# The Cognitive Benefits of Playing a Casual Exergame

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## ABSTRACT
Acute cognitive benefits, such as temporary improvements in concentration, can result from as few as ten minutes of exercise; however, most people do not take exercise breaks throughout the day. To motivate people to receive the cognitive benefits of exercising in short bursts multiple times per day, we designed an engaging casual exergame. To determine whether there are cognitive benefits after playing our game, we conducted two studies to compare playing ten minutes of our casual exergame to a sedentary version of the game or exercise on a treadmill. We found acute cognitive benefits of the casual exergame over the sedentary version (but not treadmill exercise), demonstrated by significantly improved performance on two cognitive tests that require focus and concentration. Finally, our casual exergame produces similar exertion levels to treadmill exercise, but is perceived as more fun.

## Keywords
Exercise; casual game; exergame; cognitive benefits.

## 1. INTRODUCTION
Regular exercise has general physical and cognitive benefits. Also, research shows that both single long bouts of physical activity and as few as 10 minutes of short bouts of moderate-intensity exercise can generate acute (i.e., short and temporary) cognitive benefits [15,18,24]. If performed three times daily, people doing 10-minute bursts of physical activity could not only get the physical benefits of a sustained 30-minute block of exercise [4,8,17], but could also improve their focus and concentration throughout the day [27].

To make it convenient for people to exercise for only ten minutes multiple times a day, exercise activities must be accessible and require little time to set up, such as running up and down stairs; however, these short-duration activities are not much fun. *Casual exergames* are computer games that players can learn easily and access quickly, using simple rules and special game mechanics, to motivate them to exercise at a moderate intensity for short periods of play [25]. Casual exergames are engaging, and have been shown to elevate players' heart rates to target levels for moderate-intensity aerobic exercise [25]. What remains unclear is whether playing casual exergames can result in acute improvements in cognition and whether the benefits produced are as pronounced as those produced by performing traditional exercise activities, such as running.

To investigate the potential cognitive benefits of casual exergames, we conducted two studies examining the efficacy of casual exergames and the effects of casual exergame play on cognition. We used a game that we previously developed, which was shown to produce moderate-intensity levels of physical activity when played using a Microsoft Kinect [25]. We compared our casual exergame to a sedentary version of the game played with a mouse, and to traditional exercise (running on a treadmill). In a second study, we further explored the cognitive benefits of our casual exergame compared to the mouse-based version. Study 1 showed evidence of cognitive benefits of the Kinect and exercise conditions over the mouse condition, as measured by a Stroop test [11]. In Study 2, participants performed significantly better on the d2 test of attention [3] and on a standard math test [23] after playing the casual exergame version as compared to the sedentary mouse-based version. Finally, both studies showed that our casual exergame produces similar physical benefits to exercise on a treadmill, but is perceived as more fun.



## 2. RELATED WORK
To obtain the benefits of exercise, people should do at least 30 minutes of moderate-intensity exercise a day; however, most people do not perform this suggested amount [27], citing issues such as a lack of time, not making exercise a priority, and being too lazy. Physical benefits of regular exercise are well-known, such as reducing the risks of developing coronary heart disease, hypertension, high blood pressure, cancer, obesity, and diabetes [27]. Also, there are cognitive benefits of regular exercise such as improvements in memory, visual perception, and processing speed [5]. In addition to the general relationship between aerobic fitness and cognitive function, researchers have also shown acute (i.e., short and temporary) cognitive benefits after single bouts of exercise using a number of cognitive tasks, such as the Working Memory Task [15] and the Stroop test [18,24], which measures concentration. Although most studies examining the acute benefits of exercise use longer bouts of activity, cognitive benefits can be found after performing as few as 10 minutes of moderate-intensity exercise [24]. Performing exercise in small chunks also does not reduce the physical benefits as research shows that the physical benefits of three moderate-intensity 10-minute bout are similar to one continuous 30-minute bout [4,8,17].

One way to make people exercise in an enjoyable way is through exergames [12] which can motivate players to be more physically active by combining games and exercise together. In general, research shows that exergames are fun, but there are different options about whether exergames have the same benefits as regular exercise. Some researchers argue that many exergames can be utilized as part of an overall aerobic exercise program [19]. However, another study shows that the energy that players used to play active Wii Sports games was not of high enough intensity to reach the recommended daily amount of exercise in children [6]. A meta-analysis of active video game (AVG) play confirms that exertion is well below thresholds for vigorous-intensity exercise [1]. In addition, it is also controversial whether exergames can provide similar cognitive benefits as exercise. Using a modified flanker task, O'Leary et al. [13] show that exergames (WiiFit) cannot exert the same benefits to brain and cognition as traditional exercise even though there was no difference in heart rate produced during play [13]. Staiano et al. [21], however, show cognitive benefits of Wii Active play in terms of visual spatial skills using the Bender-Gestalt test and executive functioning using the Delis-Kaplan Executive Function Scale [21]. Neither WiiFit nor Wii Active are considered to be games in the traditional definition [16], but rather are interactive exercise applications, so it is still unclear as to whether exergame play yields cognitive benefits. Playing non-active video games has also been linked to cognitive benefits, such as increased attentional capacity [7].

In terms of casual games, there is general agreement that for a game to be considered casual, it must: be easy to learn with limited instructions and simple rules and controls [9,28]; have short play times [29] and allow players to put the game on hold [9]; and should not contain objectionable content [28] to appeal to a broad range of players [29]. Therefore, games such as Tetris and Bejeweled can be considered as casual games.

Casual exergames apply the principles of casual game design to the design of exergames. Specifically casual exergames are defined as computer games that players can learn easily and access quickly, using simple rules and special game mechanics, to motivate them to exercise at a moderate intensity for short periods of play [25]. Some argue that exergames developed for gaming consoles, such as Wii Sports, can be considered casual exergames because they are easy to learn, use simple controls, and are family friendly. However, as previously described, many AVGs do not provide the required moderate-intensity exercise to be considered a casual exergame by our standards. In addition, if casual games are to be played in short play periods, they must have minimal setup time [28]. If setting up a console game requires even five minutes to boot the system, navigate menus, and calibrate controllers, then it is not in line with the duration of play expected of a casual game. Finally, the accessibility of gaming consoles, which are generally kept in domestic environments, limits their use as systems on which to play casual exergames during breaks at work or school.

# 3. STUDY 1

We compared our casual exergame to a sedentary version of the game played using a mouse, and exercise on a treadmill.

## 3.1 Experimental Conditions

Our study had three conditions. In the casual exergame condition, participants played the game using their body as the controller. Movements were sensed using a Microsoft Kinect sensor. In the sedentary condition, they played the game using a mouse as a controller. In the exercise condition, they ran on a treadmill. In this condition, we checked their heart rate every minute and adjusted the speed and incline of the treadmill to keep them within 64-76% of their target heart rate, representing moderate-intensity activity (Figure 1).

**Figure 1. Three conditions (L-R): Kinect, Mouse, Exercise.**

## 3.2 Task: GrabApple Game

GrabApple (Figure 2) is a casual exergame that can be played in 10-minute sessions. The goal of this game is for players to pick up falling red and green apples and avoid touching the falling bombs. Apples and bombs are picked and touched using a virtual hand on the screen. There are two versions of GrabApple – in the Kinect version of the game, the virtual hand is controlled through the movement of the player's body, using the player's own body weight as resistance to generate exercise. Also, we use game mechanics to motivate people to jump, duck and move around. In the mouse version of the game, we use a regular mouse to control the virtual hand on the screen; see [25] for a complete description.

**Figure 2. Screen shot of the GrabApple game.**

## 3.3 Procedures and Methods

The study took place over four consecutive days. On Day 1, participants were introduced to the study, gave informed consent, and were screened for colour vision deficiencies (CVD) using an online version of the PseudoIsochromatic Plate Ishihara Compatible (PIP), because people with CVD perform worse on the Stroop test [10], which we used as a cognitive measure (Please refer to our long version paper for Stroop test details [26]). Participants were also screened using the Physical Activity Readiness Questionnaire (PAR-Q) to look for risk factors that may be exacerbated by exercise.

After completing a demographics questionnaire, we introduced participants to The Borg Rating of Perceived Exertion (RPE) [2] questionnaire. We also introduced them to the Stroop Color and Word Test [11] that we used to measure cognitive performance and had them complete a training version. Finally, we explained the game rules and the experiment conditions, after which players trained in the Kinect and Mouse versions of GrabApple for one minute each.

On Days 2, 3, and 4, participants completed one of the three experiment conditions (Kinect, Mouse, Exercise). Order of condition was fully counterbalanced across all participants to minimize learning effects. Participants completed the experiment at the same time each day and were asked not to perform exercise prior to the study each day or consume caffeine or smoke for three hours prior to each session.

Participants performed that day's condition for 10 minutes. During the activity, they wore a heart-rate monitor (Garmin Foreruner 110) that measured their heart rate and the approximate number of Calories (kcal) burned. Then, participants filled out the Borg RPE scale. After 5 minutes of recovery time, participants performed the Stroop test, then the post-condition questionnaire.

## 3.4 Participants and Apparatus

Twenty-four participants (13 males), aged 19 to 30 (mean of 24) were recruited from a local university. The game was played on a Windows 7 PC with a 20-inch monitor. A low resolution (800×600) was used as players stood about 1.5m from the display in the Kinect condition.

## 3.5 Results of Study 1

We performed a repeated-measures MANOVA on the dependent measures of %maxHR, perceived exertion and Calories burned, with experiment condition as a factor (Kinect, Mouse, Exercise). Pairwise comparisons used the Bonferroni method of correction and all tests were conducted with α=.05. When the sphericity assumption was violated, Huynh-Feldt's method of adjusting the degrees of freedom was used. Questionnaire responses were analyzed with Friedman's Analysis of Variance of Ranks, with pairwise comparisons made with Wilcoxon Signed Ranks Tests.

### *3.5.1 Exertion and Participants' Response*

The American College of Sports Medicine defines moderate-intensity exercise as 64-76% of maximum heart rate (maxHR=220-age) [22]. The average %maxHR of our players is in Table 1. These values are within the range of moderate-intensity exercise for the Kinect and Exercise conditions. The differences in %maxHR were significant ($F_{1.7,38.1}$=195.4, $p$≈.000, $\eta^2$=.90). Pairwise comparisons showed that the Mouse game produced significantly lower %maxHR than the Kinect game (p≈.000) and Exercise (p≈.000), and that there was no significant difference between Kinect and Exercise (p=.110).

**Table 1. Means and SDs for measures of exertion and fun.**

| | % of Maximum Heart Rate | Calories Burned | Borg RPE | Fun (1-5) |
|---|---|---|---|---|
| Kinect | 74.5 (9.8) | 97.2 (20.7) | 12.5 (1.6) | 4.5 (0.5) |
| Exercise | 69.9 (3.7) | 86.2 (15.9) | 11.7 (1.0) | 2.5 (0.8) |
| Mouse | 42.7 (5.3) | 26.9 (10.6) | 6.8 (0.8) | 3.9 (0.8) |

The average Calories burned in the 10 minutes of activity are shown in Table 1. If we assume play for three 10-minute bursts/day, the average Calorie expenditure would be 291, 259, and 81 for the Kinect, Exercise, and Mouse conditions respectively, which exceeds the recommended 200 Calories per day that adults should burn through aerobic exercise [14] for the Kinect and Exercise conditions, but not the Mouse condition. The differences in Calories burned were significant ($F_{2.46}$=135.8, $p$≈.000, $\eta^2$=.86). As with %maxHR, pairwise comparisons revealed that the Mouse game produced significantly lower Calories burned than the Kinect game (p≈.000) and Exercise ($p$≈.000), and that there was no significant difference between Kinect and Exercise ($p$=.157).

The average Borg Rating of Perceived Exertion after each activity is in Table 1. The Kinect game produced perceived exertion values within the recommended intensity for improving aerobic capacity (12-13: somewhat hard to 15-16: hard) [20]. The differences in perceived exertion were significant ($F_{2,46}$=166.1, $p$≈.000, $\eta^2$=.88). Again, pairwise comparisons showed that the Mouse game produced significantly lower perceived exertion than the Kinect game ($p$≈.000) and Exercise ($p$≈.000), and that Kinect and Exercise were not significantly different ($p$=.116).

We also asked participants to rate the fun of each activity on a 5-point scale. The results are shown in Table 1. Friedman's test showed significant differences in ratings for fun ($\chi^2_2$=27.7, $p$≈.000). Pairwise comparisons showed that the Kinect version was perceived as more fun ($p$=.019) than the mouse version and exercise ($p$≈.000), while the mouse version was perceived as more fun ($p$=.001) than exercise

The Stroop test showed evidence of cognitive benefits of the Kinect and exercise conditions over the mouse condition (please refer to [26] for more information), suggesting that there was a systematic (but not significant) effect of casual exergame play on cognitive performance. Thus we conducted a second study to better explore the cognitive effects.

# 4. STUDY 2

In this study, we focused on the potential cognitive benefits of casual exergame play as compared to playing an identical, but sedentary, version of the game. We chose two cognitive tests – the d2 test of attention and the WRAT4 Math Computation test (Please refer to [26] for more details).

## 4.1 Participants and Procedure

Twenty-four participants (14 males), aged 19 to 33 (mean of 25), who did not participate in Study 1, participated.

The procedures for Study 2 were identical to Study 1, with few exceptions. Because players completed only two conditions, the study happened over two days instead of four (the study introduction occurred on Day 1). Also, players were introduced to the d2 test of attention and the WRAT4 Math Computation test rather than a Stroop test. Finally, we did not require players to complete a CVD test, as neither cognitive test is affected by CVD. The experimental apparatus was the same as used in Study 1.

## 4.2 Results of Study 2

Paired-samples t-tests ($\alpha$=.05) were used to compare the exertion and cognitive performance of the players in the two conditions. Based on Study 1 (and related research), we expected that players would exert more energy, and have better cognitive performance after playing the Kinect version, so we used one-tailed tests. Wilcoxon Signed Ranks tests were used to compare results from questionnaires on player preference.

### *4.2.1 Exertion and Participant Responses*

As expected, playing the Kinect version of the game was more exertive than playing the Mouse game as measured by %maxHR ($t_{23}$=17.2, $p$≈.000), Calories burned ($t_{23}$=11.4, $p$≈.000), and the Borg RPE ($t_{23}$=15.2, $p$≈.000). See Table 2. There was no significant difference in terms of ratings for fun (Z=0, p=1.0).

**Table 2. Means and SDs for measures of exertion and fun.**

| | % of Maximum HR | Calories Burned | Borg RPE | Fun (1-5) |
|---|---|---|---|---|
| Kinect | 72.9 (11.7) | 85.6 (26.6) | 12.9 (1.8) | 4.0 (0.7) |
| Mouse | 41.3 (8.4) | 25.9 (10.0) | 7.2 (1.1) | 4.0 (0.7) |

### *4.2.2 d2 Test of Attention.*

Participants performed significantly better on the d2 test after playing the Kinect version of the game than after playing the mouse version of the game in terms of speed (TN) and overall performance (TN-E and CP). However, there were no significant differences in terms of accuracy (E, E%). See Table 3.

**Table 3. Means and SD for d2 measures. Results of t-tests.**

| | TN | E | E% | TN-E | CP |
|---|---|---|---|---|---|
| Kinect | 479 (57) | 16 (14) | 3.3 (2.7) | 463 (51) | 186 (23) |
| Mouse | 456 (65) | 21 (18) | 4.6 (3.7) | 435 (61) | 171 (30) |
| $t_{23}$, $p$ | 2.27, .017 | 1.38, .091 | 1.6, .066 | 2.38, .013 | 2.25, .018 |

### *4.2.3 WRAT4 Math Computation Test.*

Participants scored higher on the math test after playing the Kinect version of the game (Mean=49.9, SD=3.4) than after playing the mouse version (Mean=48.2, SD=6.1). This difference was statistically significant ($t_{23}$=1.769, p=.045).

## 5. DISCUSSION AND CONCLUSION

Our results can be summarized in three findings. Playing a casual exergame for ten minutes resulted in:

- Exertion levels similar to running on a treadmill and significantly higher than playing a sedentary casual game;
- Greater perceived fun than treadmill exercise;
- Improved performance compared to a sedentary casual game on two cognitive tests that measure concentration.

Our results clearly show acute cognitive benefits of casual exergame play; however, there are limitations in what we can infer from our studies and new questions that are raised. First, the improvements were shown in tests administered five minutes after exercise; we do not know how long these acute benefits last. Second, the measured cognitive benefits were acute, i.e., short and temporary. Whether repeated casual exergame play over the long term would result in the general cognitive benefits seen in people with good aerobic fitness remains to be seen. Third, our players were motivated to play the casual exergame for ten minutes at a moderate-level of intensity. Outside of the context of our experiment, we do not know how much physical effort players would put into playing GrabApple. Finally, we saw improvements by comparing performance after playing an exergame to performance after a mouse-based game. We are currently investigating the size of the benefit by studying improvements to baseline performance.

Our study is the first to show that playing a casual exergame for ten minutes at a time can produce physical activity levels similar to traditional exercise on a treadmill, but be perceived as more fun, and can produce acute cognitive benefits over playing a sedentary version of the same game.

## 7. ACKNOWLEDGEMENTS

Thanks to the GRAND NCE and NSERC for funding.

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