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Original article

The effects of a bike active video game on players' physical activity and motivation

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Abstract

Background: Players may not acquire adequate levels of moderate-to-vigorous physical activity (MVPA) when playing commercial video games. This study's goal was to evaluate the effects of an exercise bike video game played by using a mobile application-based exergame that was designed exclusively to promote participants' MVPA, with additional attention paid to this game's ability to promote greater situational interest.
Methods: An experimental design was used with 163 students (aged 20.31 ± 1.30, 18–26 years, 61.3% male), all of whom were randomly allocated into an experimental group and a control group. Physical activity (PA) levels were assessed with ActiGraph GT3X+ (ActiGraph Inc., Fort Walton Beach, FL, USA) accelerometers. The situational interest scale was used to evaluate students' situational interest in both groups. Multivariate analysis of variance was conducted to examine the differences between sedentary behavior, PA levels, and situational interest between groups. Regression analyses were also used, with the purpose being to evaluate the strength of the relationship between PA and situational interest.
Results: Results revealed that the experimental group had higher degrees of sedentary behavior, light PA, total interest, instant enjoyment, exploration intention, attention demand, novelty, and challenge, whereas the control group received higher scores for MVPA (control 95.01% *vs*. experimental group 89.94%). Regression analysis indicated that instant enjoyment ($\beta = 0.49$, $p < 0.01$), exploration intention ($\beta = 0.18$, $p < 0.05$), and attention demand ($\beta = 0.17$, $p < 0.05$) were positive predictors for total interest, explaining 43% of its variance.
Conclusion: A newly designed mobile application-based exergame played via an exercise bike may enhance situational interest and provide a decent level of PA for players.

Keywords: Design; Exergame; Moderate-to-vigorous physical activity; Sedentary behavior; Situational interest; Young adults

1. Introduction

From 1975 to 2014, researchers from the Non-Communicable Diseases Risk Factor Collaboration Consortium reviewed population studies from approximately 200 countries in adults aged ≥18 years to determine body mass index (BMI) changes over time.[1] Findings from this comprehensive review indicated that average BMI increased from 21.7 kg/m^2 in 1975 to 24.2 kg/m^2 in 2014 in men, and from 22.1 kg/m^2 to 24.4 kg/m^2 in women. The study also revealed that if the post-2000 trends continue, by 2025, global obesity prevalence will reach 18% in men and surpass 21% in women, with severe obesity (i.e., BMI ≥ 35 kg/m^2) surpassing 6% in men and 9% in women. To mitigate this trend, researchers have focused on promoting proper health behaviors in youth and young adults to improve BMI values and reduce potential adverse health consequences associated with overweight or obesity.[2,3]

The current generation's youth and young adults are highly involved in social media[4] and video games.[5–7] Lenhart et al.[5] reported that 65% of males and 35% of females aged 12–17 years are daily gamers, whereas Gentille[6] found that 88% of American youth aged 8–18 years play video games at least once a month. According to Ream et al.,[7] this trend in video game play and social media interaction starts in early childhood and continues through adulthood. As such, leveraging the technology that most interests the current generation's youth and young adults in an

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effort to improve health outcomes in later life has become the focus of a growing body of research and practice.

In 2005, Nintendo (Redmond, WA, USA) launched the Wii, the first video game console in which players interacted with games through bodily movement. These types of games and gaming consoles would later be termed "exergames" (as known as active video games), which in contrast to sedentary video games have been defined as "video games that are also a form of exercise".[8] Exergames have received increasing attention among researchers because they offer a unique opportunity to build on youth and young adults' interest in video games, with the objective being to address the obesity crisis through increased physical activity (PA). Over the past 10 years, numerous studies have been published related to the effect of exergames on youth and adults' PA levels.[9–13] Indeed, Peng et al.[14] published a meta-analysis regarding the use of exergames for PA promotion among youth (6–17 years old) and adults (≥18 years old). Findings indicated that exergames (1) significantly increased heart rate, oxygen consumption, and energy expenditure compared with sedentary behaviors; (2) produce a similar magnitude of effect as light- to moderate-intensity PA; (3) have a similar impact for youth and adults with regard to PA intensity; and (4) are more attractive and enjoyable for youth and adults in comparison to traditional PA. Taken together, these findings suggest exergames to be a viable option to promote youth and adults' PA and health.

Despite the aforementioned benefits, youth and adults may still not acquire adequate levels of moderate-to-vigorous PA (MVPA) when playing commercial exergames (e.g., Wii Sports, Wii Fit, Dance Dance Revolution, Xbox Kinect, *etc.*). According to Beaudoin,[15] designers in the commercial exergames industry focus more on the fun and entertaining features of exergames—as opposed to aspects of game design that might increase PA intensity and subsequent health benefits—given the fact that the goal of commercial exergames is still primarily to entertain.

1.1. (Exer)games design

Despite knowing that video games can be effective educational tools,[16–18] it is still unclear how and under what conditions these games are effective. According to Gaydos,[19] video game design remains poorly understood. Indeed, designing a good video game is difficult. One way to improve the design process is to share design plans. In the literature, researchers have shared video game designs via journal articles that present design principles or a list of steps that one must follow to create or recreate a game.[20–25] Briefly, these literature reports indicate the importance of designing games that immerse the player in a virtual world where competition and autonomy are present, real-world social norms can be temporarily ignored, and there is a need to find solutions to within-game problems to achieve success.[20]

In line with these design needs, Wang and Hannafin[21] introduced a design-based research perspective defined as "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually sensitive design principles and theories". Simply put, researchers should ensure that every aspect of game design is consistent with the intended user population and overall objective of the game (e.g., to educate players on a subject, or to increase PA in players)—with the result being a more effective video game. Among the best examples of the use of the aforementioned design principles and design-based methodology comes from the Quest Atlantis team,[22] who successfully developed a video game that enhanced children's engagement in educational tasks. Given the proven effectiveness of these design principles and this methodology, these factors also need to be at the forefront of researchers' minds when developing video games for noneducational purposes (e.g., MVPA promotion among youth and/or young adults) to ensure achievement of the intended outcome.

1.2. Designing a mobile application-based exergame for an exercise bike

Despite the attractiveness of exergames among youth and adults,[14] few studies have investigated players' situational interest during exergame play.[26–29] Situational interest has been defined as an activity's appealing effect on an individual(s)[30] and emerges from an instant person–activity interaction in which the person recognizes a specific intriguing feature of this activity while being engaged in the activity.[31] According to Hidi and Harackiewicz,[32] a highly interesting activity can immediately attract individuals' attention and provide positive feelings about the activity. Within the context of PA, Chen et al.[33,34] identified 5 sources of situational interest: novelty, challenge, attention demand, exploration intention, and instant enjoyment. The aforementioned sources of situational interest have been investigated among children while playing exergames.

Sun[26,27] found that elementary school students' situational interest during an exergaming unit was higher than their situational interest in a traditional fitness unit, with their situational interest decreasing significantly over time during the latter fitness unit. Additionally, Huang and Gao[28] found that novelty was a significant predictor of MVPA during exergame play in middle school students. Finally, Roure et al.[29] found that high school students displayed a higher level of MVPA when they believed that the activity demanded greater attention and demonstrated a higher level of light PA when they deemed the activity to only provide novelty.

Therefore, to promote players' MVPA and situational interest throughout game play, Vescape GmbH (Berlin, Germany) designed a mobile application called Greedy Rabbit based on the design principles of trial-and-error and progressive challenges and feedback.[35] Broadly, the mobile application-based exergame encompasses 10 sets of 10 stages representing progressively harder challenges. In detail, Greedy Rabbit is a maze game in which a rabbit makes its way through a maze, collecting flowers and avoiding hedgehogs in chase, with the goal being to obtain a carrot placed at the end of each maze (i.e., game stage). The video game is compatible with any mobile device (e.g., tablet, smartphone) and is paired with an exercise bike via a Bluetooth (Bluetooth SIG Inc., Kirkland, WA, USA) connection to match the speed of the rabbit with the player's

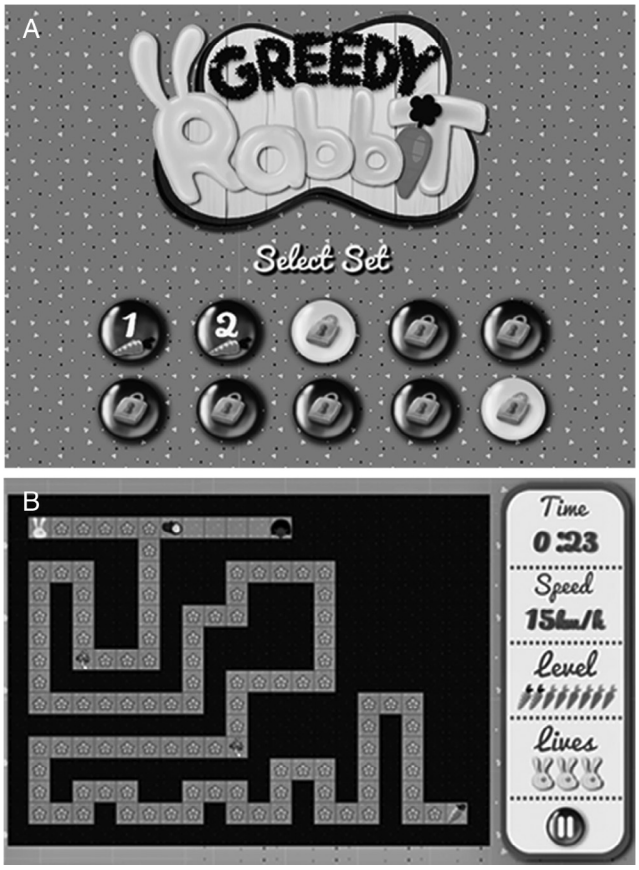

Fig. 1. Screen shots of Greedy Rabbit exergame. Greedy Rabbit home screen (A) and example of 1 level (B).

cycling speed. Furthermore, this wireless connection allows the resistance of the exercise bike to increase or decrease depending on events that occur in the game (e.g., collecting a mushroom). Players are provided with 3 lives to complete the 10 stages and lose a life each time they are caught by a hedgehog. Greedy Rabbit is included in the Vescape app available from Google Play or Apple's App Store and capitalizes on the high percentage of smartphone ownership and the desire for health apps among consumers.[36,37] Pictures of the interface and levels are presented in Fig. 1.

Given the preceding literature review, the following questions guided the current study: (1) To what extent does the Greedy Rabbit exercise bike video game promote players' MVPA and situational interest? and (2) what source(s) of situational interest have the greatest impact on players' MVPA? Participants were college students because little study of exergaming has been completed among this population. In fact, owing to the major life changes and increased responsibility brought about during college, college students are at risk of low levels of PA and higher rates of obesity[38]—necessitating innovative forms of exercise to motivate this population to be more active and to improve health outcomes. The findings of the study will inform researchers and practitioners about the effectiveness of an exercise bike paired wirelessly with a mobile application-based exergame on players' MVPA and situational interest. Additionally, findings will demonstrate how best to facilitate greater MVPA and situational interest for the greatest health impact among young adults.

2. Methods

2.1. Participants and research design

An experimental design was used to examine how 2 different exercise protocols affected the relationship between objectively measured PA levels and self-reported situational interest. The participants in the study were a convenience sample of 163 undergraduate students (aged 20.31 ± 1.30, 18–26 years, 61.3% male) recruited from the sport science department of a French university located in the northwest region of France. Notably, the current study was not part of students' course load and was purely voluntary. Permission to conduct the study was granted by the ethical board of the University of Western Brittany. Students were informed about the scope of the study, with written informed consent gathered prior to data collection. Participants were included based on the following criteria: (1) between 18 and 26 years old and (2) no reported health issues.

Participants were randomly allocated into 2 groups: an experimental group ($n = 94$) and a control group ($n = 69$). For the purposes of the current study, we desired a higher number of individuals in the experimental group than in control group. In the experimental group, students engaged in one 15 min session of the Greedy Rabbit exergame—consisting of the first set of 10 stages—using an exercise bike paired wirelessly via Bluetooth with the mobile application-based exergame. In the control group, participants engaged in one 15 min session of free cycling on an exercise bike and were told to act as if they were in a fitness center. Students in the control condition chose the level of difficulty and the cycling cadence during the 15 min session. During this session, students from the control group were informed by the exercise bike's screen about the time left, their cycling cadence, and their power output.

2.2. Measures

2.2.1. Situational interest

The 19-item French Situational Interest Scale (FSIS)[39] was used to measure students' situational interest during the exergame. The scale included 5 situational interest subscales, each representing a source of situational interest: novelty (e.g., "what I did today was new to me"), instant enjoyment (e.g., "what I did was enjoyable for me"), exploration intention (e.g., "I wanted to analyze and have a better handle on what I was learning today"), attention demand (e.g., "what I was learning demanded my high attention"), and challenge (e.g., "what I was learning was hard for me to do"). Subscales for each source of situational interest consisted of 3 items. Total interest was also measured and consisted of 4 items. The items were randomly arranged, and each was rated on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Among middle and high school students, Roure et al.[39] established the construct validity of the FSIS using exploratory and confirmatory factor analyses, in addition to reporting internal consistency for all 5 sources of situational interest.

2.2.2. PA levels

ActiGraph GT3X+ (ActiGraph Inc., Fort Walton Beach, FL, USA) accelerometers were used to assess student PA levels. These accelerometers measure motion in 3 dimensions and provide triaxial vector data to calculate metabolic equivalents in relation to participants' demographic and anthropometric characteristics. The devices are 4.6 cm × 3.3 cm × 1.5 cm in size and can be worn on the wrist, waist (hip), arm, thigh, or ankle. In this study, students wore the accelerometer on the ankle using an elastic strap. The ankle has been shown to be the best location for providing PA data during cycling.[40]

The GT3X+ is widely used in PA research and has demonstrated acceptable criterion validity and reliability for recording PA in the field and converting activity counts into different intensity levels of PA.[41] Accelerations from the ActiGraph GT3X+ were converted into activity counts, summed, and recorded using a specified interval of time called an epoch, which can range from 5 s to 1 min. In the present study, the epoch was set to 5 s. Cut-points were established using the same methodology as Puyau et al.'s study.[42] Specifically, cut-points for activity counts were as follows: sedentary behavior (0–399 counts per 30 s), light PA (400–1599 counts per 30 s), and MVPA (≥1600 counts per 30 s). The percentages of time that students spent in sedentary behavior, light PA, and MVPA were used as the outcome variables.

2.3. Data collection

This study took place during the spring semester of the 2016 school year. Researchers collected demographic and anthropometric information, such as age, gender, height, weight, and dominant foot, for all participants. This information was needed prior to the accelerometer's placement on the ankle to initialize the accelerometers via the ActiLife software (Vescape GmbH) and to collect accurate PA measures.

The accelerometers were collected after each 15 min session, and the data were immediately downloaded to a data collection computer. Students also responded to the FSIS immediately after the session. Researchers administered the questionnaire and collected it immediately after completion. To minimize students' tendency to give socially desirable responses, students were encouraged to answer honestly and were assured that their responses would remain anonymous and confidential.

2.4. Data analysis

Students' responses were aggregated respectively to the 5 sources of situational interest (instant enjoyment, exploration intention, attention demand, challenge, and novelty) and to total interest. The statistical analyses were then performed in the following steps. Preliminary analyses were first conducted on study variables to examine normality, multicollinearity, and internal reliability of the subscales. Next, a multivariate analysis of variance was conducted to examine the differences between the dependent variables within a multivariate framework. The dependent variables were the participants' PA levels (sedentary behavior, light PA, and MVPA), the situational interest sources (instant enjoyment, exploration intention, attention demand, challenge, and novelty), and total interest. The independent variables were group membership (experimental or control) and gender (female or male). Pillai's F statistic was used to determine the statistical significance of the multivariate model because this statistic "can help control the type I error rate with small or unequal sample sizes".[43] Follow-up univariate tests were then conducted based on the statistical significance of the multivariate analysis of variance test. A Bonferroni *post hoc* test was employed if there were any statistically significant differences in the participants' percentage of time in sedentary behavior or at differing PA levels in addition to assessing differences in total interest and situational interest sources. Finally, Pearson product-moment correlations and multiple regression were used, within the experimental group, to analyze the relationship between situational interest sources, total interest, and participants' PA levels. SPSS Version 23.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses.

3. Results

Analysis of the skewness (−1.60 to 1.95) and kurtosis (−1.81 to 2.28) values revealed that data were normally distributed. Multicollinearity was checked using the variance inflation factor and tolerance statistics in SPSS. Neither variance inflation factor values greater than 10 nor tolerance values below 0.2 were found, indicating no multicollinearity between the variables. The mean substitution technique[44] was chosen to replace each missing score owing to the small number of missing scores among the sample (<0.01%). Internal consistencies were good for the situational interest scale, with Cronbach's α of 0.94 for instant enjoyment, 0.90 for exploration intention, 0.91 for attention demand, 0.71 for challenge, 0.88 for novelty, and 0.92 for total interest, respectively.

Table 1 reports the means, SD, and differences between the 2 groups for PA levels, situational interest sources, and total interest measures. The results from multivariate analysis of variance revealed a significant main effect of group membership on participants' PA levels and total interest scores (Pillai's trace = 0.89; $F(9, 151) = 141.50$; $p < 0.001$; $\eta^2 = 0.89$), whereas the multivariate effects of gender were not significant (Pillai's trace = 0.07; $F(9, 151) = 1.32$; $p = 0.23$; $\eta^2 = 0.07$). In follow-up Welch analyses of variance, with an α of 0.025, it was determined that mean

Table 1
Descriptive data of PA levels and situational interest measures.

	Range	Experimental		Control		$F(1, 161)$	η^2
		M	SD	M	SD		
Sedentary	0–100	4.76	6.33	1.06	2.89	20.40**	0.11
Light PA	0–100	5.32	2.90	3.93	2.79	9.45**	0.06
MVPA	0–100	89.94	6.86	95.01	3.58	31.47*	0.16
Total interest	4–20	15.39	2.89	7.72	2.55	309.29**	0.66
Instant enjoyment	3–15	13.09	1.83	6.42	2.20	443.17**	0.73
Exploration intention	3–15	10.31	2.66	4.99	1.92	200.13**	0.55
Attention demand	3–15	7.48	2.91	3.90	1.35	89.87**	0.36
Novelty	3–15	14.29	1.92	4.00	2.22	1001.08**	0.86
Challenge	3–15	4.41	1.73	3.88	1.40	4.38*	0.03

* $p < 0.01$, ** $p < 0.001$.
Abbreviations: MVPA = moderate-to-vigorous physical activity; PA = physical activity.

Table 2
Correlations among PA levels, situational interest sources, and total interest.

	1	2	3	4	5	6	7	8	9
1. Sedentary	—								
2. Light PA	−0.04	—							
3. MVPA	−0.91**	−0.38**	—						
4. Total interest	0.05	0.03	−0.06	—					
5. Instant enjoyment	−0.11	0.14	0.04	0.62**	—				
6. Exploration intention	0.03	0.14	−0.09	0.41**	0.41**	—			
7. Attention demand	0.01	−0.13	0.04	0.26**	0.13	0.05	—		
8. Novelty	0.06	0.17	−0.13	0.05	0.05	0.00	−0.20*	—	
9. Challenge	0.01	−0.06	0.02	0.15	0.01	0.06	0.36	−0.13	—

* $p < 0.05$, ** $p < 0.01$.
Abbreviations: MVPA = moderate-to-vigorous physical activity; PA = physical activity.

scores for participants' PA levels, situational interest sources, and total interest differed significantly between the experimental group and the control group. *Post hoc* tests using the Bonferroni correction revealed a significant difference between the groups on sedentary behavior (4.76% *vs.* 1.06%; $p < 0.001$), light PA (5.32% *vs.* 3.93%; $p < 0.001$), total interest (15.39 *vs.* 7.72; $p < 0.001$), instant enjoyment (13.09 *vs.* 6.42; $p < 0.001$), exploration intention (10.31 *vs.* 4.99; $p < 0.001$), attention demand (7.48 *vs.* 3.90; $p < 0.001$), novelty (14.29 *vs.* 4.00; $p < 0.001$), and challenge (4.41 *vs.* 3.88; $p < 0.01$), whereas the control group received higher values for MVPA (95.01% *vs.* 89.94%; $p < 0.01$).

The Pearson's correlation coefficients presented in Table 2 indicated that neither total interest nor the 5 situational interest sources correlated significantly with PA levels. Additionally, the results showed that total interest correlated positively and moderately high to instant enjoyment ($r = 0.62$; $p < 0.01$), moderately to exploration intention ($r = 0.41$; $p < 0.01$), and lowly to attention demand ($r = 0.26$; $p < 0.01$). Moreover, moderate correlations between instant enjoyment and exploration intention were positive ($r = 0.41$; $p < 0.01$), whereas attention demand and novelty correlated negatively ($r = -0.20$; $p < 0.05$). Multiple-regression analyses were conducted to examine whether situational interest sources could predict total interest. Regression analysis revealed that instant enjoyment ($\beta = 0.49$; $p < 0.01$), exploration intention ($\beta = 0.18$; $p < 0.05$), and attention demand ($\beta = 0.17$; $p < 0.05$) were positive predictors for total interest, explaining 43% of its variance.

4. Discussion

Research has revealed that commercial exergames produce a magnitude of effect equivalent to light- to moderate-intensity PA.[14] Thus, the Vescape company designed a mobile application-based exergame platform, Greedy Rabbit, to be paired wirelessly via Bluetooth with an exercise bike, with the objective to promote players' MVPA. The goal of this study was to evaluate the effects of this Vescape exergaming platform on players' MVPA and, further, their situational interest.

4.1. PA and situational interest

Descriptive analyses indicated that players spent approximately 90% of their time in MVPA when playing the exergame on the exercise bike. This result differs from several studies in the relevant literature. Willems and Bond[45] observed greater proportions of light PA, as opposed to MVPA, in students aged 20–22 years old during exergame play (Wii Sports), with similar results seen in a study by Worley et al.[46] in students (mean age, 22.88 years old) playing a traditional commercial exergame (Wii Fit). Moreover, Lyons et al.[47] also recorded low-moderate PA in 100 adults aged 18–35 years playing 3 commercial exergames (Guitar Hero III, Dance Dance Revolution, and Wii Fit). The preceding literature is in agreement with a meta-analysis by Peng et al.[14] wherein of the 14 studies included, 12 studies reported light- to moderate-intensity levels of PA when playing exergames, with only 1 study reporting MVPA and another a vigorous intensity of PA.

Given the current study's favorable MVPA comparisons to previous literature, a designed mobile application-based exergame played via an exercise bike may provide health-related benefits to players.[48] However, it is worth noting that students in the control group spent 95% of their time in MVPA when asked to pedal on the exercise bike for 15 min—slightly higher than observed in the experimental group. This finding has 2 plausible explanations. First, in studying motivation and PA among sport students in 3 countries, Kondric et al.[49] found a "high motivation profile", in which students had high intrinsic and extrinsic motivation and low levels of amotivation (i.e., a lack of motivation) for PA. In essence, these students' chosen area of study (i.e., sport science) explained their highly motivated attitude and high levels of participation and proficiency in numerous PAs. Congruent with the aforementioned literature, findings from the current study with regard to the control group's high MVPA may also be explained by these students' motivational profile because all participants were sport science students. Second, it might be that because of the novelty of the Greedy Rabbit game among the experimental group, participants in this group might have spent a portion of the 15 min exercise session trying to learn how to play the game. This is important, because this learning process may have lowered the PA intensity with which these participants were able to exercise to below that of the control group participants, who were simply asked to exercise as if they were in a fitness center.

Despite students in both groups exhibiting high levels of PA, situational interest was different between exercise conditions.

Specifically, differences in situational interest between the control and experimental groups were significant for each source of situational interest. As for the mechanism explaining these findings, Greedy Rabbit's unique platform (i.e., a mobile application-based exergame played with an exercise bike) likely engaged students in a new activity that promoted emotional engagement (i.e., instant enjoyment). Furthermore, as they played, students were focused on the game (i.e., attention demand) and the exploration of the game environment (i.e., exploration intention). As a result of this unique platform, instant enjoyment, exploration attention, and attention demand were observed to be positive predictors of total interest—explaining the higher situational interest among the experimental group in addition to the aforementioned higher MVPA levels. This finding is in line with literature investigating exergaming in younger populations. Sun[26] found that fourth-grade students experienced higher situational interest from all this construct's sources during an exergaming unit compared with a fitness unit. Moreover, Roure et al.[29] found that instant enjoyment was the most significant situational interest source reported by high school students as they played an exergame. Nonetheless, although Greedy Rabbit did appear to promote situational interest in PA among college students, this exergame did not appear to result in differences in MVPA among this population—perhaps owing to the highly physically motivated and fit participants in the current trial.

4.2. Impact of exergame design

Engineers from the Vescape company designed Greedy Rabbit on the basis of the design principles[35] of trial-and-error and progressive challenges and feedback. Our study revealed that players spent 90% of their time in MVPA when playing Greedy Rabbit on the exercise bike and that the mobile application-based exergame had the ability to promote players' total interest through instant enjoyment, exploration attention, and attention demand. Although students in the control group had approximately similar MVPA levels, low levels of situational interest from all sources were seen in this group. Although the preceding findings favor Greedy Rabbit, it is notable that this exergame did not appear to represent a physical challenge for students in the experimental group. Simply put, Greedy Rabbit's first set of 10 stages may not be difficult enough for highly fit young adults (e.g., students within a sport science department), revealing a possible design issue necessitating consideration in future iterations of the game.

As Beaudoin[15] pointed out, "When examined technically, the commercial design studio relies on individual historical knowledge and game playing experience to develop new game types or adapt existing mechanics into new games." Often in the commercial gaming industry, individual designers design a game based on their own experience of effective game design tools. Challenge was one of the key design features of Greedy Rabbit, supposedly increasing the intensity of the game. Unfortunately, as stated previously, our study indicated that the challenge for the first set of 10 stages may not be sufficient for more fit young adults akin to the cohort recruited in the current study. As such, our study again suggests the need for quantifiable design practices and peer review methodology for subsequent iterations of Greedy Rabbit as well as for other tailor-designed exergames for research and practice. Using a cycle of analysis, design, implementation, and redesign as suggested by Wang and Hannafin[21] within design-based research methodology, the effectiveness of the game in promoting specific outcomes (e.g., more challenging gameplay and, thus, a greater challenge for highly fit populations) and user experience might be increased.

Unfortunately, the aforementioned process would significantly increase the time needed to redesign an exergame such as Greedy Rabbit or even to design a new exergame with similar objectives. In the fast-paced commercial gaming industry, an individual designer evaluates his or her design in the course of a few weeks based on player responses. Formal research is done when the value of the game is proven in the marketplace. At the time we conducted this study (February/March 2016), design choices had been made, and Greedy Rabbit had already been released in the Google Play Store (December 2015) and Apple App Store (January 2016). As can be seen, using a design-based research method with a peer review process would affect this design cycle. By the time researchers published results in a peer-reviewed journal, designers would be working on new game developments. One way to address this timing issue may be to have designers and researchers constantly interact with each other within a research and development department. Because we will collaborate with engineers from the Vescape company on future iterations of Greedy Rabbit based on results from this study, we will explore ways to target specific sources of situational motivation to promote MVPA for users of all fitness levels—not just the highly fit—in a timely process that minimally affects the previously outlined design cycle.

4.3. Limitations

Although this study offers a unique contribution to the literature given the study's use of a mobile application-based exergame wirelessly compatible via Bluetooth with an exercise bike in the promotion of college students' MVPA and situational interest, several limitations should be acknowledged. First, participants were young adult college students recruited from a department of sport science. Given the fact that this population had high levels of motivation for PA, in addition to high fitness levels, future studies should involve participants with varying motivations for PA (e.g., predominantly intrinsically, extrinsically, or amotivated) and physical fitness. Second, it appeared that the first set of 10 levels of Greedy Rabbit were not challenging for the highly fit population studied. Future studies recruiting fit populations should explore the higher and more progressive sets of levels contained within the application. Third, although this study did reveal the acute and beneficial effects of Greedy Rabbit on students' situational interest, the sustainability of players' situational interest is still unknown. Future studies should consider examining the effect of Greedy Rabbit on players' perceived situational interest over time using a longitudinal study design. Finally, although this study offers a unique opportunity to evaluate players' MVPA engagement in a designed exergaming platform, MVPA comparisons of the same players participating in traditional

commercial exergames were not conducted (i.e., Wii, Xbox). Future studies should consider a within-subjects research design in which the participants would be assessed playing a mobile application-based exergame on an exercise bike and while playing traditional exergames to determine potential difference in MVPA and other psychosocial outcomes (i.e., self-efficacy, enjoyment)[50] between the 2 exergaming modalities. Despite these limitations, the findings of this study provide initial evidence of the potential physical and psychological benefits that playing a design-based exergame may have.

5. Conclusion

The findings of the current study indicated a mobile application-based exergame capable of being wirelessly paired to an exercise bike can promote light PA, situational interest, and other important psychological determinants of PA participation versus traditional biking exercise. Moreover, the study's findings showed that this mobile application-based exergame can promote similar, but slightly lower, levels of MVPA as compared to traditional biking exercise. However, updates to this mobile application-based exergaming platform and other analogous platforms are advised to increase game difficulty and promote an intensity of gameplay akin to that observed during traditional biking exercise—particularly among healthy, physically fit, and active populations.

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Authors' contributions

DP designed the study, managed the data collection, participated in the data collection and data analysis, and drafted the manuscript (excluding the method section); CR participated in the study design and the data collection, managed the data analysis, and drafted the method section of the manuscript; GK participated in the study design and the data collection; ZP helped draft the manuscript and proofread it; and ZG participated in the study design and data analysis and helped draft the manuscript and proofread it. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

None of the authors declare competing financial interests.

References

1. NCD-RisC. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *Lancet* 2016;**387**:1377–96.
2. Flegal KM, Graubard BL, Williamson DF, Gail MH. Cause-specific excess deaths associated with underweight, overweight, and obesity. *JAMA* 2007;**298**:2028–37.
3. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. *Int J Obes* 2011;**35**:891–8.
4. Lenhart A. *Teen, social media and technology overview*. *Pew Research Center 2015*. Available at: http://www.pewinternet.org/2015/04/09/teens-social-media-technology-2015; 2015 [accessed 27.06.2016].
5. Lenhart A, Kahne J, Middaugh A, Macgill A, Evans C, Vitak J. *Teens, video games and civics*. *Pew Research Center's Internet & American Life Project*. Available at: http://www.pewinternet.org/Reports/2008/Teens-Video-Games-and-Civics.aspx; 2008 [accessed 27.06.2016].
6. Gentile D. Pathological video-game use among youth ages 8 to 18. A national study. *Psychol Sci* 2009;**20**:594–602.
7. Ream GL, Elliott LC, Dunlap E. Trends in video game play through childhood, adolescence, and emerging adulthood. *Psychiatry J* 2013;**2013**:301460. doi:10.1155/2013/301460
8. Gao Z, Chen S, Pasco D, Pope Z. A meta-analysis of active video games on health outcomes among children and adolescents. *Obes Rev* 2015;**16**:783–94.
9. Daley AJ. Can exergaming contribute to improving physical activity levels and health outcomes in children? *Pediatrics* 2009;**124**:763–71.
10. Graf DL, Pratt LV, Hester CN, Short KR. Playing active video games increases energy expenditure in children. *Pediatrics* 2009;**124**:534–40.
11. Lanningham-Foster L, Foster RC, McCrady SK, Jensen TB, Mitre N, Levine JA. Activity-promoting video games and increased energy expenditure. *J Pediatr* 2009;**154**:819–23.
12. Baranowski T, Abdelsamad D, Baranowski J, O'Connor TM, Thompson D, Barnett A, et al. Impact of an active video game on healthy children's physical activity. *Pediatrics* 2012;**129**:e636–42.
13. Gao Z, Xiang P. Effects of exergaming based exercise on urban children's physical activity participation and body composition. *J Phys Act Health* 2014;**11**:992–8.
14. Peng W, Crouse JC, Lin JH. Using active video games for physical activity promotion: a systematic review of the current state of research. *Health Educ Behav* 2013;**40**:171–92.
15. Beaudoin D. Serious lessons from the commercial games industry. In: Cruz-Cunha MM, editor. *Handbook of research on serious games as educational, business and research tools*. Hershey, PA: IGI Global; 2012.p.269–78.
16. Baranowski T, Blumberg F, Buday R, DeSmet A, Fiellin LE, Green S, et al. Games for health for children—current status and needed research. *Games Health J* 2016;**5**:1–12.
17. Young MF, Slota S, Cutter AB, Jalette G, Mullin G, Lai B, et al. Our princess is in another castle: a review of trends in serious gaming for education. *Rev Educ Res* 2012;**82**:61–89.
18. Clark DB, Tanner-Smith EE, Killingsworth SS. Digital games, design, and learning: a systematic review and meta-analysis. *Rev Educ Res* 2016;**86**:79–122.
19. Gaydos M. Seriously considering design in educational games. *Educ Res* 2015;**44**:478–83.
20. Squire K. Design principles of next-generation digital gaming for education. *Educ Technol* 2003;**43**:17–23.
21. Wang F, Hannafin MJ. Design-based research and technology-enhanced learning environments. *Educ Technol Res Dev* 2005;**53**:5–23.
22. Barab S, Dodge T, Thomas MK, Jackson C, Tuzun H. Our designs and the social agendas they carry. *J Learn Sci* 2007;**16**:263–305.
23. Van Staalduinen JP, De Freitas S. A game-based learning framework: linking game design and learning outcomes. In: Khine MS, editor. *Learning to play. Exploring the future of education with video games*. New York, NY: Peter Lang; 2011.p.29–55.
24. Villalta M, Gajardo I, Nussbaum M, Andreu JJ, Echeverria A, Plass JL. Design guidelines for classroom multiplayer presential games. *Comput Educ* 2011;**57**:2039–53.
25. Gauthier A, Corrin M, Jenkinson J. Exploring the influence of game design on learning and voluntary use in an online vascular anatomy study aid. *Comput Educ* 2015;**87**:24–34.

26. Sun H. Exergaming impact on physical activity and interest in elementary school children. *Res Q Exerc Sport* 2012;**83**:212–20.
27. Sun H. Impact of exergames on physical activity and motivation in elementary school students: a follow-up study. *J Sport Health Sci* 2013;**2**: 138–45.
28. Huang C, Gao Z. Associations between students' situational interest, mastery experiences, and physical activity levels in an interactive dance game. *Psychol Health Med* 2013;**18**:233–41.
29. Roure C, Pasco D, Pope Z, Gao Z. High school students' situational interest and physical activity levels in exergaming. In: Gao Z, Pope Z, editors. *Physical activity behaviors and determinants in children and adolescents*. New York, NY: Nova Publishers; 2015.p.103–17.
30. Hidi S, Anderson V. Situational interest and its impact on reading and expository writing. In: Renninger KA, Hidi S, Krapp A, editors. *The role of interest in learning and development*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.; 1992.p.215–38.
31. Mitchell M. Situational interest: its multifaceted structure in the secondary school mathematics classroom. *J Educ Psychol* 1993;**85**:424–36.
32. Hidi S, Harackiewicz JH. Motivating the academically unmotivated: a critical issue for the 21st century. *Rev Educ Res* 2000;**70**:151–79.
33. Chen A, Darst PW, Pangrazi P. What constitutes situational interest? Validating a construct in physical education. *Meas Phys Educ Exerc Sci* 1999;**3**:157–80.
34. Chen A, Darst PW, Pangrazi P. An examination of situational interest and its sources. *Br J Educ Psychol* 2001;**71**:383–400.
35. Sun CT, Ye SH, Wang YJ. Effects of commercial video games on cognitive elaboration of physical concepts. *Comput Educ* 2015;**88**:169–81.
36. IMS Institute of Health Informatics 2015. *Patient adoption of mHealth*. Available at: http://www.imshealth.com/en/thought-leadership/ims-institute/reports/patient-adoption-of-mhealth; 2015 [accessed 14.09. 2016].
37. PRC 2015. *The smartphone difference*. http://www.pewinternet.org/2015/04/01/us-smartphone-use-in-2015; 2015 [accessed 14.09.2016].
38. Desai MN, Miller WC, Staples B, Bravender T. Risk factors associated with overweight and obesity in college students. *J Am Coll Health* 2008;**57**: 109–14.
39. Roure C, Pasco D, Kermarrec G. French validation of the situational interest scale in physical education. Validation de l'échelle française mesurant l'intérêt en situation, en éducation physique. *Can J Behav Sci* 2016;**48**:112–20. [in French].
40. De Vries SI, Garre FG, Engbers LH, Hildebrandt VH, Van Buuren S. Evaluation of neural networks to identify types of activity using accelerometers. *Med Sci Sports Exerc* 2011;**43**:101–7.
41. Flynn JI, Coe DP, Larsen CA, Rider BC, Conger SA, Bassett Jr DR. Detecting indoor and outdoor environments using the ActiGraph GT3X+ light sensor in children. *Med Sci Sports Exerc* 2014;**46**:201–6.
42. Puyau MR, Adolph AL, Vohra FA, Butte NF. Validation and calibration of physical activity monitors in children. *Obes Res* 2002;**10**:150–7.
43. Ntoumanis N, Myers ND. *An introduction to intermediate and advanced statistical analyses for sport and exercise scientists*. Chichester: Wiley; 2016.
44. Kline RB, editor. *Principles and practice of structural equation modeling*. 3rd ed. New York, NY: Guildford Press; 2010.
45. Willems MET, Bond TS. Comparison of physiological and metabolic responses to playing Nintendo Wii sports and brisk treadmill walking. *J Hum Kinet* 2009;**22**:43–9.
46. Worley JR, Rogers SN, Kraemer RR. Metabolic responses to Wii Fit video games at different game levels. *J Strength Cond Res* 2011;**25**:689–93.
47. Lyons EJ, Tate DF, Ward DS, Bowling JM, Ribisl KM, Kalyararaman S. Energy expenditure and enjoyment during video game play: differences by game type. *Med Sci Sports Exerc* 2011;**43**:1987–93.
48. Ekelund U, Luan J, Sherar LB, Esliger DW, Griew P, Copper A. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. *JAMA* 2012; **307**:704–12.
49. Kondric M, Sindik J, Furjan-Mandic G, Schiefler B. Participation motivation and student's physical activity among sport students in three countries. *J Sports Sci Med* 2013;**12**:10–8.
50. Gao Z, Zhang T, Stodden D. Children's physical activity levels and their psychological correlates in interactive dance versus aerobic dance. *J Sport Health Sci* 2013;**2**:146–51.