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Response Inhibition to High Calorie Food Cues Among Adolescents

Following Active and Sedentary Video Game Play Using a

Go/No-Go Task: A Randomized Crossover Study

Joshua L. Smith

A dissertation submitted to the faculty of
Brigham Young University
in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

Bruce Bailey, Chair
Michael J. Larson
James LeCheminant
William Christensen
Larry Tucker

Department of Exercise Sciences

Brigham Young University

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ABSTRACT

Response Inhibition to High Calorie Food Cues Among Adolescents Following Active and Sedentary Video Game Play Using a Go/No-Go Task: A Randomized Crossover Study

Joshua L. Smith
Department of Exercise Sciences, BYU
Doctor of Philosophy

Sedentary behaviors, such as leisure time computer use and sedentary video games, are significant barriers to regular physical activity and contribute to high rates of overweight and obesity among adolescents. Sedentary screen time can adversely affect food intake and food selection. Active video games may be a promising way of increasing daily physical activity levels among adolescents. Active video games may help modulate response inhibition and food intake. PURPOSE: Compare the effects of an acute bout of active and sedentary video gaming on N2 amplitudes (while viewing high calorie and low calorie images), Stroop Color Word Test (Stroop test) performance and ad libitum eating. METHODS: We used a within-subjects randomized crossover design with counterbalanced treatment conditions was used among 65 participants (31 girls, 34 boys; age = 13.5 ± 1.1 year; height = 161.4 ± 10.2 cm; weight = 52.5 ± 12.3 kg; BMI = 19.9 ± 3.3 kg·m^2). Participants completed 2 separate video gaming sessions, 7 days apart, while energy expenditure during sedentary and active video game play was measured using the K4b^2 portable metabolic system. The K4b^2 system provided metabolic equivalents (METs) which are used as a measure of energy cost of physical activity. After either 60 minutes of active or sedentary video game play, participants completed a go/no-go task while viewing high calorie and low calorie images while electroencephalogram (EEG) data were collected. N2 event related potential (ERP) amplitudes were measured during the viewing task. Participants also completed a Stroop task to measure response inhibition. Finally, participants were given high calorie and low calorie snacks to consume ad libitum. We used a repeated measures ANOVA was used to measure main and interaction effects for N2 ERP amplitudes within subjects. RESULTS: Active video game play relative to sedentary video games significantly increased METs ($F = 543.1$, $p \leq 0.0001$) from 1.7 ± 0.35 to 5.0 ± 1.2 METs. A significant gender-by-condition interaction ($F = 7.03$, $p \leq 0.009$) was observed for energy expenditure with boys (5.4 ± 1.1 METs) expending more energy during the active video game than girls (4.5 ± 1.1 METs). No significant differences were observed for the N2 component ($F = 0.50$, $p = 0.48$) between video game conditions nor between genders ($F = 1.85$, $p = 0.17$). There were no significant differences ($F = 3.10$, $p = 0.08$) in the total number of calories consumed between the 2 video gaming conditions. Results from the Stroop task showed no significant differences for word naming ($F = 0.45$, $p = 0.49$), congruent condition ($F = 0.43$, $p = 0.52$) and incongruent condition ($F = 0.14$, $p = 0.71$) between the active and sedentary video games. CONCLUSION: Sixty minutes of active video gaming increases energy expenditure to a moderate intensity level but does not alter behavioral response or response inhibition to high calorie or low calorie foods.

Keywords: response inhibition, acute physical activity, N2, go/no-go task

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Table of Contents

List of Tables

List of Figures

INTRODUCTION

Increasing physical activity among adolescents is important to reduce the number of overweight and/or obese individuals.[1] More than 30% of children and adolescents in the United States are overweight or obese.[1] Current physical activity guidelines recommend adolescents accumulate at least 60 minutes of physical activity each day; however there are few adolescents who accumulate enough physical activity to meet these recommendations.[2-9] Sedentary behaviors and excess caloric intake each contribute to overweight and obesity and are of particular concern for at risk segments, such as adolescents.[7,9]

Sedentary behaviors such as leisure time computer use and sedentary video games are significant barriers to regular physical activity.[10] Sedentary screen time decreases the odds of meeting daily recommended physical activity among adolescents.[4,11,12] Sedentary screen time presents a challenge because of its increase in popularity among adolescents over the last decade.[13] Adolescents spend an average of 65 minutes per day playing sedentary video games and 83% of adolescents report access to a gaming console in their bedrooms.[14] Over 40% of adolescents spend 3 or more hours per day using a computer (compared to 22% in 2003) for nonschool related items and nearly 25% of adolescents spend 3 or more hours watching television.[15] Longitudinal data provides evidence that television viewing, video game play and leisure time computer use among adolescents increases as they age. [4,5,13]

Conversely, physical activity levels decrease with age from preteen years into early adulthood.[9] A recent national survey found that only 27% of adolescents participate in regular physical activity of any type, during or outside of school, that makes them sweat or breathe hard for at least 60 minutes per day.[15] Additionally, when physical activity is measured objectively by accelerometers, less than 15% of adolescents (ages 12–19 years) accumulate 60 minutes per day of moderate to vigorous physical activity.[16] A cross-sectional study of 1,578 adolescent girls from 6 U.S. states reported sedentary, light, moderate and vigorous activity levels using accelerometers. Results of this study showed, on average per day, girls spent 460 minutes in sedentary activity, 341 minutes in light activity, and 18 minutes of moderate intensity activity and 6 minutes of vigorous activity per day, compared to the national guidelines for adolescents of 60 minutes of moderate intensity activity needed per day.[17]

In addition to the negative impact on physical activity, sedentary screen time can also have an adverse effect on food intake and food selection.[18,19] Matheson et al showed children consumed as high as 26% of their daily calories during sedentary screen time.[20] Crespo et al[21] found that children who watched 4 or more hours of television per day had a higher prevalence of obesity. Even a single session of 60 minutes of sedentary video game play is associated with increased food intake among boys.[22]

To offset the negative impacts of sedentary screen time, active video games seem to be a promising way of increasing daily physical activity levels among adolescents.[23,24] Active video games require physical movement to interact with a gaming console instead of a handheld controller. Recent reviews of active video games demonstrate their capacity to increase energy expenditure and heart rate among adolescents.[23,25,26] Experimental data among children and adolescents showed a significant increase in daily physical activity levels and energy expenditure in children who participate in active video games.[24,27] Active video games have also been shown to increase physical activity levels to the point of improving cardiovascular endurance.[28] Graf et al compared cardiovascular endurance between active video games and treadmill walking and found both forms of physical activity had similar responses in heart rate, ventilatory rate and VO_2max.[29]

Active video games have been shown to elicit moderate intensity levels (3.0 to 6.0 metabolic equivalents, METs) of physical activity.[30-32] A recent systematic review of 18 studies compared active video games to sedentary video games and found that active video games increased activity levels and heart rate to moderate intensity levels.[23] Biddis et al investigated different types of active video games and reported higher energy expenditure and heart rate responses among active video games that involve more lower body movements.[23] Another systematic review analyzed 9 studies to examine the different types of active video games and their associated energy expenditure.[30] The results showed active video games from these studies elicited an average energy expenditure of 3.2 to 6.0 METs.[30] Both of these reviews support the use of active video games as a means to increase energy expenditure and to meet physical activity recommendations for adolescents.[23,30] Dancing type active video games required an energy expenditure that ranged between 2.9 to 4.9 METs.[33] Boxing type active video games showed an average energy expenditure of 3.0 to 5.2 METs.[34,35] Active video games that involved jumping, side-stepping or running had higher energy expenditure levels ranging from 5.2 METs to 5.9 METs.[24,30] Additional studies have found that the energy expenditure during active video games compares favorably to treadmill walking in adolescents.[29,33]

In addition to improving energy expenditure and physical activity levels, active video games may also help modulate food intake and feelings of hunger.[36,37] Feelings of hunger and appetite have most commonly been measured and analyzed using self reported questionnaires.[36,37] Advanced cognitive measuring techniques, such as functional magnetic resonance imaging (fMRI) and electroencephalogram (EEG) using event related potentials (ERPs), have been used recently to provide quantitative analysis of neural related correlates of appetite and food intake.[38-40] EEG, ERP and fMRI procedures can measure and record increased blood flow (fMRI) and electrical changes in neural activation (EEG/ERP) of reward regions of the brain after viewing images of food.[41,42] Increases in blood flow and neural activation to reward regions of the brain have been used to index food motivation.[43]

Electrical activity of the brain can be measured, recorded and analyzed to provide insight into response inhibition.[44] EEG techniques record event related potentials (ERP's) which is an effective method for measuring response inhibition among adults.[45-47] ERP's are generated when an excitatory or inhibitory neurotransmitter is released creating a net negative extracellular voltage.[48] ERP's are summated postsynaptic potentials which are greatly amplified and then averaged.[48] The N2 is a specific ERP with distinguishing characteristics (ie, amplitude and latency) that serves as an index for response inhibition.[49,50] Specifically, N2 amplitudes are more negative during trials requiring response inhibition than trials where participants do not inhibit their response.[50] The current study measured neural activity from the brain using ERP techniques with previously validated methods.[44,49,51]

Several studies using fMRI techniques report acute bouts of high intensity physical activity on a treadmill and cycle ergometer suppressed appetite and decreased total daily food intake among adults.[37,52-55] These findings are supported by additional evidence that moderate intensity exercise reduces neural responses to images of food in reward regions of the brain among adults, as measured by fMRI.[56] Complimentary data from ERP studies provide temporal insight into the effects of exercise on response inhibition.[45,47]

Response inhibition is a cognitive process which requires the suppression of inappropriate or unwanted actions in a given context.[57-60] In the context of food, response inhibition is the cognitive process which allows a person to resist eating, ignore distractive food stimuli and prevent impulsive behavior related to food choices.[60] Response inhibition is important when making decisions on what and how much to eat.[19] The magnitude of the brain's response when required to inhibit can be used to predict food intake while the lack of response inhibition is associated with overeating.[61,62] In addition to the ERP measurements of response inhibition, the current study used the Stroop Color Word Test (Stroop test), a behavioral measure of response inhibition. The Stroop test is reliable and a commonly used instrument to measure executive function and general response inhibition that has previously been validated for test retest reliability.[63]

There are many possible modulators of response inhibition related to food. One that seems to be important is physical activity. Several studies have shown that response inhibition is enhanced during and after acute bouts of physical activity although many of the details of this relationship are still unclear.[57-59,64,65] Joyce et al suggested moderate intensity physical activity improved response inhibition among adults during and after acute physical activity by improving nervous system activation.[64] Chang et al proposed that moderate intensity physical activity increases attention allocation and information processing.[65] Additional research by Soga et al supports moderate intensity physical activity as a means to exert a positive effect on response inhibition among adolescents.[66]

No studies to date have examined response inhibition after active or sedentary video games comparing high calorie and low calorie food images. Thus, it is unclear how an acute bout of moderate intensity exercise from active video games affects inhibition among adolescents. The purpose of this study was to compare the effects of 60 minutes of active versus sedentary video game play on N2 amplitudes and response inhibition to viewing pictures of high calorie and low calorie food images. The secondary outcomes of the study were to compare the effects of 60 minutes of active and sedentary video game play on Stroop test performance and ad libitum eating.

METHODS

Overview

We used a within subjects randomized crossover design with counterbalanced treatment conditions was used to compare the amount of neural inhibition to high calorie and low calorie food cues among adolescents between two conditions. These two conditions included a 60 minute session of active video game play and a 60 minute session of sedentary video game play. During each laboratory session, EEG data was recorded and then later analyzed to assess the individual ERP components following each of the two conditions. Participants completed a go/no-go response inhibition viewing task with pictures of high calorie and low calorie foods displayed on a computer monitor. The Stroop test for response inhibition was administered immediately following the cessation of the go/no-go viewing task. Following the Stroop test, participants were provided snacks to consume ad libitum.

Participants

A total of 105 applicants (56 boys, 49 girls) was assessed for eligibility. Nine were excluded for noneligibility (8 boys, 1 girl) due to attention deficit hyperactive disorder and 27 (15 boys, 12 girls) declined to participate. Sixty nine participants (36 boys, 33 girls) were allocated to the intervention. Four participants (3 boys, 1 girl) completed only 1 session and their data was not included in the analysis. Three participants (2 boys, 1 girl) had incomplete EEG data and were not included in the data analysis. A total of 62 participants (32 boys, 30 girls) were included in the final data analysis (see Figure 1). The mean age (years) for the girls was 13.3 ± 1.2 and 13.7 ± 1.0 for boys. There were no differences in body mass index ($kg \cdot m^2$) for boys 20.0

± 3.4 compared to girls 19.7 ± 3.2. Additional descriptive characteristics for the participants are shown in Table 2. Participants were excluded if they had any chronic or metabolic disease, orthopedic impairments, were diagnosed with an eating disorder (ie, anorexia, bulimia or binge eating disorder), and used medications that alter metabolism, appetite or neurological function, had a diagnosed learning disability, neurological disorder, brain injury or attention deficit /hyperactive disorder or had any food allergies. Participants had normal or corrected to normal vision. Participants completed a physical activity readiness questionnaire (PAR-Q) as part of the inclusion criteria to ensure their ability to participate in moderate intensity physical activity without restrictions. The PAR-Q contained questions regarding contraindications to physical activity.[67] Any 'yes' response on the PAR-Q excluded participants from participation in the study. Approval from the university's Institutional Review Board was obtained prior to recruitment and testing. In addition, all participants provided written assent and a parent or guardian provided written consent. Participants completed two different lab sessions 7 days apart.

Procedures

Candidates for the study and their guardians were sent an email containing a link to an online survey. The online survey was a 'yes or no' questionnaire to ensure participants met inclusion criteria. As part of the online survey, participants were asked to report any food allergies and complete a food preference questionnaire. The food preference questionnaire was used to prepare the standardized meals for each participant. Qualifying candidates were then invited to participate in the study.

Participants and their guardians completed assent and consent forms prior to the first lab session. Participants came to the Clinical Neuroscience lab, located at the University Parkway

Center (room 136). Standardized meals were delivered 1 day prior to their first lab session. Each participant was informed of the main purpose of the study and familiarized with the testing procedures. Participants were instructed to avoid consuming caffeine and other stimulants on the testing day as well as avoid vigorous intense physical activity for the 24 hour period prior to testing. Participants received a copy of the testing instructions. Testing procedures and protocols were reviewed with each participant prior to initiation of each video gaming session. Participants were contacted 24 hours before each video gaming session to remind participants of the upcoming testing session.

At the beginning of each lab session, researchers verified that participants had followed food protocols, measured height and weight and completed hunger ratings. Participants were then fitted with the COSMED $K4b^2$ portable metabolic device ($K4b^{2)}$ and taken to the appropriate room containing either sedentary or active video gaming equipment. After 60 minutes of video game play, participants were led to an adjacent room containing the EEG equipment and there performed the go/no-go viewing task. At the end of the second lab session, participants completed a picture rating task of high calorie and low calorie images. Immediately following completion of the viewing task, researchers conducted the Stroop test in an adjacent room. This room was prepared with the ad libitum snacks while participants completed the viewing task. Upon completion of the Stroop test, researchers administered the Rey auditory verbal learning test (RAVLT) test during which there was a 20 minute waiting period when the participants could consume ad libitum the prepared snacks. Following the ad libitum eating and final segment of the RAVLT test, participants were given their meals for the next lab session (see Figure 2). Participants who completed both video gaming sessions and the accompanying tests received $40 dollars for completing the study.

Standardized Meals

Participants were given a standardized breakfast and lunch for each of the testing days based on a food preference questionnaire administered as part of the initial online screening. Meals were delivered to participants' homes the day before their first testing session and their second set of standardized meals were provided to them at the end of their first testing session. The energy needs for each participant were estimated using the World Health Organization equations for predicting basal metabolic rates.[68] These equations used height (cm), weight (kg) and age (years) to predict basal metabolic rates and have been validated for accuracy and reliability.[69,70] An activity factor of 1.6 for boys and 1.5 for girls was used to estimate total daily energy requirements.[68] Rodriguez et al also validated these prediction equations by comparing them to open circuit indirect calorimetry among 116 children and adolescents and found the prediction equations to be reliable and valid.[71]

Meals were prepared based on participants' food preferences which were obtained during the online screening of applicants and based on age, gender and energy needs.[72] Breakfast items consisted of protein bars, yogurt and apple slices. Lunch items included peanut butter and jelly sandwiches, cheese sticks and wheat thins. Participants were given 25% of their daily caloric requirements for breakfast and 25% for lunch.[68] Meals were designed to represent a reasonable amount of food to provide participants with adequate food intake.[73] Participants were given the same foods for each lab session, instructed to consume only the foods they were given, to consume all foods provided to them and to finish eating two hours before arriving at the lab.[74] They were further instructed to avoid caffeine consumption and vigorous intensity physical activity 24 hours prior to testing.[75] Meal adherence was assessed at the beginning of each session by asking participants if they consumed all of the food (and nothing else) provided by the researchers. Two boys dropped out of the study because of noncompliance to the food protocols. Any noncompliance (not eating all food and/or eating other foods) required participants to return to the lab on a different day when they had followed food protocols.

Anthropometric Measurements

Body weight and height were measured for all participants at the beginning of each lab session. Body weight was measured using a digital scale (Seca GmbH & Co., Hamburg, Germany) accurate to ± 0.1 kg, and height was measured by a stadiometer accurate to ± 0.1 cm (Seca GmbH & Co., Hamburg, Germany). Body mass index (BMI) was calculated as weight (kilograms) divided by the square of height (meters).

Video Gaming Conditions

Each participant completed 2 separate lab sessions (sedentary and active) separated by 7 days. The sedentary video game condition allowed participants to choose 1 of 3 sedentary video games to play on an XBOX 360 gaming console (Disney's Cars®, Minecraft® or NBA Live 2009®) in a seated position for 60 minutes. These 3 video games were chosen because each is played from the first person perspective, and they are among the most familiar to adolescent participants. Participants were given 3 choices of sedentary video games to ensure they had options that would allow them to play for 60 minutes continuously. Participants were given a brief familiarization period to understand how to play the sedentary video games. Participants could choose between the 3 sedentary video games and were allowed to change between sedentary game choices during their 60 minutes of play. Participants were monitored every 10 minutes to ensure metabolic recording and that they were playing the sedentary games. Researchers consistently monitored the participants during active video game play. The active video game condition required participants to complete 60 minutes of active video gaming at moderate intensity levels (3.0–5.9 METs) using an open source software dance simulation game called StepMania 5.0 (Cambridge, MA).[76] The active video game StepMania required participants to move their feet on a pressure sensitive mat in order to match the step patterns shown on the television screen. StepMania and other dance simulation games elicit moderate intensity (3.0–5.9 METs) levels of physical activity.[29] The StepMania game was set at beginner skill level for 60 minutes using 15 songs with music of ≥ 130 beats per minute. Each song was approximately 2 minutes in length. The 15 songs were played twice during the 60 minute active video gaming session. These settings have been previously validated to elicit moderate intensity physical activity levels.[23,77] Participants were continuously monitored during the active video game condition to ensure compliance to the protocol and participant safety.

Hunger Ratings

Participants were asked to rate their hunger at the beginning of each session using a 100 mm visual analog scale. This allowed us to assess if participants entered each condition with a similar state of hunger and desire to consume food. The visual analogue scale included 5 different questions. The 5 questions were as follows: 1 – how hungry do you feel right now (not at all to extremely); 2 – how full do you feel right now (not at all to extremely); 3 – how strong is your desire to eat (not at all to extremely); 4 – how much do you think you could eat right now (none to extreme amount); and 5 – what is your urge to eat (extremely low to extremely high). Stubbs et al[78] validated the use and test retest reliability of this and other visual analogue scales. Ratings were completed at the beginning of each video gaming condition.

Energy Expenditure

Energy expenditure during sedentary and active video game play was measured using the $K4b^2$ portable (COSMED, Rome, Italy) metabolic system along with a heart rate monitor (Polar, Helsinki, Finland) for both active and sedentary video gaming conditions. The $K4b^2$ provides a direct breath by breath measurement of carbon dioxide production and oxygen consumption to calculate energy expenditure. The $K4b^2$ uses a galvanic fuel cell to measure oxygen consumption and a nondispersive infrared analyzer to measure carbon dioxide production. The $K4b^2$ has been previously validated for breath by breath gas collection during submaximal and maximal exercise.[79,80] Duffield et al[81k4b2] compared the portable $K4b^2$ to a laboratory metabolic cart for accuracy among 12 healthy males during running on a treadmill at 3 different running speeds and durations. These results demonstrated the repeatability of the COSMED $K4b^2$ system with measurements for V_E, VO_2, and VCO_2 compared to a stationary laboratory metabolic system.[81] Additional studies support the validity of the $K4b^2$ for both prediction accuracy and measurement reliability of energy expenditure compared to other metabolic systems[79,80,82]

The $K4b^2$ data was saved on a secured computer for storage and analysis. As part of the $K4b^2$ testing, participants were fitted with a reusable cardiorespiratory fitness mask connected to a 28 mm optoelectronic reader and a Polar Heart Rate Monitor. Gas delay calibration was performed once at the beginning of each week on the $K4b^2$ device. Room air calibration and reference gas calibration tests were performed on the $K4b^2$ at the beginning of each testing day to ensure proper calibration of the device. Turbine calibration was performed before every gaming session as recommended by the manufacturer. Data points from the $K4b^2$ were plotted at 60 second intervals.

The energy cost of the video gaming sessions was quantified using METs. A MET (metabolic equivalent) is defined as the resting metabolic rate while sitting quietly and is quantified as $3.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. Exercise intensity, when using METs, is expressed in multiples of the resting metabolic rate. For example, 3 METs is exercise intensity 3 times the resting metabolic rate. The current study used METs in order to make comparisons of exercise intensities between the current study and from previous research easier. The $K4b^2$ data output provided METs for each of the video gaming sessions.

Response Inhibition Task

Immediately following both the active and sedentary video game conditions, participants completed 2 go/no-go active viewing tasks while EEG data were collected.[49] The go/no-go tasks included pictures of high calorie and low calorie foods. Pictures for the viewing tasks were selected based on findings from Blechert et al[83] who recently reported normative ratings of 568 high calorie and low calorie food images. The images were rated for valence, arousal, palatability, desire to eat, recognizability and visual complexity. These images were also rated for color composition, contrast, brightness, and size by nearly 2,000 participants.[83] In the current study, the first viewing task used a total of 150 pictures, 100 of which included high calorie pictures and 50 low calorie pictures; the low calorie images were used as the target or 'go' stimuli. The second viewing task included a total of 150 pictures, 100 low calorie pictures and 50 high calorie pictures; the high calorie images were set as the 'go' or target stimuli. Each of the viewing tasks were shown in a different random order for each participant.[84] The high calorie pictures included images such as chocolates, candies, and doughnuts; the low calorie pictures used images such as apple slices, celery sticks and carrots. Images were shown for 500 milliseconds with an intertrial interval of 1300 milliseconds between images.[84] Following the second response inhibition task, participants were asked to subjectively rate the pictures according to pleasantness and arousal by using a self assessment manikin (SAM) picture rating scale from 1–9 (with 1 the lowest and 9 the highest).[83] To determine participant understanding of low calorie vs high calorie foods, participants completed a short task at the end of their second lab session to categorize each food picture as either low calorie or high calorie. Participants rated all pictures following the conclusion of the second session and accurately identified the high calorie and low calorie images more than 90% of the time for both conditions (see Table 4).

Go/No-Go Paradigm

For the high calorie portion of the go/no-go task, participants were instructed to press a button with their right index finger when they saw an image of a low calorie food, which was the target stimuli. The low calorie foods were the target stimulus and the participants had to commit their response by pressing the appropriate button. This portion of the task was called "go." The "no-go" portion of the task required the participants to withhold pressing the button when images of high calorie foods were presented. The second go/no-go task used the opposite instructions of the first task. Participants were instructed to "go" or press a button when pictures of high calorie foods were presented and to withhold, or "no-go," when images of the low calorie foods were presented. The high calorie foods were the target stimuli. Images for both tasks were presented in random order using 150 pictures displayed for 500 m milliseconds with an intertrial interval of 1300 milliseconds. Participants were instructed to remain as still as possible and to minimize their eye blinks to reduce the number of artifacts (disruptions or noise) while EEG data were recorded.[48,49]

Electrophysiological (EEG) Data Recording

Electrical brain activity was recorded using EEG techniques using the Electrical Geodesics amplifier system (EGI: Electrical Geodesics Inc., Eugene, OR). The EEGs were recorded continuously with a sampling rate of 250 Hz using a 24 bit analog to digital converter. The vertex sensor served as the reference electrode. Impedances were kept below 50 kΩ according to EGI guidelines.[85] A right posterior electrode approximately 2 inches behind the vertex electrode was used as the common ground. Electroencephalographic data was segmented off line and single trial epochs rejected if voltages exceeded 100 μV, transitional (sample to sample) thresholds were greater than 100 μV or eye channel amplitudes were above 70 μV. Offline, data were digitally rereferenced to an average reference then digitally low pass filtered at 30 Hz.

Participants were fitted with a 128 site geodesic sensor cap covering their head and given instructions for the go/no-go task. Participants were seated approximately 17 inches away from a 20 inch computer monitor with the middle of the computer monitor at eye level to the participant.[49] Participants viewed pictures which have been validated and matched for color, texture and size.[83] Participants were assessed using EEG equipment following both the active and sedentary video gaming sessions.

Mean amplitudes were recorded from ERP components between 100 and 350 milliseconds and between 400 and 600 milliseconds. The N2 component of the ERP served as the index to quantify inhibition and thus was the primary component of focus.[85] The N2 component was expected to be larger as participants viewed pictures of high calorie vs low calorie foods. The N2 component was quantified as the mean amplitudes between 100 and 350 milliseconds.[45] The ERPs were epoched from 250 to 400 milliseconds (the N2 was later in adolescents than adults) and averaged across 4 frontocentral electrode locations (6 [FCz], 7, 106, and 129 [Cz]).[61] The 200 millisecond segment prior to the onset of the stimulus was used for baseline adjustments.[87]

Of the participants who completed both the active and sedentary sessions, 4 were subsequently excluded due to poor EEG data quality. Poor EEG data quality was defined as having insufficient ERP trials for reliable ERP averages above .70. The final sample for ERP analysis, therefore, included 62 individuals (32 boys, 30 girls) who completed both the active and sedentary video game sessions. Given that reliability is dependent on the context of a specific task and sample[88] we calculated estimates (a generalizability theory [G theory] analogue of reliability) for each condition separately using formulas provided by Baldwin et al[89] in the ERP Reliability Analysis (ERA) Toolbox v 0.3.2[90] using CmdStan v 2.10.0 (Stan Development Team, 2016). Final dependability estimates, 95% credible intervals, mean number of trials, and trial count range as a function of condition are presented in Table 1. Overall, conditions showed high to excellent dependabilities for all conditions in both the active and sedentary conditions.[88] Thus, different dependabilities between conditions do not represent a confound of the ERP analyses.

Stroop Color Word Test

Following the EEG data recordings, participants completed a Stroop test to assess selective attention to task relevant information and inhibitory control of task irrelevant information. The Stroop test is a reliable and commonly used instrument to measure a variety of cognitive functions and general response inhibition and it consists of 3 parts.[63] Part 1, participants read words, printed in black ink, which are names of colors. Part 2, participants named the color of x's printed in 3 different colors of ink. The second part was referred to as the congruent condition. Part 3, participants named the color of ink in which the words were printed (ie, to say "blue" when the word "red" is printed in blue ink). This third part was referred to as the incongruent condition.[91] The number of items correctly identified in 45 seconds after each condition was recorded. Participants who were 12–14 years old were given the children's version of the Stroop test, while those 15 years old were given the adult version, in accordance with

Stroop testing guidelines for administration and interpretation.[92] Higher scores indicated the participants responded correctly and had stronger inhibition of task irrelevant information.[63]

Rey Auditory Verbal Learning Test

To further examine the behavioral effects of moderate intensity video game play on ad libitum eating, participants were given several food choices while completing the Rey auditory verbal learning test (RAVLT). This test was administered as a means to keep the participant in the lab and test their actual food choices in an ad libitum setting. The RAVLT was administered according to the protocol validated by Vakil et al which is described previously.[93] After the sixth trial of the RAVLT, participants were given 20 minutes before the final portions of the learning test to consume high calorie and low energy dense foods ad libitum. During the 20 minute delay period, participants were given snack foods to consume ad libitum. Following the 20 minutes of ad libitum eating researchers finished the final portion of the RAVLT test, which consisted of 2 additional word recall trials. Completion of the RAVLT test concluded the entire session. The RAVLT was not used for data collection purposes. The test was used as a sham to keep the participants in the lab for the ad libitum eating portion of the intervention.

Ad Libitum Eating

Participants were presented with high calorie and low calorie snacks after completion of a auditory verbal learning test. The food items used during the ad libitum eating were chosen a priori and participants were asked to indicate (during the online food preference questionnaire) that they liked these snack choices. High calorie snacks included chocolate candies, cookies, potato chips, beef jerky and snack crackers. Low calorie snacks included apple slices, baby carrots and snap peas. These snacks were premeasured and weighed to the nearest 0.1 gram beforehand and placed in front of each participant, in bowls, as they waited for the 20 minute delay period of the auditory verbal learning test. During the 20 minute delay period, participants were left alone in the testing room with all of the premeasured snack items and allowed to consume them ad libitum. After the 20 minute delay period and completing the auditory verbal learning test, researchers weighed each snack item to the nearest 0.1 gram to determine the number of grams consumed. Grams were recorded for each item consumed and then used to calculate calories consumed. Macronutrient content for each snack was calculated using a previously validated software and database.[86]

Power Analysis

The number of participants was estimated based on a meaningful shift in N2 amplitudes. Since exercise has been shown to have a moderate effect on neural responses to food cues among adults, an estimated mean difference of 0.50 microvolts was used.[95,96] A mean standard error of 0.63 microvolts was also used in this analysis based on previous research which helped establish a test retest reliability of N2 amplitudes using EEG techniques.[96] Thus, based on a mean N2 difference of 0.5 microvolts, a mean standard error of 0.63 microvolts and an alpha of 0.05, a sample of 55 participants was needed to have 90% power. In addition, based on previous experience measuring ERPs, we expected to lose 10% of the EEG measurements due to poor or incomplete data. To account for this loss, we recruited an additional 10 participants, for a total of 65 participants.

Statistical Analysis

Statistical analyses were performed using SAS statistical software (version 9.4; SAS Institute, Inc., Cary, NC). The distribution of the data was analyzed visually and did not require transformation. N2 data were analyzed within each subject using a 2-condition (active, sedentary) x 2-task (go, no-go) x 2-picture type (high calorie, low calorie) repeated measures

ANOVA to evaluate the main and interaction effects. In this model we used condition as a within subjects factor. Condition refers to which session (active, sedentary) was completed during the first and second lab visits. Metabolic data (METs, energy cost, RER, HR), ad libitum snack results (energy, carbohydrate, fat and protein intake) and Stroop test results were analyzed using a repeated measures ANOVA with order as a between subjects factor and condition as the within subjects factor. Order and gender were used as covariates in all statistical models. Participant data were reported as means and standard deviations. An alpha level of $p \leq 0.05$ was a priori established for use in all analyses.

RESULTS

The influence of gender was assessed for all outcomes of interest. The only gender x condition interaction ($F = 7.03$, $p \leq 0.05$) observed was found when assessing METs, with boys expending more energy during the active video game condition (see Table 3). In addition, boys tended to consume more calories ($F = 15.11$, $p \leq 0.05$), carbohydrates, fats, and proteins than girls (see Table 5). However, these differences in food consumption were independent of the video game condition.

Energy Expenditure Analysis

Active video game play relative to sedentary video games significantly increased METs ($F = 543.1$, $p \leq 0.0001$) as expected (see Table 3). Active video games (5.0 ± 1.22 METs) significantly ($p \leq 0.0001$) increased METs nearly 3 fold compared to sedentary video gaming (1.7 ± 0.35 METs). In addition to increasing METs, active video game play increased heart rate ($F = 284.2$, $p \leq 0.0001$), VO_2 ($F = 368.2$, $p \leq 0.0001$) and RER values ($F = 4.9$, $p = .03$) (see Table 3). We also observed significant gender x condition differences ($F = 475.2$, $p \leq 0.001$) in

METs with boys (5.4 ± 1.1 METs) having higher METs values during the active video games than girls (4.5 ± 1.1 METs).

Response Inhibition

We observed significant differences ($F = 4.12$, $p = 0.04$) between the EEG paradigms (go vs no-go) for both video game conditions. The N2 amplitudes were more negative for the no-go than the go responses. No significant differences ($F = 0.50$, $p = 0.48$) were observed among amplitudes for the N2 component between video game conditions nor between genders ($F = 1.85$, $p = 0.17$) for active and sedentary video game play (see Table 4). Also, we did not observe any differences in N2 amplitudes in response to viewing high calorie and low calorie picture types ($F = 0.88$, $p = 0.35$) between the 2 conditions. Further, there were no significant differences between go vs no-go accuracy ($F = 0.32$, $p = 0.57$) or response time ($F = 0.01$, $p = 0.98$) between video gaming sessions. Stroop test results following active and sedentary sessions are detailed in Table 6. Results from the Stroop test task showed no significant differences among word condition ($F = 0.448$, $p = 0.49$), congruent condition ($F = 0.43$, $p = 0.52$) nor incongruent condition ($F = 0.14$, $p = 0.71$) between the active and sedentary video game sessions.

Ad Libitum Eating

There were no significant differences ($F = 3.10$, $p = 0.08$) in the total number of calories consumed immediately after the 2 video gaming conditions (see Table 5). Total calories consumed from carbohydrates ($F = 0.04$, $p = 0.84$), protein ($F = 3.28$, $p = 0.07$) and fat ($F = 4.38$, $p = 0.28$) also were not significantly different between conditions. However, when we analyzed gender interactions, we did find boys consumed significantly more total calories ($F = 15.11$, $p = 0.0002$), total fat ($F = 11.15$, $p = 0.001$), total carbohydrates ($F = 11.81$, $p = 0.0008$) and total protein ($F = 12.86$, $p = 0.0005$) compared to the girls (see Table 5). At the beginning of each lab session, participants rated their sensations of hunger using 5 questions measured on a 100 mm analog scale. No significant differences were observed for any of the ratings between sessions.

DISCUSSION

Overall our data showed that there were no significant within subject differences in N2 amplitudes to high calorie and low calorie foods nor changes in Stroop test performance following 60 minutes of active and sedentary video gaming. This was true despite an almost 3 fold increase in energy expenditure from 60 minutes of moderate intensity (4.5 ± 1.1 METs for girls and 5.4 ± 1.1 METs for boys) active compared to sedentary video gaming. The exercise intensity of the active video game used for this study was like that of other studies evaluating energy expenditure of active video games involving lower body movements.[24,26,32]

The literature evaluating the influence of acute exercise on neural responses to visual food cues in adolescents is limited. The most studied EEG waveform is the P3 component.[84,97] The P3 component is thought to reflect greater attention and processing of motivational stimuli.[44] This in turn has been used to measure how much attention is given to images of food and interpreted as an index for food motivation. Fearnbach et al[84] measured changes in P3 amplitudes following exercise and found 45 minutes of moderate intensity cycling decreased P3 amplitudes as participants viewed images of food using a go/no-go task compared to a resting condition. Similarly, Drollete et al saw a decrease in P3 amplitudes following only 20 minutes of moderate intensity treadmill walking among low fit children.[97] However, Drollette et al found no differences in P3 amplitudes among high fit children.

In contrast to the P3 component, the N2 EEG component reflects attention focused onto a potential target item. N2 amplitudes are larger when inhibiting a motor response, which reflects the underlying neural activity associated with motor stopping and inhibition.[48,85,98] In other words, the N2 component is a measure of response inhibition or the ability to commit a correct response or withhold an incorrect response. To our knowledge, only one other study to date has examined the effects of acute exercise on N2 amplitudes to measure response inhibition among adolescents.[97] Drollette et al compared 20 minutes of treadmill walking to a quiet resting condition among children on response inhibition using a modified Flanker task.[97] Notably, our study compared N2 responses to food images while Drolette et al compared N2 responses to a Flanker task. Participants displayed smaller N2 amplitudes following treadmill walking compared to rest. Based on those results, we hypothesized that 60 minutes of moderate intensity video game play would also decrease N2 amplitudes and improve response inhibition to images of high calorie and low calorie foods. However, our results did not support this hypothesis and we did not see a difference in N2 amplitudes between video game conditions.

The null findings from the current study may partially be explained by not having a true resting condition. We compared the neural responses to food images following sedentary and active video game play, unlike previous studies that compared running on a treadmill or cycling on a stationary bike to quiet rest.[66,98] Resting conditions commonly required participants to remain still and seated for at least 20 minutes and restricted intellectual tasks such as reading, talking or watching TV.[84,97,98] This is in contrast to our study, which allowed for intellectual engagement with the sedentary video game play during the control condition. Specifically, children in our study played first person perspective video games on the nonactive day.

First person video games have been shown to improve prefrontal cerebral blood flow among children compared to other types of sedentary video games.[99] Increased blood flow is an indication of increased executive function, attention allocation and improved working memory.[100] Improvements in attention allocation, executive function and selective visual attention may in turn improve response inhibition.[101,102] Several researchers have reported that first person type video games improved response inhibition through perceptual decisions, attention allocation and accuracy on response inhibition tasks.[103-105] It is therefore possible that the first person sedentary video games may have improved response inhibition through improvements in attention allocation and executive function and potentially mitigated the differences in N2 amplitudes between active and sedentary video game play, compared to other sedentary video games.

Similar to the N2 results, we did not find any difference in response inhibition using the Stroop test.[50] Studies looking at behavior related measures of response inhibition following acute bouts of exercise among adolescents are limited and have shown inconsistent results. Our results agree with those presented by Soga et al[66] who found approximately 15 minutes of treadmill walking had no effect on performance of a modified Flanker task among adolescents exercising at 60% and 70% of max HR compared to a resting condition. However, our results do not support those presented by Hillman et al who reported that a single bout of moderate intensity exercise improved cognitive control on a modified Flanker task following 20 minutes of treadmill walking at 60% of estimated maximum heart rate compared to rest.[58] The differences between these 2 remains unclear. Our results from the Stroop test reinforce our findings from the N2 measurements that 60 minutes of moderate intensity active video games do not affect response inhibition.

Exercise duration is one possible variable that influences response inhibition. Among adults, acute moderate intensity exercise ranging in duration between 20 and 30 minutes seems to have the greatest impact on behavior related measures of response inhibition, such as Stroop test performance.[58,64,65,106] Chang and colleagues measured Stroop test performance following moderate intensity (65% HR reserve) cycling and found improved performance on the Stroop test after 20 minutes of cycling compared to 10 and 45 minutes of cycling.[65] Results from Chang et al among adults suggest moderate intensity cycling lasting less than 20 minutes is insufficient to elicit significant changes or improvements in Stroop test and cognitive processing.[65,107] Joyce et al found that 30 minutes of stationary cycling at 40% of maximal aerobic power had beneficial effects on response inhibition, measured by a stop signal task, among adults.[64] Conversely, moderate intensity exercise lasting 45 minutes or longer has minimal influence on response inhibition measured by Stroop test performance.[65,107] The physiological mechanism underlying these subdued behavior related responses to acute exercise sessions lasting longer than 45 minutes may be attributed to dehydration and its impacts on higher order decision making processes like response inhibition.[106] It is possible 60 minutes of moderate intensity video games dehydrated participants to some degree and, in turn, negatively affected response inhibition.

In addition to objectively quantifying the neurological responses to images of food, the current study addressed the effects of acute video game play (active and sedentary) on adolescents' postexercise ad libitum eating. Our results agree with those reported by Bozinovski et al who found no difference in food intake following acute treadmill walking among adolescents.[108] However, there are some who have reported differences in energy intake following acute exercise.[109,110] For example, Thivel and colleagues found low intensity (40% VO_2max) cycling did not alter 24 hour energy intake but that high intensity cycling (75% VO_2max) did.[109] Fearnbach et al showed moderate intensity cycling (65% VO_2max) decreased energy intake among adolescents.[84] Differences in exercise intensity may partially explain the reason for the varied outcomes in energy intake following acute exercise.

There are several limitations associated with the present study. First, the study compared active video games to sedentary video games without using a true resting control condition. It is possible that the differences in N2 amplitudes between conditions may have been more pronounced if we had compared active video games to a true resting control condition. Second, the study used hunger ratings before both video game conditions, but did not test that measure at any other time during the study. Adding one more hunger rating after each condition may have provided insights into the participants' postexercise food behaviors. Lastly, the current study compared high calorie and low calorie images as the go and no-go stimuli. This may have made it more difficult to observe N2 differences between video game conditions compared to using nonfood images because of the underlying salient nature of food.

Our study had several strengths despite the above mentioned limitations. We used several novel comparisons that may provide meaningful results for application in promoting physical activity among adolescents. First, because adolescents play an average of 65 minutes per day of sedentary video games,[14] we compared active video game play to sedentary or seated video games. This comparison has greater ecological validity than having someone sit and be quiet during the control condition. Second, our study compared neurological differences to viewing high calorie and low calorie images instead of using control images of objects or plants. This allowed us to examine how acute exercise effects adolescents' food choices when presented with high calorie and low calorie options. Third, our study used neural and behavioral measures such as ad libitum eating and allowed participants to choose the quantity of snacks to determine the relationship between moderate intensity video game play and food choice. Fourth, we controlled for dietary and time of day influences. Specifically, we provided each participant with the same quantity and content of meals (breakfast and lunch) for each testing day as well as testing the participants at the same time of day. Fifth, our study used multiple measures of response inhibition and food choice. We found no differences in N2 amplitudes, Stroop test performance and ad libitum eating. The results from these different measures of response inhibition supported the findings that 60 minutes of moderate intensity video game play had no effect on response inhibition compared to sedentary video game play.

CONCLUSION

Results from our study indicate that 60 minutes of active video game play increases energy expenditure to a moderate intensity level, but has a similar impact on response inhibition and energy intake as sedentary gaming. Despite observing a nearly 3 fold increase in energy expenditure, neither N2 amplitude to high calorie and low calorie pictures nor Stroop test performance were different for either active or sedentary gaming. These findings were supported by the fact that food consumption during an ad libitum snack consisting of high calorie and low calorie food options was also not different. Further research should focus on measuring N2 differences between active video games using a true resting condition that limits any neural stimulation. Another important factor to investigate in future research is the duration of acute video game play and the effect on N2 amplitudes.

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Table 1. ERP Dependability as a Function of Session and Condition

	Dependability	95% CI	Mean # Trials	Trial Range
Active High Calorie Task Go	.97	.96; .98	88.6	21; 137
Active High Calorie Task No-Go	.92	.89; .95	29.4	7; 51
Active Low Calorie Task Go	.97	.96; .98	87.9	32; 134
Active Low Calorie Task No-Go	.92	.89; .95	28.0	10; 56
Sedentary High Calorie Task Go	.96	.95; .98	91.3	27; 133
Sedentary High Calorie Task No-Go	.92	.88; .94	28.8	6; 55
Sedentary Low Calorie Task Go	.97	.95; .98	85.7	16; 129
Sedentary Low Calorie Task No-Go	.91	.87; .94	27.2	5; 54

Table 2. Participant Characteristic Data

	Girls	*Boys*	*Combined*
Sample size	31	34	35
Age (yr)	13.3 ± 1.2	13.7 ± 1.0	13.5 ± 1.1
Height (cm)	159.8 ± 7.5	162.6 ± 12.2	161.4 ± 10.2
Weight (kg)	51.3 ± 10.4	53.4 ± 13.9	52.5 ± 12.3
BMI ($kg \cdot m^2$)	19.7 ± 3.2	20.0 ± 3.4	19.9 ± 3.3

Means ± standard deviations for participant descriptive data.

No significant differences observed between genders.

Abbreviation: BMI, body mass index

Table 3. Metabolic Data in Sedentary and Active Viewing Sessions Among Boys and Girls

	Girls (n = 31)		Boys (n = 34)		Combined (n = 65)	
	Active	*Sedentary*	*Active*	*Sedentary*	*Active*	*Sedentary*
EE (kcal/hr)	236.9 ± 72.6 $^{*\,t}$	83.1 ± 14.6	298.2 ± 83.5 $^{*\,t}$	94.2 ± 20.3	268.9 ± 83.7 *	88.9 ± 18.6
RER	0.89 ± 0.08 *	0.87 ± 0.05	0.89 ± 0.06 *	0.86 ± 0.04	0.89 ± 0.07 *	0.87 ± 0.05
HR (beats/min)	127.5 ± 19.6 *	86.7 ± 14.2	129.5 ± 15.4 *	82.1 ± 13.2	128.6 ± 17.4 *	82.8 ± 17.2
METS	4.5 ± 1.1 *	1.6 ± 0.4	5.4 ± 1.1 $^{*\,t}$	1.7 ± 0.3	5.0 ± 1.2 *	1.7 ± 0.35

Means ± standard deviations for participant metabolic data.

Abbreviations: EE, Energy expenditure; RER, Respiratory exchange ratio; HR, heart rate; METS metabolic equivalents.

* difference between the active and sedentary video game sessions within genders and combined ($p \leq 0.05$)

^{t} difference between boys and girls in the active sessions ($p \leq 0.05$)

Table 4. N2 Amplitudes and Food Picture Accuracy Among Boys and Girls

	Girls (n = 31)		Boys (n = 34)		Combined (n = 65)	
Image Type – Task	Active	Sedentary	Active	Sedentary	Active	Sedentary
High Calorie – Go Task	-2.6 ± 4.4	-2.4 ± 3.4	-4.1 ± 4.1	-3.6 ± 3.1	-3.38 ± 4.28	-3.08 ± 3.28
High Calorie – No/Go Task	-3.4 ± 4.9	-3.3 ± 3.9	-4.4 ± 3.8	-4.5 ± 3.8	-3.92 ± 4.43	-3.93 ± 3.91
Low Calorie – Go Task	-2.4 ± 4.5	-2.7 ± 3.8	-4.3 ± 3.4	-3.6 ± 3.1	-3.42 ± 4.06	-3.12 ± 3.46
Low Calorie – No/Go Task	-2.6 ± 4.4	-3.2 ± 3.8	-4.4 ± 4.1	-3.6 ± 4.2	- 3.52 ± 4.34	-3.39 ± 4.00
High Calorie – Accuracy	92.5% ± 6.4%	93.3% ± 5.4%	89.5% ± 9.9%	94.3% ± 5.3%	90.9% ± 8.4%	93.8 % ± 5.3%
Low Calorie – Accuracy	95.1% ± 4.2%	94.4% ± 5.0%	93.1% ± 6.5%	96.9% ± 3.7%	94.1% ± 5.5%	95.7% ± 4.5%

Means ± standard deviations for participant EEG data.

N2 amplitudes are presented in µV.

No significant differences between active or sedentary conditions for boys or girls.

Accuracy in identifying images had no observed significant differences.

Table 5. Calorie Intake During Ad Libitum Eating Among Adolescent Boys and Girls

	Girls (n = 31)		Boys (n = 34)		Combined (n = 65)	
	Active	*Sedentary*	*Active*	*Sedentary*	*Active*	*Sedentary*
Total kcal	530.1 ± 249.3	485.3 ± 247.6	710.5 ± 289.7*	664.6 ± 240.7*	615.0 ± 292.1	580.4 ± 258.4
CHO (g)	64.8 ± 33.8	55.6 ± 31.3	84.2 ± 43.1*	80.2 ± 36.6*	73.8 ± 40.6	68.6 ± 36.1
Protein (g)	13.7 ± 10.3	12.5 ± 7.9	19.9 ± 10.3*	18.0 ± 8.0*	16.8 ± 9.6	15.4 ± 8.4
Fat (g)	23.9 ± 12.3	23.6 ± 12.1	32.6 ± 12.7*	30.2 ± 12.6*	28.1 ± 13.5	27.1 ± 12.7

Means ± standard deviations

Abbreviation: kcal, kilocalorie; CHO, carbohydrate; (g), grams;

* difference between boys and girls for both conditions ($p \leq 0.05$)

There was no difference between sedentary and active conditions for any variable of interest.

Table 6. Stroop Test Performance Results Between Video Game Sessions

Stroop Condition	*Active Video Games*	*Sedentary Video Games*
Word Condition	94.7 ± 12.3	94.0 ± 10.9
Congruent Condition	68.1 ± 13.0	67.9 ± 12.5
Incongruent Condition	42.5 ± 10.2	42.8 ± 10.7

Means ± standard deviations for participant Stroop data.

No significant differences observed between conditions.

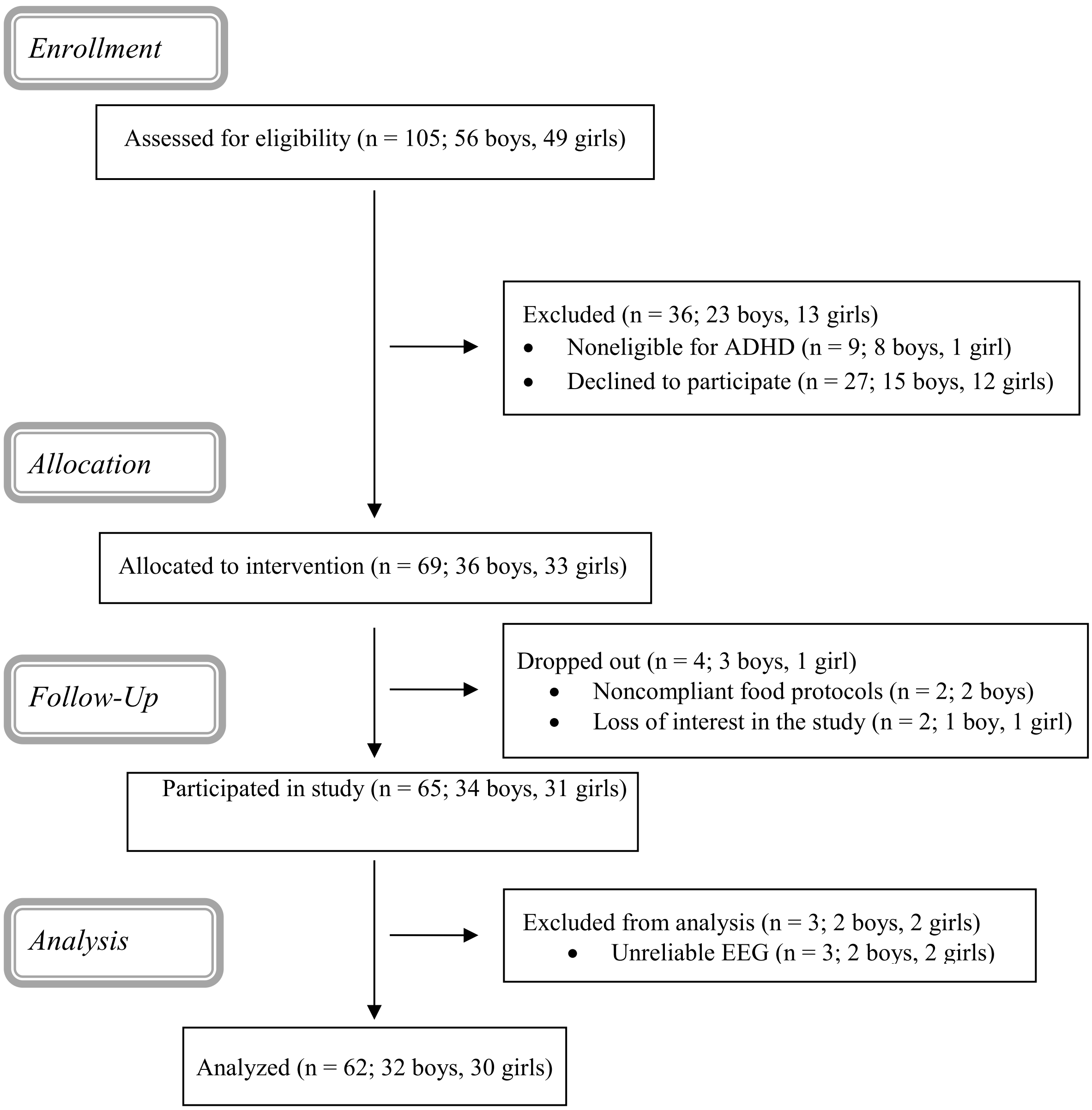

Figure 1. Enrollment Flow Chart

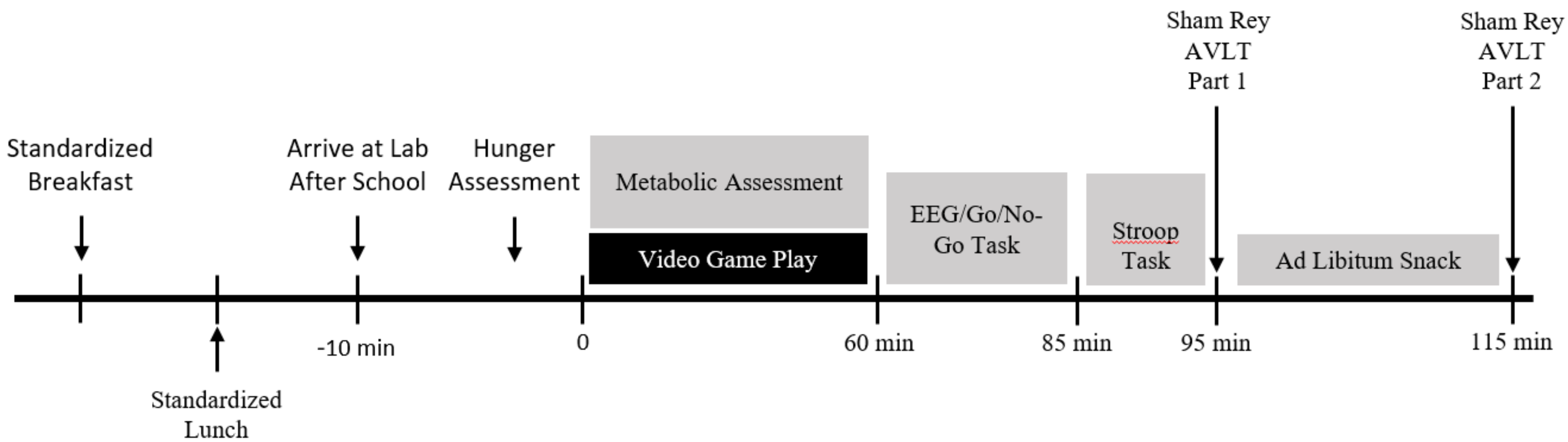

Figure 2. Overview of Experimental Protocol

Appendix A: Physical Activity Readiness Questionnaire

Young Person's 'Physical Activity Readiness' Questionnaire

Dear Parent / Guardian,

There are many health benefits to be gained when children and young people exercise regularly. It is sensible however to consider their health status prior to commencing physical activity. This questionnaire aims to identify your child's health status so that we can provide exercise advice and avoid any risk of injury or illness.

Registration Information

First Name: ………………………………………Surname: …………………………………..

Address: ……………..……………………………………………………………………….

……………………..………………………………………………………………………….

…………………………………………………...Postcode……………………………………

Home No: ……………………………………… Mobile No: ..……………………………….

Gender: Male / Female (please circle) Date of Birth: …………………………………….

The following questions relate to the health of the young person. Please read the questions carefully and provide a correct answer by circling Yes or No. Where necessary, please provide details.

			Details
Has a doctor ever diagnosed your child with a heart condition?	Yes	No	
Has your child recently had chest pains during or after exercise?	Yes	No	
Does your child ever feel faint or have spells of severe dizziness?	Yes	No	
Is your child currently receiving treatment or medication for high blood pressure?	Yes	No	
Is your child currently receiving treatment or medication for any other condition?	Yes	No	
Has your child broken any bones in the past six months?	Yes	No	
Does your child suffer from any bone or joint problems which exercise may aggravate?	Yes	No	
Does your child suffer from epilepsy or chronic asthma?	Yes	No	
Is your child diabetic? If yes, is the diabetes type 1 or Type 2?	Yes	No	
Has your child undergone any recent surgery?	Yes	No	
Is there any other reason which has not been mentioned that may affect your child if they took part in physical activities?	Yes	No	

It is important to note that if you have answered “YES” to any of the above questions, there may be restrictions on your child’s ability to participate. If you are unsure of any of the information you have provided we strongly advise that you consult with your primary care physician before allowing your child to participate.

Parent / Guardian Declaration

1. I confirm that the above answers are correct, at this point in time, to the best of my knowledge and belief.
2. I will inform the primary investigator at once if any of the above information changes.
3. I agree that my child will abide by the rules of this study and follow the instructions of staff at all times.

Signature: …………………………………………………………………………………

Print Name ………………………………………………………………………………..

Relationship to Child ……………………………………………………………………..

Date ……………………………………………………………………………………….

Appendix B: Food Preference Questionnaire

Food Preference Questionnaire:

Please rate the following foods on a scale of 1-10
1 = extremely dislike
10 = extremely like/enjoy

______	Watermelon	______	Apple Pie	______	French Fries
______	Fruit Snacks	______	Chocolate Bars	______	Green Salad
______	Taffy	______	Celery	______	Black Beans
______	Steak	______	Bananas	______	Yogurt
______	Beef Jerky	______	Rice	______	Doughnuts
______	Pasta	______	Spinach	______	Asparagus
______	Chocolate Cake	______	Granola Bar	______	Almonds
______	Potato Salad	______	Onion Rings	______	Crackers
______	Carrots	______	Cheetos	______	Hamburger
______	Tortilla Chips	______	Omelet	______	Oreo
______	Tacos	______	Garlic	______	Turkey
______	Pizza	______	Cheddar Cheese	______	Apples
______	Broccoli	______	Brownies	______	Bread

Do you have any food allergies? If so, please list them:

Appendix C: Parental Permission Form

Parental permission for son or daughter to be a research participant

Introduction

This research study is being conducted by Josh Smith, doctoral candidate in the Department of Exercise Sciences, under the direction of Professor Bruce Bailey at Brigham Young University. The purpose of this study is to compare brain activity to pictures of food following either active video game play or seated video gaming. To participate in this study your child must be (1) between the ages of 12-15, (2) have no known chronic or metabolic disease, (3) have not been diagnosed with an eating disorder, (4) do not abuse alcohol or tobacco, (5) do not have a learning disability, (6) do not have a neurological disorder or brain injury, (7) do not have attention deficit hyperactive disorder, (8) have normal vision or corrected to normal vision and (9) physically able to complete the active video gaming protocol.

Procedures

Participation in this study will include two visits to the Brigham Young University Clinical Neuropsychology Lab located at the University Parkway that will last about 2 hours each visit. Before your child's visits we will provide them with breakfast and lunch for each of the days they come to the lab for testing. They will be asked to eat all this food and nothing else before coming to the lab. The food will be the same for both testing days.

Upon arrival to the lab, your child will be familiarized with the active and passive/seated video games. We will also show your child the EEG (measures brain activity) device that we will use after playing the video games. We will ask your child to play the active or passive/seated video games for 60 minutes. While your child is playing the video games we will use a heart rate monitor and metabolic cart to measure the calories they burn during video game play. The metabolic cart is a small device that fits like a mask that covers their mouth and nose but does not restrict air flow. After the video game play we will take your child to the Neurocognitive lab where your child will complete the EEG measurements.

As the measurements are being taken we will show your child different pictures of foods. Some foods are high calorie and others are low calorie. As your child is viewing different pictures we will be taking measurements of your child's brain activity. In order to measure your child's brain activity we have a cap that will fit on their head to allow us to record brain activity. The entire test, with set up, will take about 30 minutes to complete.

After the EEG measurements of brain activity, we will ask your child to complete two simple word tests. One of the tests requires a 30 minute break. During this break your child will be provided a snack. After they've finished with these two word tests their session is complete.

Risks/Discomforts

The video games your child will be asked to play will make them feel like they're going on a brisk walk. Your child's heart rate and breathing will increase as they play the video games. These games are generally safe and do not pose any known risks. We will have certified professionals present at all times to ensure safety. Recording your child's brain activity while they look at pictures of food does not present any known risks to them.

Benefits

There are no direct benefits from participation in this study. The results of this study may benefit other adolescents and society by providing supporting evidence to engage in active video games.

Confidentiality

The information we gather will be reported anonymously. Your child's name and other identifying information will be discarded so that your child's information will be anonymous. All of the data we record from this study will be protected and kept on a password protected computer in a locked office. Any identifying information will be destroyed after we're finished with the study.

Compensation

We will pay your child $40 after they complete both video gaming sessions. We will pay your child $5.00 if they drop out of the study, withdraw for any reason or do not want to finish the study.

Participation

Participation in this study is voluntary. You and your child have the right to withdraw at any time or refuse to participate entirely. Your child's participation in this study may be terminated by the researchers if your child does not or is not able to comply with the procedures.

Questions about the Research

If you have questions regarding this study you can contact Josh Smith (801) 815.5621 or brotherjoshsmith@gmail.com or Bruce Bailey (801) 422.8674 or bruce_bailey@byu.edu

Questions about your rights as a research participant

If you have questions regarding your rights as a research participant and would like to speak with someone other than the research group, you may contact the Institutional Review Board (IRB) Administrator, Brigham Young University, A-285 ASB Campus Drive, Provo UT 84602. Phone: (801) 422-1461 or irb@byu.edu

Parents your signature below indicates your permission for your child to participate in this research project.

__________________________________ _______________________

Signature – Parent/Guardian Date

Appendix D: Participant Assent Form

Assent to be a Research Subject

<u>Introduction</u>

This research study is being conducted by Joshua Smith, a doctoral student, at Brigham Young University in the department of Exercise Sciences, under the direction of Professor Bruce Bailey. The purpose of this study is to compare brain wave activity after you've played active video games and seated video games. You were invited to be in this study because:

1. You are between 12 and 15 years old
2. You don't have any diseases, such as heart disease or diabetes
3. You don't take any medications
4. You don't have a learning disability
5. You don't have a brain injury or brain disorder
6. You don't have ADHD (attention deficit hyperactive disorder)
7. Your vision is normal or you have glasses/contacts to help you see normally
8. You can complete 60 minutes of active video games at a beginner level

<u>Procedures</u>

This study will include 2 different video game sessions. After you complete one of the sessions we will ask you to come back another day to complete the other session. Each video game session will take about 2 hours. Here's what to expect during each of your visits:

- We will give you breakfast and lunch that contains foods you told us you like to eat for those meals. We ask you to eat those specific meals that we give you on the days you come to the lab.
- You will be asked to play active video games for one of the sessions and seated video games for the other video game session.
- Each of the video game sessions will take about 2 hours to complete.
- After you play video games, we will ask you to do a picture viewing task where you look at pictures of different foods. While you're looking at the pictures, we are going to measure your brain activity using a cap that has sensors in it. The cap fits on your head easily and will help us measure your brain activity.
- After we measure your brain activity you will be asked to complete two learning tasks, this will take about 30 minutes and take place in the same room as the picture viewing task.
- The first learning task involves a word color test, where you will need to name the color of the printed words, this will take about 7 minutes in the same room as the picture viewing task.
- The second learning task will be a word learning task. Researchers will read words out loud and ask you to repeat them back. This this test takes about 30 minutes.
- As you are completing the second learning task, we will provide you with a variety of snacks.

At the beginning of your first visit to the Neuropsychology Lab the researchers will show you the different testing rooms and testing equipment. During your first session, the researchers will also measure your height and weight. The researchers will answer all of your questions before you begin.

Risks/Discomforts

Participation in the active and seated video games do not have any known associated risks. As with moderate exercise your heart rate and breathing will increase as a normal response to exercise. The brain activity measurements are safe and do not have any known risks. Certified professionals (health care and clinical psychologist) will be onsite for all sessions for safety and can answer any questions you have.

Benefits

There are no direct benefits from being in this study. The results of this study may benefit adolescents and society by providing information that will encourage teenagers to exercise daily.

Confidentiality

All of the information we gather during our research will be kept confidential. Your name and identity will not be connected to any of your test results. All of the information from this study will be locked up in a filing cabinet inside a locked office. All of the information on the computers from this study will be locked with passwords. All identifying data will be destroyed after the study is completed.

Compensation

You will be paid $40 after you complete both video gaming sessions. If you start this study, but decide to drop out or withdraw before you finish the study, you will be paid $5.00.

Participation

Participation in this study is voluntary. You have the right to withdraw at any time or refuse to participate entirely. Your participation in this study may be terminated by the researchers if you do not or are unable to comply with the testing rules.

Questions about the Research

If you have questions regarding this study you can contact Josh Smith at brotherjoshsmith@gmail.com or Bruce Bailey at bruce_bailey@byu.edu

Questions about your rights as a research participant

If you have questions regarding your rights as a research participant and would like to speak with someone other than the research group, you may contact the Institutional Review Board (IRB) Administrator, Brigham Young University, A-285 ASB Campus Drive, Provo UT 84602. Phone: (801) 422-1461 or irb@byu.edu

________________________________ ______________________

Signature Date