controlled experiments.

It is not difficult for one to recognize the natural connection between physical movement and cognitive engagement in video games that children love to play. The environment created by a video game is clearly suitable for research on PA-cognitive functioning/learning associations. The new generation of video game consoles include activity-promoting games (active video game, AVG) that require children to put in a high volume of body movement in association with the usual cognitive functioning tasks while playing. Limited research on effects of these games has shown that AVGs can increase energy expenditure as compared to sedentary video games.¹¹ Although a small number of AVGs have been identified as providing moderate-intensity activity in youth,¹² studies suggest that most AVGs could only elicit light-to-moderate-intensity PA.^{13–15} Research evidence summarized in a meta-analysis indicated that AVGs elicited higher energy expenditure in children than adults; thus, playing AVGs particularly benefits children.¹⁵

Recognizing their potential to increase energy expenditure and promote PA among children, researchers have attempted to implement AVGs in the school setting, including recess and PE. Findings from one study on recess ($n = 30$) suggested that AVGs appeared to accumulate greater steps per day than “traditional” recess activity during the first week of intervention.¹⁶ However, this pattern was reversed by the mid and end points of the intervention. The researchers suggested that AVGs have an acute but unsustainable effect on children’s PA during recess.¹⁶ In PE, a series of studies following a group of children over 2 semesters in PE^{17,18} revealed that AVGs in a structured instructional setting did not generate the desired moderate-to-vigorous level of PA. Nevertheless, in-class PA intensity was significantly higher in the second semester than in the first semester for students who were novice AVGs players.

Although the benefits from AVGs on PA intensity and energy expenditure have been extensively studied, research that focuses on the association between AVGs and academic achievements is rather sparse. The first study investigating such associations employed a repeated-measures crossover design to identify the impact of Dance Dance Revolution (DDR) on Latino children’s physical fitness and academic achievement.¹⁹ Children in the intervention group participated in a 30-min, structured DDR-based exercise program 3 times per week at school. The findings suggested that children in the intervention condition demonstrated greater improvement than children in the control condition on a 1-mile run test across time (effect estimate = -1.5). More importantly, the results showed that the intervention group children displayed greater improvements on their math test scores than comparison group children overtime (effect estimate = 0.67). In addition, there was also a trend for increased reading scores in the intervention group children overtime, although this did not reach statistical significance. That study provided empirical evidence that AVGs such as DDR may not only improve children’s cardiorespiratory fitness, but also have the potential to enhance their academic achievements in school. These findings are promising, and also call for more studies along this line to accumulate evidence that will help draw a definitive conclusion.

There is little doubt that AVGs have the potential to motivate children to become active players. Although research on the effectiveness of using AVGs to motivate users to engage in PA is still in the early stages,²⁰ the motivational effect of AVGs has been revealed in a number of studies.^{17,18,21,22} For example, one study found that AVGs can exert strong attractive characteristics capable of inducing a high level of situational interest (SI),¹⁷ which is defined as the appealing effect characteristic of an activity on individuals.²³ SI derives from a person-activity interaction in which the person is perceiving the appealing characteristics of the activity.²⁴ Previous studies used multi-sample designs to investigate students’ perceptions of SI in different PAs, and found that high novelty, high attention demand, intensive exploration opportunity, instant enjoyment, and moderate physical challenge were key elements for an activity to be situationally motivating.^{25,26} In AVG research, one study examined the effect of AVGs on elementary children’s ($n = 78$) in-class PA level. In that study, students in the fourth grade experienced a 4-week AVG unit and a 4-week traditional fitness unit. It was reported that students rated all SI source dimensions higher for an AVG unit than for the traditional fitness unit.¹⁷

Educational video games have been incorporated into the learning process in order to provide motivating and meaningful learning experiences. For example, one study evaluated the effectiveness of a concept map-embedded gaming approach for developing educational computer games in an elementary school natural science course, and reported that embedding concept maps in game situations could not only improve the learner’s achievement, but also decrease their cognitive load.²⁷

Based on a review of the previous findings described above, the current study was designed to answer the following ques-

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