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# Impact of an Active Educational Video Game on Children's Motivation, Science Knowledge, and Physical Activity

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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.


*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 inveitable.[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 achievement[8] 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 multisample 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 questions: a) to what extent would a student's performance on science knowledge tests differ between the treatment group with an AVG versus the comparison group with a sedentary video game; b) to what extent would a student's PA intensity level differ between the 2 groups; and c) to what extent would a student's perceived SI differ between the 2 groups. We hypothesized that: a) a student's performance on science knowledge tests in the treatment group would be better than that in the comparison group; b) a student's PA intensity level in the treatment group would be higher than that in the comparison group; and c) students in the treatment group would perceive a higher level of SI than those in the comparison group.

## 2. Methods

### *2.1. Research design and experimental/comparison conditions*

A randomized-control comparison design was used in this study. The experimental condition was structured on an AVG. In contrast, the comparison condition used the same educational video game without the required activity portion. The content of the video game was identical for both conditions, which is called: "Earth, Moon, and Sun (EMS)— an interactive learning experience" (http://www.earthsunmoon.co.uk/). In the game, students are expected to explore the EMS, and learn scientific knowledge about the solar system. For example, during the exploration on the Earth, students learn that the Earth takes 365 days to orbit the Sun and an orbit is the path an object takes through space around another object. They watch the animated Earth on its continuous orbiting movement around the Sun and the year change. On the Moon, students learn that the Moon appears to shine at night and that moonlight actually is a reflection of sunlight. In addition, students would know that the reason that the Moon appears to change shape is because the position of the Moon and the Sun's reflection on it keeps changing. It takes approximately 20–25 min to play this game.

The game played by the students in the experimental condition was attached to the Gamercize® GZ Pro-Sport™ stepper (Gamercize, Southampton, UK). The stepper was connected to a computer, and functioned as the controlling device for gameplay. In other words, the game will continue as long as the player exercises by continuously stepping, and will pause when the player stops stepping. In order to continue playing the game, the player needs to exercise throughout the entire gameplay period. In this study, the height of the stepper was also adjusted appropriately for the height of the elementary school students.

### *2.2. Participants*

Before any participants were recruited, the study was approved by the University of South Florida Institutional Review Board. Students in the 3rd, 4th, and 5th grades from a local elementary school were invited to participate in this study. As the result of the recruitment, 53 (31 males, 22 females) students returned their parent/guardian permission forms. Among these students, 75.5% were African Americans, 9.4% Latinos, 3.8% Caucasians, 5.7% Asian Americans, and 5.4% multiracial Americans. These students were then randomly assigned within grade to either the experimental or comparison condition (e.g., if there were 2 third graders, 1 was randomly assigned to the experimental group and 1 was assigned to the comparison group).

### *2.3. Instruments*

#### *2.3.1. Science knowledge*

The students' knowledge about the Earth, Sun, and Moon was assessed using a standardized knowledge test. The content validity of the questions and the age/grade appropriateness of the content, as well as the wording/vocabularies used in the test construction, were determined by the researchers and the school science teacher. A known-group method was used to further generate validity evidence for each question.[28] The index of difficulty (ID) and the index of discrimination (net D) were computed by contrasting the responses to each question by the 2 groups of students. The selection of questions was based on typically-recommended standards as follows: questions with ID between 40% and 60% were determined as "usable"; those between 45% and 55% as "must-use"; those out of these ranges were determined as "unusable".[28] A 40% threshold was set for the net D. Specifically, those questions between 40% and 60% were classified as "usable"; above 60% as "must use"; and those below 40% as "unusable". A total of 10 questions met both standards. Ten questions were then selected for use and attached with a multiple-choice format. A correct answer was assigned a score of 1, and incorrect choices were assigned a score of 0. The maximum possible score a student could earn is 10. The total score represents the performance on the test and, consequently, signifies how much a student knows about the content.

#### *2.3.2. PA intensity level*

The student's PA level during gameplay was measured using Polar RS400 (Polar Electro Inc., Lake Success, NY, USA) heart rate (HR) monitors. The maximum HR ($HR_{max}$) was calculated using the formula recommended by Tanaka et al.: $HR_{max} = 208 - (0.7 \times \text{age})$.[29] The following criteria were used to determine the intensity level: an intensity of 55%–65% $HR_{max}$ for low PA level (110–130 bpm for this age of students in the current study), 65%–75% $HR_{max}$ for moderate PA level (130–150 bpm), and 75%–90% $HR_{max}$ for vigorous level (150–180 bpm).

#### *2.3.3. SI*

SI was measured using the 15-item Situational Interest Scale–Elementary School.[30] This scale measures elementary PE students' responses to SI in the PAs they are experiencing. The 15 items include 5 dimensional sources of the SI construct: Attention Demand, Challenge, Exploration Intention, Instant Enjoyment, and Novelty. The items are randomly arranged, and each is attached to a 4-choice descriptor representing a 4-point Likert type interval scaling. For example, an item for the Instant Enjoyment dimension is: "The game I just played was . . ." with descriptor choices of "Very exciting", "Somewhat exciting", "Rather dull", or "Very dull" scaled as

4, 3, 2, and 1 for data analysis. This scale has been determined to be useful, with strong evidence for content and construct validity (factor loading ranging from 0.78 to 0.99).[25,30] The internal consistency reliability has been reported to be acceptable in previous studies (Cronbach $\alpha$ coefficient ranging from 0.78 to 0.95).[25,30]

### 2.4. Procedure

The data were collected at the elementary school's media center. There were 20 computers at the media center that allowed for 20 students to play the game simultaneously. Students were taken to the media center from the classroom during non-academic time, and returned to their homeroom after they finished the game. The researchers established the testing protocols, and provided training to 2 data collectors in order to minimize any discrepancies that might result from different data collectors. The data collection lasted for 2 weeks, during which time the students finished 3 practices of gameplay with a 3-day interval between the practices. Before each practice, the data collection protocols were reviewed by the research team to ensure that the protocol was followed faithfully.

The students' knowledge was pre- and post-measured. The pre-test was conducted before the intervention started, and the post-test was administered after the students finished their third practice of the game. The HR data were collected during each practice. Before the students started playing the game, the research team set up the HR monitor for each individual student, and helped the students to put on their transmitter and receiver. SI was measured immediately after the students finished their first practice of gameplay.

To ensure the independence of the students' responses during data collection, the data collectors instructed the students to take the knowledge test and SI instrument individually and truthfully. The data collectors read all items on the SI and knowledge test to the students, and answered any questions from the students. All students were informed that their teachers would not have access to their individual responses, and would not use their responses for grading purposes.

### 2.5. Data analysis

The responses to the SI scale were coded and aggregated according to the dimensions of Novelty, Attention Demand, Exploration, Challenge, and Instant Enjoyment. The knowledge test scores were calculated based on the correct answers. Descriptive analysis was performed to compute the means, standard deviations, and internal reliability of each measure. Then correlation analysis was performed to assess the associations among SI, science knowledge, and PA intensity. A mixed 2 (treatment/comparison) by 2 (pre–post) repeated measures ANOVA on the knowledge test was performed to determine the main effect of the Treatment, Time, and the Treatment × Time interaction. An independent $t$ test was used to examine differences in the students' HRs between the 2 conditions. Finally, a multivariate analysis of variance (MANOVA) was performed to compare the students' perceived SI between the 2 conditions.

## 3. Results

Descriptive statistics, shown in Table 1, indicated that the students' SI in both conditions were moderate-to-high. The Cronbach $\alpha$ coefficient for SI was 0.85, indicating satisfactory data reliability. The results of descriptive analysis also suggested that students' HRs in the experimental condition were within the Target-Heart-Rate-Zone, at the level of moderate intensity (mean experimental HR = 134 bpm) and higher than the mean HR level of the comparison condition (mean comparison HR = 103 bpm). Table 1 also shows that students' science knowledge test scores were in the range of low-to-moderate performance level.

As expected, all 5 SI variables were positively and significantly correlated to each other, as reported in Table 2. It is also worth noting that students' perceived exploration opportunity provided by the games was moderately related to their HRs ($r = 0.444$, $p < 0.05$). The results from the correlation analysis indicate a positive function of SI from the AVGs as a motivator.

The repeated measures ANOVA on knowledge test suggested that there was no statistically significant main effect from the experimental condition ($F(1, 51) = 0.868$, $p = 0.356$, $\eta^2 = 0.017$). The test of within-subjects effects revealed a statistically significant effect for time ($F(1, 51) = 48.13$, $p < 0.001$, $\eta^2 = 0.486$). In addition, the results showed no statistically significant effect of interaction between time and the treatment ($F(1, 51) = 588$, $p = 0.447$, $\eta^2 = 0.011$). Overall, the statistically significant difference between the pre- and post-test scores indicates that the students in both conditions performed significantly better on the post-test than on the pre-test. In terms of the difference in HR between the 2 conditions, an independent $t$ test confirmed that the average HR in the experimental group was significantly higher than in the comparison group ($p < 0.001$, effect size: Cohen's $d = 1.97$).

The MANOVA analysis revealed statistically significant multivariate effects of the treatment (Pillai's Trace = 0.301, $F = 3.96$, $p < 0.01$, and $\eta^2 = 0.301$; Pillai's Trace was used due to a violation of the homogeneity of variance-covariance assumption, Box M = 29.25, $p = 0.038$). The subsequent univariate analyses indicated that the students in the experimental condition rated the 3 SI source dimensions significantly higher than students in the comparison condition

Table 1
Descriptive analysis (mean ± SD).

| Measure | Treatment group | Comparison group | Total |
|---|---|---|---|
| $HR_{baseline}$ (bpm) | 86.3 ± 14.7 | 77.8 ± 7.1 | 81.5 ± 11.7 |
| $HR_{max}$ (bpm) | 162.8 ± 17.8 | 115.7 ± 15.1 | 136.5 ± 29.4 |
| $HR_{mean}$ (bpm) | 134.0 ± 17.4 | 103.2 ± 13.7 | 116.6 ± 18.2 |
| Knowledge (pre-test) | 4.26 ± 2.18 | 3.63 ± 1.94 | 3.90 ± 2.05 |
| Knowledge (post-test) | 6.03 ± 1.85 | 5.83 ± 1.65 | 5.92 ± 1.73 |
| Attention | 3.46 ± 0.56 | 2.93 ± 0.96 | 3.17 ± 0.84 |
| Challenge | 2.59 ± 0.64 | 2.10 ± 0.83 | 2.33 ± 0.78 |
| Exploration | 3.18 ± 0.52 | 2.36 ± 0.72 | 2.72 ± 0.75 |
| Enjoyment | 3.46 ± 0.58 | 3.09 ± 0.82 | 3.20 ± 0.74 |
| Novelty | 3.46 ± 0.49 | 3.10 ± 0.92 | 3.26 ± 0.78 |

Abbreviation: HR = heart rate.

Table 2
Correlation coefficients.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| $HR_{mean}$ (1) | – | | | | | | | |
| Enjoyment (2) | 0.124 | – | | | | | | |
| Challenge (3) | 0.209 | 0.479** | – | | | | | |
| Attention (4) | 0.068 | 0.700** | 0.481** | – | | | | |
| Exploration (5) | 0.444** | 0.550** | 0.618** | 0.649** | – | | | |
| Novelty (6) | 0.210 | 0.734** | 0.359** | 0.545** | 0.464** | – | | |
| Pre-test (7) | 0.061 | 0.124 | −0.057 | 0.020 | 0.098 | 0.076 | – | |
| Post-test (8) | 0.143 | 0.278 | 0.021 | 0.057 | 0.236 | 0.299 | 0.639** | – |

**Correlation is significant at the $p < 0.01$ level (2-tailed).
Abbreviation: HR = heart rate.

(Attention: $F(1, 50) = 5.606$, $p = 0.022$, $\eta^2 = 0.101$; Challenge: $F(1, 50) = 4.958$, $p = 0.031$, $\eta^2 = 0.090$; Exploration opportunity: $F(1, 50) = 21.015$, $p < 0.001$, $\eta^2 = 0.296$).

## 4. Discussion

The results of this study supported the effectiveness of an AVG on elementary school students' science knowledge learning, PA intensity, and SI. One of the major findings was that students in both groups performed significantly better on the post-science knowledge test than on the pre-test after playing the video game, regardless of whether there was an activity component. The large effect size confirmed that the students did learn science knowledge from playing the educational video game at a similar pace. It is also important to note that students in the experimental group did not outperform their counterparts in the comparison group. In other words, the AVG used in this study was not superior to a traditional educational video game for enhancing students' science knowledge test scores.

From another perspective, however, these findings suggest that the PA component of the video game did not distract students from learning. This result echoes the previous finding that the increased moderate intensity PA opportunities did not interfere with cognitive learning while providing health benefits to children.[31] It is worth pointing out that this finding may not be conclusive. And discrepancies with findings from other studies do exist. For example, it was found in a previous study that elementary school children playing AVGs (e.g., a DDR-based exercise program) demonstrated greater improvements in math scores than children without AVG over time.[19] The authors speculated that context-specific DDR games might have the potential to influence specific brain activity through timing and pattern-reading, which are both important to learning geometry, which could lead to improved math achievement.[19] In addition, these discrepancies may be due to the conditions of the comparison group; the students in the control/comparison group in the previous study did not receive any kind of alternative treatment, whereas the comparison students in the present study played the EMS game. In the present study, the experimental and comparison groups played the identical game with respect to the science content. The only difference was the PA component in the experimental condition. The evidence suggests that students in both AVG and sedentary educational video game environments can acquire an equal amount of cognitive concepts to enhance their scientific knowledge. The result seems to further suggest that the learning context or content specificity differences resulting from adding a physically active component may not be a significant factor to sway cognitive learning outcomes. From this perspective, although the AVG-EMS game was not superior to the traditional EMS with respect to enhancing knowledge learning, one might speculate that the discrepancy would not have existed if the comparison group had only received a placebo (e.g., non-educational-based AVGs). In other words, AVG-EMS might be similar to DDR in that it also provided the necessary brain activities to enhance science knowledge learning.

Our second research question was about the group differences of the students' PA intensity during the gameplay. In contrast to the results on cognitive knowledge learning outcomes, the results from the independent *t* test showed that the average HR in the experimental condition was significantly higher than in the comparison condition. More importantly, the descriptive statistics of the HR data showed that the average HR from the experimental condition was within the Target-Heart-Rate-Zone at the moderate intensity during the entire game playing period, while the average HR from the comparison group was at the low intensity level. These results further suggest that stepper-exercise based AVGs are able to provide the sufficient intensity recommended in various PA guidelines for children who may concentrate on cognitive tasks at the moment. The present results support the findings from research on other popular AVGs using different software such as Wii Fit™ and EA Sports Active™.[32] The HR data (144 bpm for EA Sports Active™ and 136.6 bpm for Wii Fit™) from the study on Wii Fit™ and EA Sports Active reported that both games could help children achieve moderate PA intensity.[32]

The literature has long argued that a necessary condition for children to not only develop, but also sustain, an active lifestyle is self-initiated motivation. Interest in PA seems to be an effective motivator for children to develop and sustain such activity. The results of the MANOVA revealed that students in the experimental group perceived a significantly higher level of SI than students in the comparison group. In particular, students who played the educational game with the steppers structure felt that the game demanded higher attention, provided more opportunities for exploration, and was more challenging than students who played the same game in the traditional sedentary structure. This finding is important in that it revealed a PA-cognitive integrated effect on the students' perception of SI, an important source of motivation, which is particularly crucial for children.[17] It seems that the PA component added to the cognitive engagement, and required and challenged the player to construct different mental models that can help them navigate through the game.[33] In turn, this different cognitive demand became a key component that formed a strong basis for perceiving the game as situationally interesting and motivating.[25]

The high level of perception of SI in the experimental condition is of great theoretical importance. SI, as an important motivator for children, is evoked by certain aspects of the immediate environment, such as the ways in which learning tasks are organized and presented.[34] A situationally interesting activity can immediately attract a learners' attention, involve them in the process, and provide instant, positive feelings about the activity.[35] In education, task-based SI refers to the interest triggered by changing the task itself, or by changing the way in which learners approach the task.[36] Although previous studies have mostly examined SI in text-based material, one study focused on the concreteness (in the form of examples, analogies, or graphics) of the visual representations of a learning task.[37] Specifically, the study investigated changes in elementary school students' ($n$ = 140) SI as a function of the task characteristics, and suggested that the characteristics of the task and of the working situation can support the arousal of SI. Since the 2 groups in this study played the identical game, it can be reasoned that the PA component in the AVG was the major factor contributing to the higher level of SI.

## 5. Limitations

It must be noted that the present study has several limitations. First, the sample size was relatively small. Although a randomized control design was used, the small sample size may be one reason for the insignificance of the dependent measure. However, this study has provided useful preliminary data/statistics, based on which power analyses can now be performed to determine whether the sample size is adequate in similar studies in the future. In addition, although the sample size is comparable to sample sizes used in many previous studies on AVGs in literature,[13,15,16] caution should be taken when generalizing the present study results to different populations and/or settings. Second, this study was performed over a short period of time (2 weeks). Although a significant time effect was detected, in-depth cognitive learning might not occur during this short period. In addition, a 2-week duration may not be sufficient to determine the long-term motivational effects of AVGs in comparison to traditional video games. A longitudinal study found that students' SI in AVGs declined dramatically over two semesters.[18] Therefore, not only longitudinal studies, but also studies that investigate important factors for sustainable motivation in AVGs for children are needed.

## 6. Implication: practical significance

In conclusion, the results of this study suggest that AVGs might be feasible tools used at school to provide students with an enjoyable learning experience and sufficient PA intensity for health benefits. Researchers have suggested the potential of educational video games to engage children, and help them learn difficult concepts through experiencing situations first-hand and through role-play.[38] Since many studies have reported the motivational effects of educational video games in classrooms, this study provided evidence for adopting the game structure for enhancing both cognitive and physical benefits for children. The findings of the present study seemed to advocate the use of AVGs in the classroom (such as in science lessons) to increase amount of students' PA time (e.g., PE class, recess) in schools. In addition, these findings also suggest that a science teacher may use activity-based science educational videos as a motivating tool to enhance students' science knowledge performance. These findings are promising in that AVGs developers could design activity-based educational video games to be incorporated into classroom instruction as a supplement to other in-school PA opportunities to assist children in meeting the 60-min moderate-vigorous intensity PA recommendation. Similarly, PE teachers could also use AVGs in their PE classes to engage students in moderate PA.

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### Authors' contributions

HS conceived of the study and drafted the manuscript. YG conceived of the study and performed analyses as well as approved the final version. Both authors have read and approved the final version of the manuscript, and agree with the order of presentation of authors.

### Competing interests

Neither of the authors declare competing financial interests.

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