EFFECT OF EXERCISE SETTING ON ENERGY EXPENDITURE AND ENJOYMENT DURING ACTIVE VIRTUAL REALITY GAMING

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In

Kinesiology

by

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CERTIFICATION OF APPROVAL

I certify that I have read Effect of Exercise Setting on Energy Expenditure and Enjoyment During Active Virtual Reality Gaming by Trenton Huynh Stewart, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirement for the degree Master of Science in Kinesiology: Exercise Physiology at San Francisco State University.

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EFFECT OF EXERCISE SETTING ON ENERGY EXPENDITURE AND ENJOYMENT DURING ACTIVE VIRTUAL REALITY GAMING

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INTRODUCTION: Recent work by our lab (Gomez, et al., 2018) has shown that active virtual reality games (AVRGs) can elicit exercise intensities that meet recommended exercise guidelines for preventative health benefits. However, much of the work focusing on this topic has been limited to laboratory settings. **PURPOSE**: Investigate differences in energy expenditure (VO_2) and enjoyment of college-aged students while playing AVRGs in different settings (lab, gym, home). **METHODS**: A repeated measures design was used with 32 participants (16 males, 16 females, Age 22.6 ± 2.6 yrs), all of whom completed two 45-minute AVRG sessions in the lab and gym. A subset of 4 participants completed an additional home session. **RESULTS:** Significant differences in VO_2, F (1, 28) = 9.128, p = .005 were observed between AVRGs. However, differences in VO_2 and enjoyment failed to reach significance (p = .076) between settings. **DISCUSSION**: The findings suggest that the setting in which AVRGs are played neither affects how enjoyable they are perceived nor the intensity in which they are played.

I certify that the Abstract is a correct representation of the content of this thesis.

Marialice Kern ____________________ 5·21·19
Chair, Thesis Committee Date

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INTRODUCTION

Background

Obesity is a public health crisis affecting millions of individuals in the United States. The Center for Disease Control and Prevention (CDC) released a report in 2016 stating 40% of U.S. adults were considered obese [body mass index (BMI) > 30 kg/m]. This was preceded by a significant increasing linear trend in obesity rates beginning in 2000 where, at that time, 30% of U.S. adults were considered obese (Matthews et al., 2008). Evidence suggests that this linear increase will continue to remain on the rise and may eventually lead to future generations in the U.S. having a shorter life expectancy than their parents (Sturm, 2013). As such, college-aged students are a population at risk especially as they transition into a period of their life where decisions of nutrition and physical activity become more autonomous. Not surprisingly, the increased time students spend in classrooms, studying, working a job to support themselves, plus prevalently high screen-use, limits the time available for physical activity and induces sedentary behavior (Melton et al., 2014). This physical inactivity has been shown to be a risk factor for obesity and the consequences of obesity are well-known, including an increased risk for cardiovascular and metabolic disease (Kahn et al., 2002; Salmon et al., 2003). Unfortunately, nearly half of the college students in the United States are not meeting the recommended physical activity guidelines set forth by the American College of Sports Medicine (ACSM) for preventative health benefits (minimum 150 minutes per week of moderate-intensity exercise) (American College of Sports Medicine, 2017). This higher prevalence of sedentary behavior in adulthood has been attributed, at least in part, to increases in television and computer screen time, with >50% of adults playing some form of video games on a regular basis (Lenhart, 2016).

A study in 2008 examined video game use in 209 college students and found that, on average, they spent 10 hrs/wk playing video games and sometimes upwards of 35 hrs/wk (8.5% of students) (Wack, 2009). Instead of competing against a highly valued activity, an alternative strategy is to replace passive screen time with active screen time. However, incorporating physical activity participation into the daily routines of individuals is time and resource intensive. Therefore, new strategies are needed that focus on individuals' motivations to voluntarily participate in physical activity. There is considerable evidence that the amount of physical activity is largely dictated by enjoyment and preference (Henderson & Ainsworth, 2002; Wankel, 1993). This motivation also drives individuals' desires to partake in sedentary behaviors, including passive screen time and, more specifically, video game play.

Video games utilizing virtual reality (VR) have gained recent popularity in their potential to become significant positive contributors to increasing physical activity (Gao, 2015). VR-gaming consoles such as the HTC VIVE® incorporate human sensory biology with a head-mounted display to stimulate a user's physical presence in a virtual environment and allows for interaction with their virtual surroundings. This emerging technology requires the user to be physically active and, at times, perform whole-body movements seldom seen in traditional sitting hand-controlled video game designs. A recent review of active virtual reality games (AVRGs) found them capable of eliciting light-to-moderate physical activity intensity although their use in long-term efficacy of physical activity promotion remains unknown (Gao, 2015). However, given college students' unique relationship and interest in technology, technology-adapted physical activity experiences could prove effective for promoting long-term positive health benefits (Melton, 2014). Furthermore, AVRGs have the potential to overcome the barriers associated with physical activity. Notably, recent evidence indicates an overall lower rating of perceived exertion (RPE) during moderate-to-vigorous intensity active video gameplay potentially stemming from the enjoyable nature of the AVRGs (Yoo et al., 2017). Consequently, AVRGs have been shown to be an alternative option for exercise compared to traditional exercise programs due to significant increases in energy expenditure above resting while playing and eliciting ACSM's exercise recommendations of moderate-intensity exercise (Gomez, et al., 2018).

Alongside increased interest in AVRGs to be positive contributors to physical activity levels, VR consoles are becoming more accessible and affordable. Already, AVRGs are being utilized for a wide variety of applications such as treatment of phobias, transfer of skills in the workplace, and rehabilitation (Colbert, Yee, & George, 2016; Laver, et al., 2015; Parsons, 2008). However, work focusing on energy expenditure during AVRGs exercise is limited to laboratory settings. Few studies have focused on nonlaboratory settings such as the free-living gameplay setting of home or the group-based setting of a gym. Depending on the social environment where physical activity takes place, research suggests that some environments are more appropriate for promoting motivation and quality exercise experiences (Ajzen, 1991). For example, exercise adherence is higher in group exercise classes than individual exercise programs. On the other hand, group exercise classes may present problems for those with social physique anxiety.

Aim

Given the above arguments, this study had 2 main purposes: (1) examine the effect that physical activity setting (lab, gym, home) has on energy expenditure and enjoyment while playing three different AVRGs and (2) assess sex differences in energy expenditure and enjoyment while playing three different AVRGs.

Specific Objectives

To evaluate whether the exercise setting (laboratory, wellness center, or home) in a sample of college students will:

- Elicit energy expenditure to meet that of the recommended physical activity guidelines set forth by the American College of Sports Medicine (ACSM) for preventative health benefits (minimum 150 minutes per week of moderate-intensity exercise) measured by the continual monitoring of oxygen consumption (VO_2) and heart rate (HR).
- Result in perceived levels of enjoyment that are close to/higher than enjoyment levels during traditional physical activity measured by a 1-10 Likert scale.

- Elicit higher or lower ratings of perceived exertion (RPE) during AVRG gameplay measured by The Borg Scale of Perceived Exertion.
- Result in positive psychological states of optimal experiences and feelings of social physique anxiety measured by the Flow State Scale (FSS).

Research Question

Recent work by our lab has shown that active virtual reality games (AVRG) can stimulate significant energy expenditure to help meet ACSM's recommendations for physical activity (Gomez, et al., 2018). However, studies exploring this topic have been limited to laboratory settings. This investigation aims to determine: (1) Does exercise setting (laboratory, gym, or home) affect energy expenditure (calories) of participants while exercising in virtual reality? (2) Does exercise setting affect levels of immersion/enjoyment of participants while exercising in virtual reality?

Significance of the Study

Studies that examine energy expenditure during active virtual reality gaming (AVRG) are rare in the field of physical activity and health promotion, due to the only recent gain in popularity and accessibility of VR gaming consoles. This study will build upon our previous work (Gomez et al. 2018) and contribute to the knowledge base by exploring the efficacy and feasibility of physical activity promotion through AVRGs with a multi-layered approach (lab, gym, home). It is also innovative with the inclusion of user-experience and enjoyment questionnaires. The data from this study can help consumers, coaches, and exercise/fitness professionals develop new AVRG programs.

Hypothesis

The primary hypothesis was that, for a sample of college-aged students, nonlaboratory physical activity settings (gym and home) would result in significantly higher energy expenditure levels as measured by oxygen consumption via direct (Quark CPET metabolic cart) and estimated means (Polar, H10). A secondary hypothesis was enjoyment levels while playing AVRGs in nonlaboratory settings would be higher than those compared to playing AVRGs in a laboratory setting.

METHODS

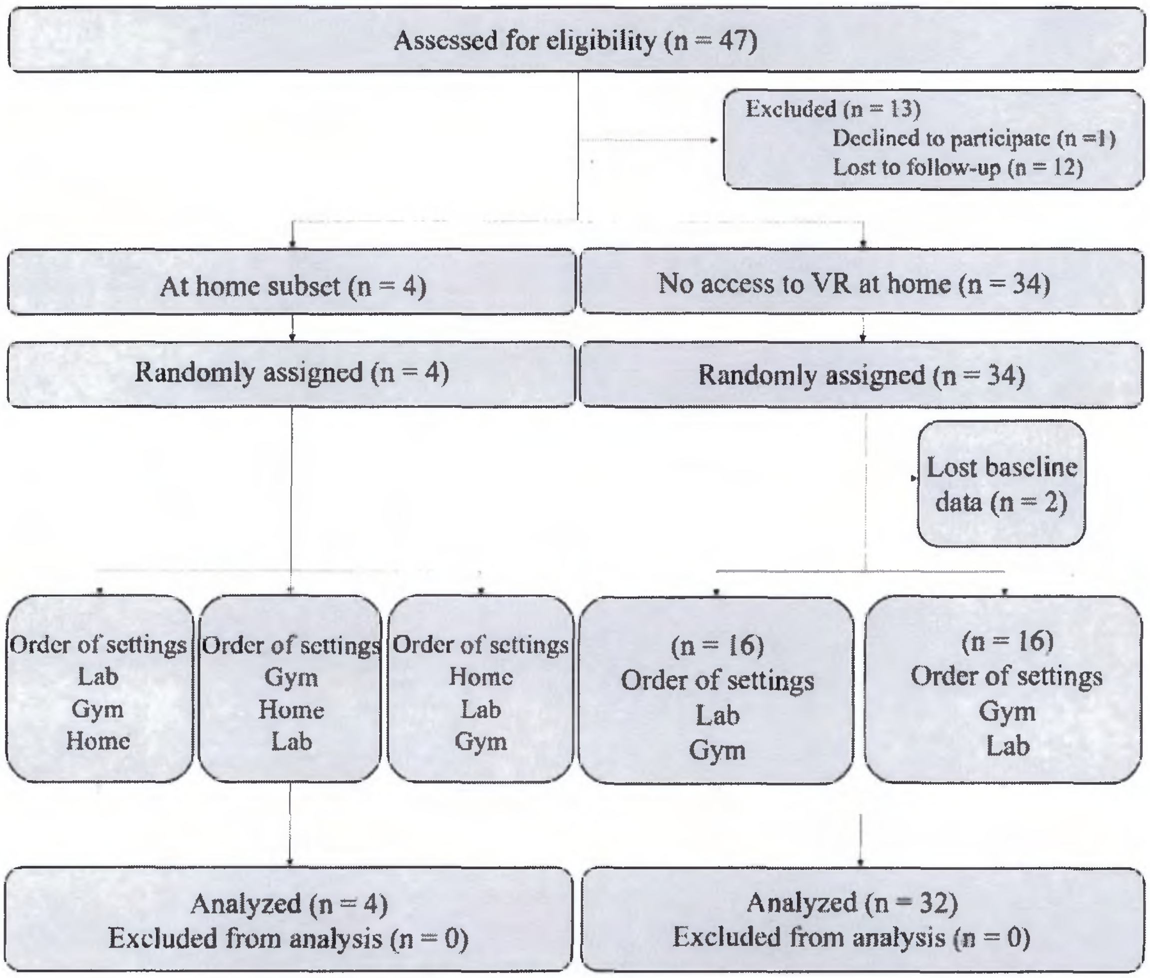
Participant Recruitment

The participants in this study were undergraduate students enrolled in Kinesiology classes at San Francisco State University. The classes that students were recruited from were primarily upper-level Kinesiology courses (e.g. Exercise Physiology and Neuromotor Control Processes). Students often enroll in these courses to satisfy degree requirements to graduate with a bachelor's degree in Kinesiology. Details of the study were sent to the instructors of these courses and students were offered extra credit by the instructors of the course upon successful completion of the study. Permission to recruit from the Kinesiology Department on campus was granted by the Kinesiology Department Chair and the Internal Review Board approved the planned research.

Inclusion Criteria

Eligible participants were students, faculty, or community members within the San Francisco Bay Area who were at least 18 years of age at the time of testing and no older than 39 years. Additional inclusion criteria included no musculoskeletal injuries, not currently on any drugs or medication that would affect the metabolic processes of the body and had no history of nausea or motion sickness that can be triggered with virtual reality use.

Figure 1. Participant Recruitment Flowchart



Exclusion Criteria

Participants were excluded from the study if they had contraindications to exercise (e.g. cardiac or metabolic disease, family history of cardiovascular disease) as assessed through a modified Physical Activity Readiness Questionnaire (PAR-Q).

Instrumentation

The following section discusses the instrumentation used in the study for specific outcome measures and the rationale behind them.

Body Composition: Air Displacement Plethysmography

The measurement of body composition is necessary for evaluations of general health and obesity classification. Moreover, body composition measurements are used by health professionals to gauge the effectiveness of training/exercise programs. Physical performance may also be hindered in individuals with higher body fat percentages and the effect that body composition has on performance while playing AVRGs is scarce. The Bod Pod (Cosmed, Rome, ITL, Europe) is a device that uses air displacement plethysmography to determine body composition. The Bod Pod has been shown to be a highly valid and reliable tool to assess body composition in a wide range of individuals (Vescovi, 2002).

Oxygen Consumption: Graded Exercise Test/Indirect Calorimetry

The graded exercise test (GXT) is the most widely used test to determine the dynamic physiological responses during incremental exercise. Protocols of a GXT contain a systematic, linear increase in the workload placed on an individual until they are unable to tolerate or maintain the exercise intensity. While participants are wearing a facemask connected to a gas analyzer, expired air samples are collected and calculated for fractional concentrations of oxygen and carbon dioxide. One of the physiological variables assessed is an individual's maximal oxygen consumption (VO_{2max}) and is a criterion measure of cardiorespiratory fitness. It provides a quantifiable measure of the body's aerobic oxidative system's ability to supply oxygen during strenuous exercise. Maximal oxygen consumption (VO_{2max}) was evaluated in the Exercise Physiology Laboratory using a COSMED T150 treadmill and Quark CPET metabolic cart (Cosmed, Rome, ITL, Europe). A self-paced GXT with 2-minute stages was chosen for this study as it has shown to elicit significantly higher VO_{2max} values compared to a controlled GXT (Mauger). Oxygen consumption was also measured during AVRG gameplay. Participants were hooked up to the same metabolic cart used during the GXT and were placed in the VIVE VR headgear. Submaximal measurements of oxygen consumption using the Quark CPET mixing chamber have shown to be accurate when comparing it to other gas exchange measurement systems (Douglas Bag) (Nieman, 2013).

Heart Rate: Single-Lead Electrocardiogram

Single-lead electrocardiograms (ECG) are used to help track heart rate while exercising. Polar H10 heart rate sensor (Polar, Kempele, FI, Europe) utilize single-lead electrocardiogram worn by participants in this study. The heart rate monitor is worn around the chest and transmits real-time heart rate to a smartphone application. Its use as a criterion measure for heart rate has been validated against other heart rate measuring devices such as a 12-lead electrocardiogram. (Dooley, 2017)

Ratings of Perceived Exertion: The Borg Scale of Perceived Exertion

The Borg RPE Scale is a widely used psycho-physical assessment tool to measure subjective ratings of exertion during exercise. During incremental maximal exercise testing, the Borg scale helps researchers monitor exercise intensity of the participant. The scale includes 15 numerical categories (ranging from 6 to 20), each representing the rate of perceived exertion or exercise intensity: “very very light” (7), “very light” (9), “fairly light” (11), “somewhat hard” (13), “hard” (15), “very hard” (17), “very very hard” (19), and “maximal exertion” (20). The values on the RPE scale have been validated against a number of physiological variables such as heart rate and, in most cases, is reliable for nearly all populations. The Borg RPE scale was also utilized during AVRG gameplay. After completion of each game participants rated their highest perceived level of exertion during that gameplay session. Retrospective RPE measurements of an exercise bout have been shown to be valid forms of assessment when compared to RPE measurements during exercise (Milanez, 2011).

Video Game Immersion/Social Physique Anxiety: The Flow State Scale

The FSS is a self-report assessment tool to examine the “flow” experience with 9 different subscales: 1) challenge-skill balance, 2) action-awareness merging, 3) clear goals, 4) unambiguous feedback, 5) concentration on the task at hand, 6) paradox of control, 7) loss of self-conscious, 8) transformation of time, and 9) autotelic experience.

Participants answered 1-5 point Likert scale with responses: “strongly disagree” (1), “disagree” (2), “neither agree nor disagree” (3), “agree” (4), and “strongly agree” (5). The use of FSS has been primarily used for athletes to link feelings of flow with increases in performance and has been shown to equally report positive psychology findings in the areas of visual arts, music, and recreational activities (Jackson & Marsh, 1996).

Enjoyment: 10-point Likert Scale

This study specifically looks at enjoyment in the context of motivation to engage in a physical activity. A standard format was used in this study that consisted of levels of enjoyment that represented participants’ experience exercising in virtual reality: “no enjoyment” (1), “high level of enjoyment” (10). When compared to traditional forms (Detailed Approach) of measuring criteria, Likert scales have shown similar measurement of psychometric properties and equivalent reliability (Maurer, 1998). Participants were first assessed on their level of enjoyment to engage in the current physical activities that they partake in. Furthermore, participants were assessed on their level of enjoyment after each AVRG was played in each setting and were asked to rate their overall level of enjoyment playing AVRGs in each setting.

Experimental Procedure

Day 1

Participants reported to the Exercise Physiology lab for their first visit. Participants followed the same pre-test procedures for each of their visits. Participants were given a brief overview of the study and were assured that their participation was voluntary and confidential. Participants were then asked to sign informed consent documents and complete a questionnaire that assessed their demographic information, experience playing video games/virtual reality and current physical activity participation and enjoyment. Participants' height was measured to the nearest half-centimeter by trained research assistants using a Detecto eye-level mechanical weigh beam (Detecto, Webb City, MI, USA). Afterwards, participants were led to the Resting Metabolism laboratory where weight and body composition was evaluated using air displacement plethysmography via the BOD POD (Cosmed, Rome, ITL, Europe). Maximal oxygen consumption (VO_{2max}) was evaluated in the Exercise Physiology Laboratory using a COSMED T150 treadmill and Quark CPET metabolic cart (Cosmed, Rome, ITL, Europe). Before the test began, participants were given details of the test and were familiarized with the Borg's Rate of Perceived Exertion Scale. Participants followed a ramp protocol for the graded exercise test (GXT) on the treadmill. Participants were reminded that the researchers will stop the test at any point if the participant felt like they have reached their max or wished to stop the test. The test consisted of two-minute stages and required participants to run at a self-determined pace while the grade of the treadmill is changed. To warm up, participants were placed on the treadmill to determine the pace they want to run at by changing the speed of the treadmill until they reached a speed they felt comfortable with. Participants were only allowed to choose a speed above 5.0 mph to ensure cardiorespiratory capacity was stressed before muscular fatigue set in. Sufficient time was given to participants for their heart rate to reach resting levels before initiation of the graded exercise test. The first stage of the test participants walked at a speed of 3 mph at 0% incline. Starting from stage 2, the speed of the treadmill remained at the participants' self-determined pace until termination of the test. Additionally, starting at stage 3, the incline of the treadmill rose 2% until termination of the test. Termination of the test was based on 2 of any of the 3 following conditions: a) VO_2 or HR decreases with an increase in workload b) respiratory exchange ratio (RER) > 1.14 and c) RPE =20. At the point of termination, both the speed and incline of the treadmill are lowered so that the participant walked at a speed of 3.0 mph for 3-minutes to maintain circulation of blood throughout the body.

Table 1. Graded Exercise Test (GXT) Ramp Protocol with 2-minute Stages

Stage	Speed (mph)	Grade (%)
1	3	0
2	Self-determined pace	0
3	" "	2
4	" "	4
5	" "	6
6	" "	8
7	" "	10
8	" "	12
9	" "	14

Following the graded exercise test, participants underwent a familiarization session of the AVRGs games and equipment they played during their 2nd and 3rd visits. No data was collected during the familiarization session and the session took place in the Exercise Physiology Laboratory. Trained research assistants fitted a VO_2 facemask and HR monitor on participants then, while participants remained standing, placed a VIVE VR headgear system (HTC, Taoyuan, TWN, China) on participants. VIVE VR controllers with wrist straps were placed in participants' hands and they were given details of the button layout. Researchers launched all of the games during the familiarization session and subsequent visits from Steam, a digital video game platform (Valve Corporation, Bellevue, Wa, USA). Participants played the 3 AVRGs in the study for 5-minutes and the order of the games played were randomized: Fruit Ninja VR (FNVR) (Halfbrick Studios, Brisbane, AU), Beat Saber (BS) (Beat Games, Prague, CZ, Europe), Holopoint (HP) (Alzan Studios, Longwood, FL, USA). A synopsis of each game that included the purpose of the game and use of controllers/buttons to progress in the game were read aloud to the participants by trained research assistants. After 5-minutes of playing each AVRG, participants were notified that the researchers were going to close the AVRG and launch the next one. Participants were given sufficient time to rest in between games before they started the next one.

Day 2

Participants reported to either the Exercise Physiology Laboratory, Mashouf Wellness Center, or played AVRGs at home (if HTC VIVE unit was accessible) for their second visit (randomized from an online randomizer tool).

Day 3

Participants reported to either the Exercise Physiology Laboratory, Mashouf Wellness Center, or played AVRGs at home (if HTC VIVE unit was accessible at home) for their third visit (randomized from an online randomizer tool).

Day 4

The subset of participants with access to an HTC VIVE unit at home reported to either the Exercise Physiology Laboratory, Mashouf Wellness Center, or played AVRGs at home for their 4th visit (randomized from an online randomizer tool).

Laboratory Setting

The laboratory setting took place at the Exercise Physiology Laboratory (teaching side) located on the San Francisco State University campus. Participants sat in a chair while an oro-nasal VO_2 mask (7450 series, Hans Rudolph, Shawnee, KS, USA) was fitted and chest strap heart rate monitors (H10 series, Polar, Kempele, FI, Europe) were suited and synced to the Polar Beat smartphone application on a research assistant's phone. All heart rate data is uploaded automatically from the smartphone application to the Exercise Physiology Laboratory database where researchers have sole access to the data.

Participants were then equipped with VIVE VR controllers and wrist straps were fastened by trained research assistants. The 6 ft. long wires connected to the VO_2 facemask were situated so that they came under the participants left arm and extended to the metabolic cart. The wires coming off of the VIVE VR headgear were placed behind the participant so that they did not cross the metabolic cart wires and were out of the way of participants' arms and frontal region. An elastic piece of nylon rope was used to tie together the VO_2 facemask and VIVE VR headgear to avoid a situation where the VO_2 facemask caused the VIVE VR headgear to move too far up on the participants head leading to blurred vision. A trained research assistant held the VIVE VR headgear wires behind the participant at waist level so to avoid the risk of the wires tripping the participant during gameplay. A separate research assistant stood next to the metabolic cart and rolled it when the sampling lines became tight due to participant movement. The order of the games played were pre-determined by an online randomizer tool. Each game was played for 10-minutes with 5-minutes of rest between games to allow participants HR and VO_2 to return back to 10% of resting levels. When each 10-minute AVRG was completed, trained research assistants untied the elastic nylon rope and removed the VIVE VR headgear from the participants. However, participants remained attached the VO_2 facemask during rest. Participants were given a chair to sit in each rest period and answered a 1-10 Likert scale of enjoyment after each game: (1) = no enjoyment, (10) = high level of enjoyment. Additionally, participants rated their highest perceived exertion during the 10-minutes of gameplay for each game. Enjoyment and RPE were manually recorded by trained research assistants and later inputted into the laboratory's database in the same day. After the completion of all 3 AVRGs, participants sat at a private desk within the lab and rated their overall level of enjoyment playing AVRGs in the laboratory setting and completed the Flow State Scale (FSS).

Gym Setting

Data collection in the gym setting took place at the Mashouf Wellness Center. A large room with windows housed two VIVE units and was the only activity occurring in the room at the time of data collection. Participants wore the same chest strap heart rate monitors as in the lab which were synced to a smartphone application. The VIVE VR headgear was then placed on the participants and adjusted for a comfortable fit. Similar to the laboratory setting, the wires coming off the VIVE VR headgear were situated behind the participant to allow the best possible freedom of movement and a trained research assistant held the wires at waist level during gameplay. The order of the games played followed the same order as the participant's first AVRG session (lab or gym). Each game was played for 10-minutes with 5-minutes of rest between games. During rest, participants were assessed on their level of enjoyment and highest RPE experienced during the 10-minute gameplay session. Enjoyment and RPE were manually recorded then uploaded into the laboratory's database later that same day.

Home Setting

At home participants were sent home with the chest strap heart rate monitors and were given instructions on how to download the smartphone application and set up an account. Participants were given instructions to complete the at-home visit with the same procedures used in the laboratory and gym setting (order of games played, gameplay settings, etc.).

Gameplay Modes

FNVR was played using its Zen Mode gameplay mode. In this mode, a continuous stream of fruit is launched into the air for 2-minutes where participants have to slice the fruits with the controllers that are represented as a sword in each hand inside the virtual setting. The 2-minute rounds can be extended by slicing special glowing fruits that extend the round by 2 seconds for every special fruit sliced. Participants are allowed to move around in the play space but in this game mode it is not a requirement to perform well. When the 2-minute round ends participants are instructed to press the retry button and start the next round. BS was played in the solo game mode setting. All participants played the same 5 songs from the original game soundtrack on hard difficulty or until the end of the 10-minute data collection. The order of the songs played were the same across all participants: 1) $100 Bills, 2) Beat Saber, 3) Balearic Pumping, 4) Breezer, and 5) Lvl Insane. Participants were instructed to "move or duck out of the way" of the barriers they encountered during the songs Additionally, the "no fail" option was selected to avoid less-skilled participants failing the songs and having to restart. HP was played in the classic game mode setting. Participants started the game at wave 1 and were able to freely progress through the game. If participants reached the wave 5 checkpoint, then on their next attempt they were given the option of starting the game at wave 5 instead of wave 1. Instructions were given to participants to "duck out of the way or dodge" objects.

Statistical Analysis

All data was analyzed using SPSS (Version 25.0; IBM Corp., Chicago, IL, USA). Results for the main outcome variables are expressed as means ± SD. Significance was set at the 0.05 level. To compare energy expenditure (oxygen consumption), enjoyment, and RPE between conditions, a repeated measures multiple analysis of variance (MANOVA) was conducted with all three dependent variables in a 2 (condition: lab or gym) by 3 (condition: FNVR, BS, or HP) MANOVA with gender and video game experience as between subjects factors. Simple univariate analysis further located pairwise differences when there was a significant difference. *Post hoc* analysis utilized Bonferroni's adjustment to assess significant main effects or interactions. Finally, bivariate correlation analyses were performed to explore relationships between the Flow State Subscales and main outcome variables (oxygen consumption, enjoyment, and RPE).

RESULTS

A total of 32 participants completed the study. Table 1. shows the descriptive characteristic of the male (n = 16) and female (n = 16) participants. Data was recorded as the mean ± standard deviation. Participants identified as Asian American (25%), Pacific Islander (25%), Hispanic (22%), Caucasian (19%), African American (6%), and East Asian (3%). A higher percentage of male participants (94.4%) reported playing video games compared to female participants (31.3%). Home data was excluded from the analyses due to a small number of participants (n = 4) that completed the at-home session. Results of repeated measures MANOVA test analyses revealed that there were no significant differences for the combined variables (enjoyment, oxygen consumption, and RPE) between settings, F (3, 26) = 2.57, p = .075. However, significant differences in oxygen consumption and RPE were observed between games, F (6, 26) = 3.38, p = .015. Further examination of oxygen consumption data showed participants averaged 35%, 31%, and 47% of their maximal aerobic capacity while playing FNVR, BS, and HP in the laboratory setting compared to 41%, 38%, and 52% in the gym setting, respectively.

Table 2. Descriptive Characteristics of Participants

	Male (n = 16)	Female (n = 16)	All (n = 32)
Age, y	22.9 ± 2.8	22.3 ± 2.3	22.6 ± 2.6
Height, cm	178.5 ± 9.7	156.7 ± 6.5	168.2 ± 13.8
Weight, kg	78.3 ± 12.2	54.4 ± 6.4	67.1 ± 15.6
Total body fat, %	15.3 ± 9.1	25.3 ± 5.9	20 ± 9.2
Body mass index, (kg/m^2)	24.7 ± 4.2	23.5 ± 3.8	22.1 ± 2.6
VO_2 max, mL/kg/min	47 ± 5.6	42.7 ± 5	44.9 ± 5.7
VO_2 rest, mL/kg/min	4.9 ± 0.7	5.1 ± 0.8	5 ± 0.3
HR rest, bpm	68.4 ± 8.7	72.8 ± 8.9	70.5 ± 9
Resting metabolic rate, kcal/day	1729 ± 196	1096 ± 93	1431 ± 355

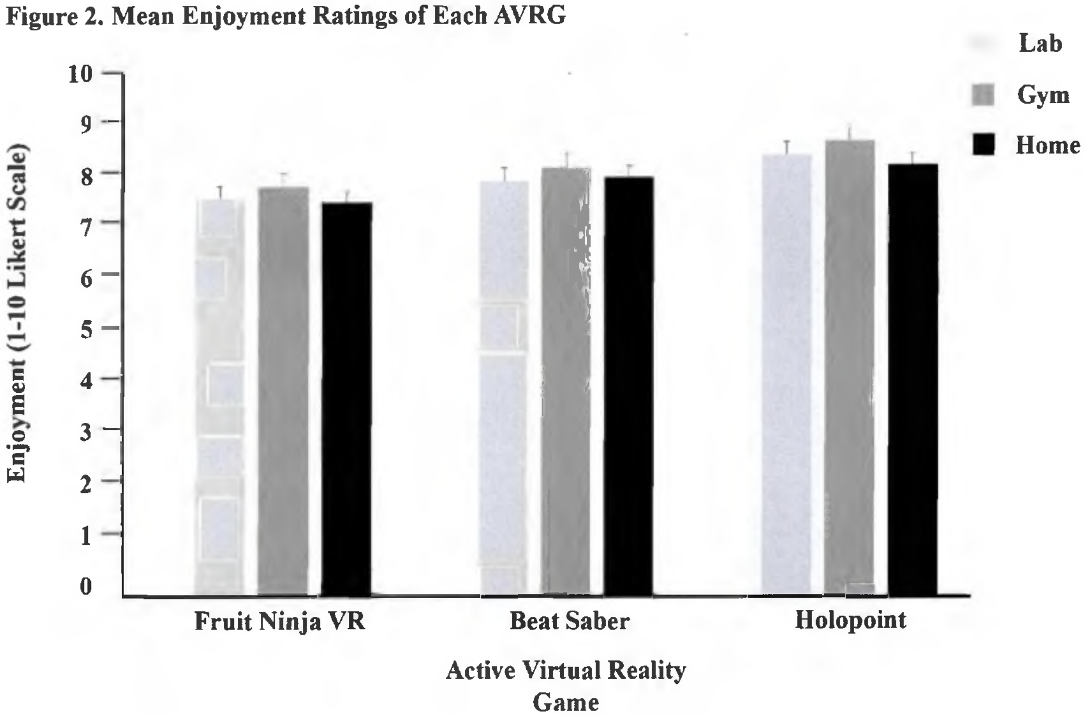
Values are reported as mean ± SD for male (n = 16) and female (n = 16) participants.

Table 3. Video Game Experience of participants

	Male (n = 16)	Female (n = 16)	All (n = 32)
Currently plays video games	17 (94.4)	5 (31.3)	22 (64.7)
Experience using virtual reality	4 (22.2)	1 (6.3)	5 (14.7)

Values are reported as mean ± SD for male (n = 16) and female (n = 16) participants.

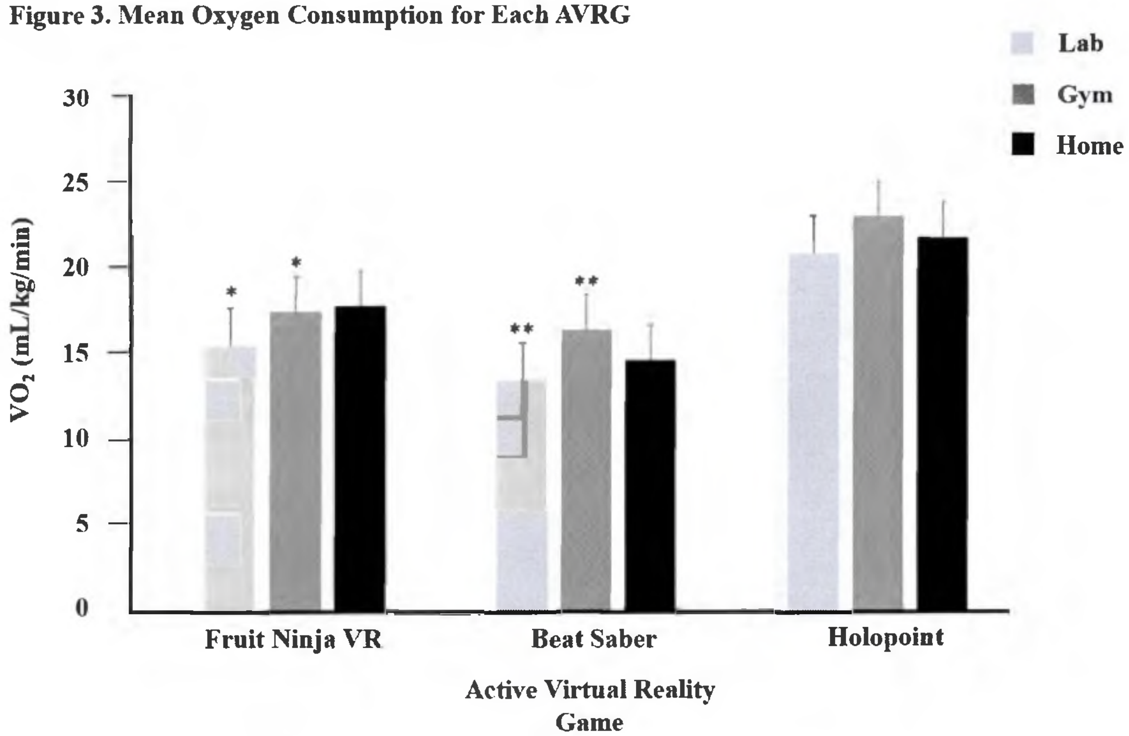
Figure 2. Mean Enjoyment Ratings of Each AVRG



Enjoyment

Figure 2 shows the mean enjoyment ratings during all three gaming conditions between settings. Enjoyment was rated high for all conditions but was higher in the gym setting compared to the lab setting. The highest enjoyment rating was during HP gameplay in the gym (9 ± 1.1) followed by HP gameplay in the laboratory (8.8 ± 1.1). Participants also rated enjoyment of BS higher in the gym setting (8.4 ± 1.4) compared to the lab (8.2 ± 1.7). The least enjoyable game was FNVR (8.1 ± 1.4 in gym setting vs. 7.8 ± 1.7 in lab setting). There were no significant differences for enjoyment between settings or between games (*p*>.05).

Figure 3. Mean Oxygen Consumption for Each AVRG



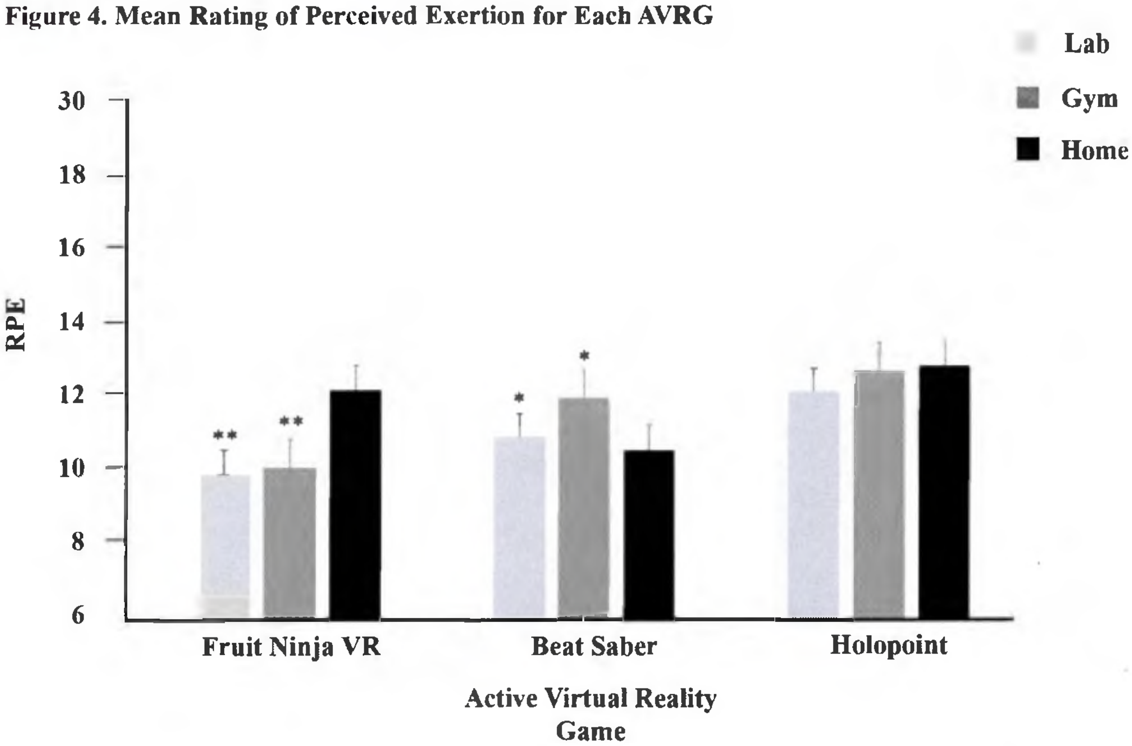
Oxygen consumption of participants (n = 32) during three AVRG gaming conditions (Fruit Ninja, Beat Saber, Holopoint) in three different settings. * p<0.05 vs. Holopoint; ** p<0.01 vs. Holopoint.

Oxygen Consumption

Figure 3 shows the mean oxygen consumption during all three gaming conditions between settings. Participants had the highest oxygen consumption when playing HP in the gym (23.07 ± 8.4 mL/kg/min) but consumed less oxygen when playing HP in the lab (20.69 ± 5.4 mL/kg/min). Contrary to expected differences in exercise intensity between FNVR and BS, participants had lower oxygen consumption during BS in both settings.

The lowest oxygen consumption was observed in the lab when participants played BS (13.53 ± 2.5 mL/kg/min) but participants consumed more oxygen when playing BS in the gym (16.43 ± 7.1 mL/kg/min). FNVR ($p<.05$) and BS ($p<.01$) differed significantly and at different confidence levels from HP.

Figure 4. Mean Rating of Perceived Exertion for Each AVRG



Rating of perceived exertion for participants (n = 32) during three AVRG gaming conditions (Fruit Ninja, Beat Saber, Holopoint) in three different settings. * p<0.05 vs. Holopoint; ** p<0.01 vs. Holopoint

Rating of Perceived Exertion

Figure 4 show the mean RPE during all three gaming conditions between settings. Participants rated their RPE to be higher in the gym setting compared to the lab setting for all conditions and between settings. The highest observed RPE for conditions that were analyzed was HP in the gym (13 ±2.2) followed by HP in the lab (12 ± 2.5).

Participants had similar RPEs for FNVR between the lab (9 ± 1.8) and gym (9 ± 2.1). Participants rated their RPE to also be the same during BS between the lab (10 ± 2.1) and gym (10 ± 2.1). There were no significant differences for RPE between settings, however RPE for FNVR ($p<.01$) and BS ($p<.05$) were significantly different compared to HP.

Flow State Subscales

Table 4 shows the correlations between enjoyment, RPE, and the Flow State subscales in the laboratory. Overall, positive relationships were observed between the level of enjoyment playing AVRGs in the in the laboratory and all 9 subscales of flow. There was a strong positive correlation between overall enjoyment of playing AVRGs in the lab and *Challenge-Skill Balance* ($r = .384$), *Unambiguous Feedback* ($r = .425$), *Paradox of Control* ($r = .532$), and *Autotelic Experience* ($r = .606$). Table 5 shows the correlations between enjoyment, RPE, and the Flow State subscales in the gym. Similar positive relationships were observed between overall level of enjoyment playing AVRGs in the gym and the 9 subscales of flow. Additional strong positive relationships emerged between overall enjoyment and *Clear Goals* ($r = .529$) and *Concentration on Task at Hand* ($r = .422$) for the gym setting. Table 6 shows the correlations between oxygen consumption and the Flow State subscales in the lab. Overall, positive relationships emerged between oxygen consumption of all three games and *Challenge-Skill Balance*, *Paradox of Control*, and *Autotelic Experience*. Table 7 shows the correlations between oxygen consumption and the Flow Sate subscales in the gym. Overall, strong positive relationships were observed between HP and all 9 subscales.

Table 4. Pearson Product-Moment Correlations Between Enjoyment, RPE, and Flow State Subscales in *Laboratory*

Scale	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Overall Enj	-	.617**	.376*	.595**	-.192	-.152	-.327	.384*	.315	.323	.425*	.328	.532**	.332	.323	.606**
2. Enj Fruit Ninja		-	.162	.440*	-.357*	-.385*	-.187	.179	.164	.147	.286	.336	.417*	.211	.292	.354*
3. Enj Beat Saber			-	.365*	-.043	.092	-.099	.363*	.537**	.355	.330	.103	.071	.346	.358	.334
4. Enj Holopoint				-	.035	.063	.128	.477**	.309	.270	.404*	.201	.379*	.215	.219	.561**
5. RPE Fruit Ninja					-	.596**	.402*	.056	-.022	-.158	-.126	.095	.030	-.086	.143	-.092
6. RPE Beat Saber						-	.667**	-.023	-.234	-.242	-.319	-.002	-.061	-.270	-.012	-.151
7. RPE Holopoint							-	-.049	-.319	-.230	-.196	.013	-.085	-.180	-.193	-.079
8. C-SB								-	.662**	.645**	.653**	.221	.625**	.362*	.210	.689**
9. A-AM									-	.659**	.587**	.333	.443*	.414*	.421*	.523**
10. CG										-	.909**	.164	.341	.390*	-.032	.443*
11. UF											-	.247	.309	.478**	-.090	.524**
12. CTH												-	.413*	-.003	.509**	.429*
13. POC													-	.179	.376*	.619**
14. LSC														-	.183	.377*
15. TT															-	.391*
16. AE																-

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Table 5. Pearson Product-Moment Correlations Between Enjoyment and RPE and Flow State Subscales in *Gym*

Scale	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Overall Enj	-	.534**	.604**	.537**	-.264	-.169	-.049	.420*	.256	.579**	.438*	.422*	.607**	.284	.123	.636**
2. Enj Fruit Ninja		-	.484**	.406*	.076	-.001	-.010	.243	.244	.466**	.419*	.359*	.373*	.338	.158	.465**
3. Enj Beat Saber			-	.106	-.172	.104	-.065	.100	.114	.159	.145	.144	.181	.152	.192	.241
4. Enj Holopoint				-	.100	-.028	.179	.332	.011	.262	.279	.341	.408*	.188	.126	.521**
5. RPE Fruit Ninja					-	.509**	.463**	.178	.378*	-.068	.181	.102	.034	.233	.044	.036
6. RPE Beat Saber						-	.604**	-.044	.067	-.242	-.043	-.205	-.169	-..037	.008	-.095
7. RPE Holopoint							-	.327	.287	.093	.322	.121	.163	.169	.111	.110
8. C-SB								-	.480**	.686**	.724**	.651**	.753**	.599**	.350*	.611**
9. A-AM									-	.538**	.550**	.442*	.518**	.491**	.176	.374*
10. CG										-	.821**	.567**	.758**	.453**	.069	.510**
11. UF											-	.515**	.771**	.586**	.254	.530**
12. CTH												-	.754**	.541**	.231	.735**
13. POC													-	.712**	.255	.745**
14. LSC														-	.436*	.497**
15. TT															-	.364*
16. AE																-

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Table 6. Pearson Product-Moment Correlations Between Oxygen Consumption and Flow State Subscales in *Laboratory*

Scale	1	2	3	4	5	6	7	8	9	10	11	12
1. VO_2 Fruit Ninja	-	.537**	.438*	.159	.260	.010	-.025	-.096	.253	-.030	.094	.165
2. VO_2 Beat Saber		-	.262	.123	.273	.113	.124	.135	.224	-.096	.111	.308
3. VO_2 Holopoint			-	.349	.074	.085	.136	-.205	.134	.108	-.060	.358*
4. C-SB				-	.662**	.645**	.653**	.221	.625**	.362	.210	.689**
5. A-AM					-	.659**	.587**	.333	.443	.414	.421*	.523**
6. CG						-	.909**	.164	.341	.390*	-.032	.443*
7. UF							-	.247	.309	.478**	-.090	.524**
8. CTH								-	.413*	-.003	.509**	.429*
9. POC									-	.179	.376*	.619**
10. LSC										-	.183	.337*
11. TT											-	.391*
12. AE												-

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Table 7. Pearson Product-Moment Correlations Between Oxygen Consumption and Flow State Subscales in *Gym*

Scale	1	2	3	4	5	6	7	8	9	10	11	12
1. VO_2 Fruit Ninja	-	.780**	.662**	.203	.401*	.128	.209	.265	.161	.163	.130	.068
2. VO_2 Beat Saber		-	.618**	.250	.434*	.255	.326	.354	.212	.076	.165	.222
3. VO_2 Holopoint			-	.533**	.415*	.412*	.412*	.523**	.451**	.324	.256	.340
4. C-SB				-	.480**	.686**	.724**	.651**	.753**	.599	.350*	.611**
5. A-AM					-	.538**	.550**	.442*	.518**	.491**	.176	.374*
6. CG						-	.821**	.576**	.758**	.453**	.069	.510**
7. UF							-	.515**	.771**	.586**	.254	.530**
8. CTH								-	.754**	.541**	.231	.735**
9. POC									-	.712**	.255	.745**
10. LSC										-	.438*	.497**
11. TT											-	.364*
12. AE												-

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

DISCUSSION

The purpose of this study was to explore the effects that exercise setting has on energy expenditure and enjoyment during active virtual reality gaming. To date, the potential of AVRGs to increase physical activity and health has been explored in laboratory settings. Yet, few studies have examined AVRG exercise in settings where the majority of gameplay would take place. To our knowledge, this is the first study to investigate comparisons in energy expenditure and affective responses for three AVRGs across different settings. It was expected that there would be increases in oxygen consumption and enjoyment during AVRG gameplay in the free-living settings (gym and home) compared to the laboratory setting. Home data was excluded from analysis due to a small number of participants (n = 4) completing the at-home visit. These differences were expected due to the tenets of the Theory of Planned Behavior (TPB) which states that an individual's intent to partake in health activities will change when the setting changes (Ajzen, 1991). Specifically, the magnitudes of social pressure and perceived control over participation will vary between the laboratory, gym, and home setting. Furthermore, these three settings are common locations where people exercise which warrants an investigation pertaining to this study. The present study found that energy expenditure and enjoyment were higher in the gym setting compared to the lab setting but analysis revealed that these differences were not significant. However, consistent with previous studies (Gomez et al., 2018; Peng, Crouse, & Lin, 2012; Gao, Pasco, & Pope, 2015) exercise intensity changed depending on the game being played. That is, specific movements required to perform successfully in the game will affect energy expenditure during gameplay. The present study also found overall positive correlations between Flow State subscales, enjoyment, and oxygen consumption.

Enjoyment is an important predictor for motivation to participate and adhere to physical activity (Wankel, 1993; Salmon et al., 2003). Some researchers have postulated that physical activity in natural environments may result in more favorable mood responses for enjoyment compared to laboratory settings (Focht, 2009; Gauvin et al., 1996). In this study, enjoyment was rated fairly high for all conditions between settings. Additionally, minimal differences in enjoyment were observed between the games and settings. Enjoyment must be considered as health professionals and researchers look to develop exercise programs. Fortunately, this study revealed that individuals may be able to play AVRGs across different settings without any decreases in enjoyment. Furthermore, for untrained individuals, enjoyment decreases as exercise intensity goes up (Heisz et al., 2016). At times during this study, the most intense game (HP) was played at 80% or more of participants' maximal aerobic capacity without noticeable decreases in enjoyment. These findings are congruent with previous studies that AVRGs can elicit exercise intensities to meet national guidelines for physical activity but also provide noteworthy evidence that AVRGs are highly enjoyable exercise activities that may be able to reach a broader audience that are unmotivated to participate or find it difficult to adhere to conventional forms of exercise.

The maximal rate of oxygen consumption (VO_{2max}) measured during a graded exercise test is considered the gold standard measurement of integrated cardiopulmonary and muscular function. Increases in VO_{2max} improve exercise tolerance in individuals as well as long term health statuses (Astorino et al., 2016). Although specific training adaptions to AVRG gameplay with traditional exercise program durations (8-12 weeks) was not examined in this study, the intensity of exercise observed in the most intense game (HP) stimulated sufficient percentages of maximal aerobic capacity (avg: 56%) required to improve VO_{2max} (Huang et al., 2005). This exercise intensity was attenuated when participants played in the laboratory setting compared to the gym setting. For all three games, lower oxygen consumption levels were observed when participants played in the laboratory setting. Although the differences did not reach significance, this key finding could be explained by participants' perceived control over participation. The gym setting is a common setting where individuals volitionally go to exercise compared to the laboratory setting where behavior is usually under controlled circumstances. Montano and Kasprzyk (2007) found that perceived control is determined by the presence or absence of facilitators and barriers to behavioral performance. In this context, the gym setting had less barriers and more facilitators to behaviors that would increase the oxygen consumption of participants while playing AVRGs.

The nine different subscales of the Flow State Scale are important predictors for motivation for an activity. With regards to enjoyment during AVRG gameplay, there were overall positive relationships between the subscales and enjoyment. When Flow

State subscales are rated highly during an activity, the performer is totally connected to the experience. Use of the Flow State Scale is extensive as its underlying psychological affect, the flow state, is examined in elite athletes and sports participants of all levels (Jackson S. & Marsh. H. 1996). Its exploratory use in this study is, to our knowledge, the first of its kind to relate the psychological experience of playing AVRGs in different settings. *The Challenge-Skill Balance* (CSB) dimension is a central determinant in flow states and important regarding traditional forms of video games. Allowing progression through games to a wide-range of players' skill level has been observed to be critical in developing highly enjoyable video games (Chen, 2007). In the current study, CSB was positively correlated with overall enjoyment for both the lab and gym settings. *Unambiguous Feedback* was also correlated with enjoyment for both settings. According to Csikszentmihalyi (1980) video game design must incorporate an ongoing dynamic process where individuals must aim to continually adjust their actions in response to game play mechanics. One way to achieve this dynamic is to create tight feedback loops which reinforces positive actions and discourages negative ones. The findings from this study suggest AVRGs that are well-suited to create feedback loops through unambiguous feedback result in overall more enjoyment during gameplay for participants, regardless of the setting in which they are played. *Paradox of Control* was revealed in this study to be positively correlated with enjoyment in both settings. This dimension of flow has been examined in previous studies to be control over one's body but specific to this study is a disconnect from the physical play space and the virtual play space. The alteration of

Paradox of Control to mean control over one's actions compared to control over the body was utilized in this study to better define the flow state in the context of AVRG gameplay.

In the gym setting additional Flow State subscales were positively correlated with overall enjoyment. Participants found the AVRG experience more enjoyable in the gym when they had higher affective responses to *Clear Goals* and *Concentration on the Task at Hand.* Furthermore, *Clear Goals* was the only subscale that was positively correlated with oxygen consumption for any gaming condition (HP) between settings (gym). *Clear Goals* are defined as a strong sense of knowing exactly what to do in an activity. Csikszentmihalyi (1988) states sporting activities that are the most intense and pleasurable are usually the ones where performers had focused attention and clearly set goals. The findings from this study suggest that AVRGs can operate the same way that traditional high intensity sporting activities do in regard to activities that are the most intense become more pleasurable if clear goals are able to be defined within the AVRG experience. In particular, this interaction between specific flow states and AVRGs might help sustain engagement and motivation to partake in exercise programs when AVRGs are used in exercise programs or in conjunction with traditional exercises.

Limitations and Future Research

Although the current study contributes a unique perspective on energy expenditure and enjoyment during active virtual reality gaming between settings, future research needs to examine the long-term effects of an AVRG exercise program. The majority of participants in the current study did not have previous experience using virtual reality in any context. The duration of the current study was not long enough to test the effect of AVRGs as a novel experience and its outcomes for oxygen consumption and enjoyment. Thus, an exercise program utilizing AVRGs at a sufficient enough duration with participants unfamiliar with virtual reality can attempt to detect the effect that novelty of the experience may have on the main outcome variables examined in this study. A small subset of participants (n = 4) completed an at-home AVRG session due to the difficulty of finding participants who owned a virtual reality unit. The current price point of on-the-market virtual reality units limits the accessibility of virtual reality at home. Participants may not have interpreted the use of the RPE scale to the intent of the study. Even though the researchers provided an explanation of the scale during the initial visit to the lab, participants often interpreted their exertion to be based on the difficulty of the game instead of their own perceived levels of physical exertion.

CONCLUSION

This study suggests that the oxygen consumption and enjoyment of college-aged participants during active virtual reality gaming does not change when the exercise setting changes. However, oxygen consumption varies depending on the AVRG that is being played. Furthermore, this study reinforces previous research that suggest AVRGs are a possible alternative to traditional forms of exercise and may reach a broader audience who have hard time adhering to conventional exercise programs. More research is warranted to detect what effect the novelty of the experience has on oxygen consumption and enjoyment when played over a longer period of time. Future investigation should include measurements during at-home gameplay once the accessibility of virtual reality units become more commercial-friendly.

APPENDICES

Review of Literature

Introduction

Keywords and concepts to appropriate the literature for this review were entered into the following databases: ERIC (EBSCO, PubMed, SPORTDiscus, Science Direct, and Google Scholar. Keywords that were used include: virtual reality, energy expenditure, active video games, physical activity, video games, motivation, HTC VIVE, Nintendo Wii, immersion, enjoyment, Flow State Scale, presence, and exergaming.

Epidemiology and Prevalence of Obesity in the United States

Obesity is a public health crisis affecting millions of individuals in the United States. The Center for Disease Control and Prevention (CDC) released a report stating 40% of U.S. adults were considered obese in 2016. This was preceded by a significant increasing linear trend in obesity rates beginning in 2000 where 30% of U.S. adults were considered obese (Mattews et al., 2008). Evidence suggests that this linear increase will continue to remain on the rise and may eventually lead to younger generations in the U.S. having a shorter life expectancy than their parents (Deurenberg, Yap, & Staveren, 1998). In observational studies, obesity was correlated with sedentary and physically inactive individuals having a greater percent body fat (Mokdad et al., 2003; Okorodudu, 2010).

Interventions that aim to increase physical activity levels result in weight loss and reductions in fat distribution (Donnelly et al., 2009; Harris et al., 2009; Hunter et al., 1997; Slattery et al., 1992). Therefore, much of the obesity prevalence observed in the U.S. is perhaps, at least partially, due to sedentary, physically inactive lifestyles.

ACSM Recommendations for Physical Activity

The consequences of obesity are well-known, including an increased risk for cardiovascular and metabolic disease (Alberti et al., 2009; Kahn et al., 2002). Unfortunately, less than half of U.S. adults (46.9%) currently adhere to the recommended physical activity guidelines set forth by the American College of Sports Medicine (ACSM) for preventative health benefits (minimum 150 minutes per week of moderate-intensity exercise). Promotion of physical activity has been examined in numerous studies with a range of strategies and interventions explored. In a recent systematic review, the effectiveness of interventions that focus on education-based curriculums to reduce television viewing and video game playing had significant effects in reductions on their main outcome (television viewing and video game time) but the interventions did not consistently correspond with increases in physical activity. Therefore, interventions that aim to increase physical activity should focus on factors that eliminate any of the barriers to physical activity rather than decrease amount of time in sedentary behaviors (Kahn et al., 2002). Potential barriers to physical activity include time constraints, a lack of motivation, feelings of tiredness, a lack of resources, and not feeling competent or skilled enough in a specific activity (Salmon et al., 2003). Following the ACSM's recommendations for exercise, adults should aim to do any physical activity as some is better than none. For children and adolescents ages 6-17, 60-minutes of physical activity a day is recommended. However, incorporating physical activity participation into the daily routines of individuals is time and resource intensive. Therefore, new strategies are needed that focus on individuals' motivations to voluntarily participate in physical activity. There is a considerable amount of evidence that the amount of physical activity is largely dictated by enjoyment and preference. This motivation also drives individuals' reasons to partake in sedentary behaviors, including screen time and video game play.

Emergence of Active Video Games to Promote Physical Activity

About 50% of adults play some form of video game on a regularly basis and 83% of American youth have access to a video game console in their bedroom (Biddiss & Irwin, 2010). Furthermore, participation in video gameplay has become the fastest growing mode of recreation for humans. Instead of competing against a highly valued activity, an alternative strategy is to replace passive screen time with active screen time. An emerging technology are video games that require the user to be physically active and reach energy expenditure levels beyond those of resting observed in traditional sitting-hand-controlled designs, essentially turning passive screen time into active screen time. These active video games (AVGs) have the potential to overcome the barriers associated with physical activity. A recent review of AVGs found them capable of eliciting light-to-modest physical activity intensity although the long-term efficacy of physical activity promotion remains unknown (Peng, Crouse, & Lin, 2012). Therefore, the goal of this review is to provide a more comprehensive understanding of the current knowledge pertaining to new active virtual reality games play and the promotion of physical activity and health. Specifically, the objectives are (1) to provide explanations for higher prevalence of sedentary behavior due to increase video game play (2) to explore the history of video games and the introduction of newer videos games for health (3) discuss the motivation that drive video game play and the consequences of increased immersion during gameplay (4) interpret the physiological responses to active video game play and (5) to investigate potential differences in enjoyment and physiological outcomes during active video game play in specific settings.

Increases in Television, Computer Screen Time, and Video Game Play

The amount of time an individual is engaged in sedentary behavior has been shown to be independently associated with increased risk for weight gain, diabetes, cardiovascular, and metabolic diseases (Matthews et al., 2008). Sedentary behaviors are considered to be a range of activities that an individual participates in that result in energy expenditure no greater than 1.5 times' resting energy expenditure. In 2008, a study by Matthews and colleagues quantified the amount of time spent in sedentary behaviors from a large representative sample (6,329) of U.S. adults and children. It was found that adults and children in the United States from the years 2003-2004 spend approximately 55% of their waking day, or 7.7 hours/day, engaged in sedentary behavior. Black and white populations had similar sedentary levels whereas Mexican-Americans were the least sedentary group. Furthermore, girls were found to be more sedentary than boys and the period of adolescence saw substantial increases in sedentary behavior. Although, overall level of sedentary behavior was observed there was no evaluation of the specific activities that participants were engaged in during the day.

Obesity and Video Game Use

Watching television and playing video games are the two activities that dominate the discussion surrounding the "couch-potato" hypothesis - watching television and playing video games increases weight in individuals because they displace physical activities. Thereby, less physical activity puts individuals more at risk for obesity. This has been a primary topic in the U.S. due to an observed increased prevalence of obesity in both adults and children. However, the causal evidence linking television time and video game play has been mixed at best. One limitation of past studies is the premise that one potential cause of obesity can be linked to television viewing time and, by extension, video game play as well. A recent study investigated obesity in a nationally representative sample of 2831 children (51% boys, 49% girls) and its independent associations with television screen time and video game play (Vandewater et al., 2004). There was no evidence that television time was associated with children's' weight status. Yet, the results indicated that video game play was strongly related to higher weight in children. That is, children with higher weight statuses spent more time engaged in video game play compared to children with lower weight statuses. Thus, it may be that the increased prevalence of obesity seen in U.S. children is better explained by video game time rather than television time.

Prevalence of Video Game Use in the United States

In 2007, a representative sample of about 2,000 adults in the U.S. were assessed on their video game use (Lenhart, Jones, & Macgill, 2008). Data was collected from telephone interviews over a 3-month period (October - December). It was found that about one in five adults play video games every day or almost every day. Furthermore, almost half of adult gamers play video games at least a few times a week. Younger adults are markedly more likely to play video games than their older adult counterparts. Particularly, 81% of persons ages 18-29 play video games, while only 23% of older adults ages 65 or older reported playing video games. Even though a substantial number of adults play video games (53%) they are still outnumbered by the number of teens who play video games (97%). Compared to higher sedentary levels of girls than boys in childhood, adult men (55%) are more likely to play video games than women (50%). Interestingly, education level was a predictor of video game play. In general, those with higher education levels (57%) reported playing video games more than those who have less than a high school education (40%). There existed no differences between ethnic groups on video game play whether it be on a computer or console device. The highly valued activity of playing video games and amount of time spent playing them can be attributed, at least in part, to a changing economic scheme and the technological advances of the 21st century.

An examination of type of leisure activities that make up young men's total leisure time found that there was a 45% increase in recreational computer time from 2004 to 2015 (Aguiar et al., 2017). Of the total 5.2 hours per week of recreational computer activities, 3.4 hours of it was dedicated to video games. Parallel to the increase in leisure time was a drop in labor demand for young men ages 21-30 between 2000 and 2015. That is, market hours worked by younger men fell by about 200 hours per year as manufacturing and routine employment opportunities decreased. Of particular note is the one percent increase in leisure time observed was associated with a 2.1 percent increase in time playing video games. Compared to other leisure activities including socializing and watching TV/movies, an increase in leisure time did not see the same magnitude of increase in hours spent per week of these activities. Therefore, video gaming is an especially strong leisure luxury for younger men but is not represented in other demographics such as younger women, older men and older women.

Traditional Video Games

Video games have become so embedded in American society that its growth as an industry puts it at one of the largest entertainment industries in the world (Wolf, 2008). The recognition of video games in academia took close to forty years of its existence as a commercial industry. This may have been due to the graphically simple designs early in video game conception and. Compared to the unchanged, linear depictions of text, sound and images seen in traditional media, video game events are confoundedly different from person to person (Wolf, 2001). Although, viewing media can be referred to as "active," where the viewer is paying close attention to the content, video games require the user to physically input an action for the game to function. Therefore, the unique, interactive experiences that video games afford have opened new possibilities in the form of interactive entertainment.

Over the years, the medium of video games have appeared on numerous types of consoles with different technological capabilities. The first designs in the 1960's ran on refrigerator-sized computers and were only found in research centers and laboratories. With primitive gameplay and limited accessibility to a mass audience, the popularity of video games did not occur until a commercially available home system was invented (Kent, 2001). In 1971, the Atari company released the Atari 2600 which was the first home video game system of its type. The move from big mainframe computers to minicomputers was accelerated by the invention of microprocessors and soon made video game consoles a household appliance. Parallel to the reduction in computer size was an increase in imaging technology that allowed video game consoles such as the Nintendo 64, Sony Playstation, and Microsoft Xbox to take their place in American culture (Schilling, 2003). The real-time interactions with images on a screen have continued to progress to a point where now players are being immersed into three-dimensional (3-D) interactive virtual environments. The idea of placing individuals in a virtual reality are often hyped in movies but is slowly becoming the staple type of gameplay among video game players (Zyda, 2005). For the past 20 years, researchers have been examining virtual reality in the realm of an actively moving and exploring player.

The notion of having a virtual simulated environment that observers could feel like they were "in" can date back to the 1950's when the Hollywood motion picture industry was booming. From this idea, the Sensorama was invented that allowed observers to ride a motorcycle through a simulated city environment (Stanney, 2002). In an attempt to make the Sensorama a truly multisensory experience wind generators, chemical scents, and vibrating pieces were manufactured into the design. The bulky arrangement that the Sensorama required to run eventually led to its demise because incorporating units was unfeasible in most locations. Shortly after, the inventions of head-mounted displays (HMD) served as the next window into a virtual world (Fisher et al., 1988). It wasn't until the 1980's that advances in optical technology and haptic devices led NASA's research branch to develop their virtual reality system. The Virtual Interface Environment Workstation (VIEW) utilizes a head-mounted display and haptic gloves to allow human-computer interactions. This human and computer interaction complex made its way into military training regimens where World War 2 pilots wore HMDs during flight simulations. The success of HMDs set the foundation for other industries to utilize headsets in their attempt to connect human and computers even more.

The video game console market had skyrocketed during its early years quickly making it a $5-billion industry and part of American urban and suburban life (Whittaker, 2003). New video games were being released to audiences at a rapid pace across different video game consoles. The market soon became saturated with consoles and video games which significantly reduced the price of both across the board. Eventually, video game companies had a hard time keeping up with the demands of consumers for new titles and consoles. In 1983, the video game industry went from a $5-billion industry to a market revenue of $100-million that year. New innovative video game technologies were one solution to bringing back the mass audience after the crash. Consequently, Nintendo releases the Famicom 3D system which used liquid crystal shutter glasses worn by the player to "augment" the real world to have graphics superimposed on top. This was the first instance of "augmented reality" available for consumers and led to the development of more commercially available 3D viewing experiences (Messinger et al., 2008). Following the Famicom's active shutter glass technology, Nintendo brings the Virtual Boy console to the market in 1995. Instead of graphic displays layed over the real world, the Virtual Boy used vibrating, oscillating mirrors to project reflection images to a near-eye display headset. The downside to this kind of design was that players had to be seated in one position to be able to view the images on the headset. Players were wanting to more accurately gauge their movements in virtual environments but were burdened with the lack of positional sensing in the first generation designs. A year later, Sony released the PLM-50 Glasstron that used a positional sensor located on top of the headset to record and depict players' head movements. The ability to track player's head movements while in the game resulted in a breakthrough for the virtual reality consoles. By tracking the position of a player's head, games could now give a fully immersive 3D environment in which players could explore by the simple act of looking around. The virtual reality display systems seen today (PlayStation VR, Oculus VR, HTC VIVE, and Samsung Gear VR) all have head motion tracking systems, accelerometers, gyroscopes, and eye tracking sensors implemented in their designs. This multi-component setup opens the door for numerous goal-directed behaviors that requires players to engage in activities without the seamless idea for external rewards (Sherry et al., 2006). With this idea and the amount of time spent playing video games, researchers attempt to examine video games through a motivational lens.

Video Game Motivation and Feelings of Immersion

As video games become a more ubiquitous part of human experience, explanations for the draw that players feel to continually enter virtual worlds become more complex than the explanations for books or traditional media. Historically, video game debates have been centered around if they are good or bad, yet recent research has suggested numerous learning principles that envoy specific factors that create and sustain motivation (Anderson et al., 2010; Ferguson, 2007; Gee, 2003; Prensky, 2003). The term "cycle of expertise" was first introduced by researchers interested in what makes chess grandmasters excel in their competitive field. It is identified as situations that individuals experience repetitively until mastery of skills to progress occur yet when faced with new situations or tasks, individuals are forced to rethink their mastery of certain skills (Gee, 2003). Video games place players in theses "cycles" repeatedly throughout the whole game, usually requiring large amounts of time learning new skills. From cognitive science, motivation is understood as a learner's continual voluntary commitment to engage in new scopes of learning. Therefore, video games are considered good models for the production of learning and therefore, motivation.

If video games are to eliminate any of the barriers to physical activity, then they must be inherently enjoyable to play (Maloney et al., 2008). Already, millions of players forgo other leisure activities and choose to engage in video game play on a national level (Przybylski et al., 2010). The cost of playing video games can extend beyond game expenses and subscription fees to also have social implications such as angry parents and loss of social time. Furthermore, the majority of players are playing video games without any apparent external rewards given to them (Millar & Navarick, 1984). One theory that researchers have focused on when examining video game motivation is the self-determination theory (SDT). According to SDT, an individual's behavior that stems from the inherent satisfaction in performing that behavior is identified as intrinsically motivated and behaviors pursued for a desired end goal are said to be extrinsically motivated (Ryan & Deci, 2000). Therefore, video games offer experiences that are inherently enjoyed by the player due to the absence of external rewards (Tamborini et al., 2010; Wang et al., 2008). However, because motivation to play video games is tied to the psychological well-being of players, researchers often use cognitive evaluation theory (CET)-based approaches. CET explains greater intrinsic motivation arises when feelings like efficacy, autonomy, and relatedness are perceived higher by participants in the activities that they are engaged in. From this view, a motivational model of video game play was developed by researchers in which the appeal of video games is based on the psychological need satisfaction that they offer. The basic psychological needs (competence, autonomy, and relatedness), when satisfied, have been previously demonstrated to foster greater intrinsic motivation for video game play by Ryan and colleagues (Ryan, Rigby, & Pryzbylski, 2006).

One study by Ryan and colleagues was conducted to measure competence, autonomy, relatedness and how immersed college-aged players felt during their video game experience. From a sample of novice video game players who played a 3D platform game, self-reports of autonomy and competence while playing resulted in greater enjoyment of the video game. Furthermore, if the psychological needs were met during gameplay then participants felt more immersed while playing. Immersion in the context of motivational climate in video games can lead to more player vitality, self-esteem, and affect (Jin & Igarashi, 2016). These experiences of enjoyable video game play also predicted if the player would re-engage in this activity during a free-choice period. It is also interesting to note that each of the psychological needs can independently contribute to immersion, enjoyment, and future engagement. To examine each of the psychological needs independently, the same researchers isolated factors such as game content, player skill, and participant demographic and how these contributed to the psychological needs becoming satisfied. The findings reinforced the hypothesis that higher levels of autonomy and competence led to more enjoyment, preference for future engagement, and immersion. A closer examination of the three psychological needs and their independent associations to intrinsic motivation employed the same self-determination theory in a non-digital game-based context. Participants who answered higher on competence and relatedness scales also rated more intrinsic motivation during game play. Thus, while topics on video game motivation have focused on linkages between the appeal of specific video game genres (violent, multiplayer, etc.) and motivational outcomes, it may be better, from an applied standpoint, to address motivation to play video games by examining the fundamental psychological need satisfactions (Sheldon & Filak, 2008).

A fundamental quality of all video games is player engagement of "action at a distance." That is, along the same lines of remotely controlling a robot, a player's actions and decisions of their video game character feel as though the player has embodied these experiences themselves (Gee, 2008; Kilteni, Groten, & Slated, 2012). The concept here is that highly immersive video games don't offer detachment between the virtual and physical worlds, rather the player's mind and body construct a sense of presence and self in the virtual world (Lombard & Ditton, 1997). Players might feel as though they are "immersed" and even "present" in virtual environments. Specifically, the two states differ from one another where immersion is generally understood to be the additive multisensory inputs from technology while presence is the psychological perception of being "there" in a virtual environment (James & Kalyanaraman, 2007). Therefore, the general presence state felt by players may be able to influence player psychology by allowing them to experience need satisfactions. The use of virtual environments for players to explore can have a significant effect on a player's interpersonal goals during gameplay.

One study conducted by Weinstein and colleagues used two different types of virtual settings (a city with skyscrapers and a forest with streams) and found that players had greater self-focused goals when in the manufactured setting compared to greater prosocial goals in the nature setting (Weinstein, Pryzbylski, & Ryan, 2009). Furthermore, the more presence a player measured on the Physical Presence subscale, adapted from the Player Experience Need of Satisfaction Scale, the greater shift in interpersonal goals were observed. When set against conventional models of motivation to engage in video gameplay, it is not the degree of graphics and sound provided by the virtual environment but rather how that environment satisfies fundamental motivational needs that increases a player's sense of presence (Witmet & Singer, 1998). From an evolutionary standpoint, presence is a consciously tracked state by humans to monitor actions and experiences (Csikszentmihalyi, 1990). Humans will assess the current state of their environment and variations in feelings of presence then enact their intentions on what is afforded in the environment. In this view, human's perception of successful actions is based on how much the action deviates from our "habitual standard" and "being-in-the-world." Virtual environments that afford players opportunities to act in it and monitor how successful their actions were, are highly motivating based on the principle that humans tend to seek out activities associated with positive and rewarding states of consciousness (optimal experiences).

Virtual Reality Potential to Increase Physical Activity

The main caveat of AVRGs being used to replace sedentary behaviors, instead of displacing naturally occurring and traditional physical activities, comes from several studies that addressed the hypothesized effects of AVRGs on the amount of physical activity levels in different populations. Even though AVRGs were introduced to the market in hopes of enhancing the game's appeal, researchers have investigated their use for promoting the public's health. In a recent study, Reynolds and colleagues (2018) in an experimental study examined whether a 30-minute AVRG physical education class could increase children's PA levels to meet national guidelines for health benefits. The investigators had participants (N = 27) play an interactive dancing game (Just Dance 4) over the 30-minute class session each day for a week. During the class participants averaged 1,891 steps per class. In addition, for the 30-minutes allotted, participants spent 9-minutes of it engaged in MVPA. Following the suggested 60-minutes/day of MVPA, it is recommended that children take more than 12,000 steps/day. From the class session, the amount of steps taken could equate to 16% of the daily recommended number of steps. The investigators note that the use of pedometers in their study could have failed to account for increases in exercise intensity from arm and non-locomotor movements during gameplay and that heart rate monitors may more accurately assess PA intensity. Nonetheless, the researchers argue that the use of an AVRG in PE classes has the potential to increase PA and amount of time spent in MVPA.

A study by Gao and colleagues (2017) used accelerometers to measure PA levels and determine the long-term impact of a combined AVRG and PE class intervention on physical activity levels in children. Over the 2-year long study, the intervention group accumulated significantly more MVPA at school compared to the PE only group. The investigators assigned a total of 261 middle schoolers to a 125 min per week PE class consisting of either typical state and national PE activities or a hybrid PE and AVRG class equipped with Wii and Kinect systems. Group by time interactions showed no effects for MVPA indicating that AVRG combined with PE, as argued by the researchers, to be at least as effective as traditional PE based classes. During a follow-up the intervention group showed significantly more MVPA than the comparison group. This effect was argued by the investigators to be indicated by AVRG might provide children with increased self-efficacy and enjoyment of partaking in physical activity. Similar findings were reported in a study by Pasco and colleagues (2017) that used a video game (Greedy Rabbit) connected to a stationary bike where participants must control the speed of a virtual rabbit on a television screen to navigate a maze before being captured by the enemy. The study sought to determine how much an AVRG-bike design can contribute to PA levels and intensity of exercise in young adults (20.13 ± 1.30 yr). Participants were assigned to two groups including a AVRG-bike group and a traditional stationary bike. The AVRG-bike group cycled for 15-minutes playing the game while the traditional bike group cycled for 15-minutes with feedback regarding time left, cadence, and power output. During gameplay, the intervention group spent approximately 90% of the time in MVPA and rated higher degrees of situational interest. However, of note is that the comparison group spent 95% of the time in MVPA which is slightly higher than the intervention group. Because of the relatively short duration of the intervention effects more research is needed to understand new AVRG platform designs in regard to exercise programs. Nevertheless, an AVRG-bike design does hold some promise for promoting MVPA in college-aged adults.

From the studies it is apparent that commercially available AVRGs have the potential to increase the amount of time engaged in PA and at a intensity adequate enough to meet national guidelines for substantial health benefits. Amount of PA and exercise intensity was at least comparable to traditional forms of PA but not considered to be better which supports the current argument of AVRGs being better suited to promote PA by displacing sedentary behaviors. However, more research is required to understand the impact new AVRG systems have on PA levels as well as studies of longer durations to determine the long-term effects of AVRG on health and fitness. Once these questions are answered then we may see AVRGs having the potential to replace conventional forms of PA.

Physiological Response to Virtual Reality

In a systematic review, Biddiss and Irwin (2010) examined 18 studies that focused on energy expenditure and exercise intensity during active video game (AVRG) play in children. The studies, which were conducted between 1998 and 2010, found that the increases in HR and energy expenditure while playing AVRGs were adequate enough to elicit light to moderate physical activity. From the studies, there was a mean increase of 222% in energy expenditure above resting levels during AVRG gameplay. Furthermore, higher percentages of energy expenditure were obtained for AVRGs that promoted both upper and lower body movements which suggests exercise intensity can vary across games depending on type of movement required to play the game. Similar findings were reported in a review by Foley (2010) where 11 studies quantified the energy cost of children playing AVRGs and found mild to moderate exercise intensity during gameplay. Additionally, studies that reported METs had values ranging from 2.2 to 9.8 which indicated that the nature of gameplay could have effect on energy cost which is similar to Biddiss and Irwin's inferences. Wu (2015) examined adults playing 6 different AVRGs with varying types of body movement (whole-body, upper-body dominant, lower-body dominant) and found that games such as boxing and beach volleyball that, to some extent, required players to use whole-body movements elicited the highest energy expenditure compared to games such as ping pong and bowling. If physiological health benefits are to occur, then AVRGs should attempt to incorporate full-body movements. A more recent review by Sween and colleagues (2014) examined 27 studies conducted between 2002 and 2012 that investigated the effect on AVRGs on energy expenditure. The review also compared the exercise intensity of gameplay with that of the national guidelines for physical activity. Although, most of the studies looked at the acute effects (10 - 30 minutes) of AVRG play, it was an adequate amount of time to meet ACSM guidelines for health and fitness. Upwards of 300% increases in energy expenditure were observed in some of the AVRGs, specifically games that employed whole-body movements to progress in the game (Dance Dance Revolution). Of the 27 studies examined, only 5 of them included adult participants and similar exercise intensity levels remained at moderate levels. One review by Miller and colleagues (2014) reviewed 14 studies that investigated the effects of AVRGs use on healthy older adults. The reviewers could not draw any conclusive results due to a number of issues such as intervention adherence, safety, and acceptability of technologies. However, a study by Chuang et al. (2003) compared exercise responses of older adults during VR-assisted stationary cycling and VR-unassisted stationary cycling. There were similar responses in peak oxygen consumption and heart rate between the two conditions. However, the VR-assisted cycling group had significant increases in cycling time, distance, and caloric expenditure compared to the VR-unassisted cycling group. The most current meta-analysis of the effects of AVRGs on energy expenditure in children and adolescents by Gao and colleagues (2015) examined 35 studies conducted between 1985 and 2015. The researchers found substantial effect sizes for comparisons in physiological variables (energy expenditure, heart rate, and VO2max). In accordance with previous reviews, AVRGs increase energy expenditure, METs, VO2, and heart rate compared to resting, however compared to laboratory-based exercises (treadmill running/walking and stationary cycling), AVRGs were not significantly different in increasing the same variables, except for heart rate. The researchers reported the effect sizes of heart rate favored AVRGs with small margins. Overall, the evidence from the reviews suggest that AVRGs may increase energy levels above those of resting and depending on the nature of movement required to play the game can achieve exercise intensity levels of those established by national guidelines.

A closer examination of the effect of AVRGs on energy expenditure levels in young adults is needed due to as much as a 24% reduction in physical activity levels as individuals transition from high school to college (Howe, 2015). If AVRGs can meet the physical activity guidelines of moderate-to-vigorous exercise intensity, then AVRGs can aid in replacing many of the sedentary behaviors exhibited by this age group or become an alternative to traditional forms of exercise. A study by Howe and colleagues (2015) examined young adults (18-35 y) on their energy expenditure while playing 6 different AVRGs (Xbox Kinect) compared to traditional sedentary video games (Madden NFL 12 & Sonic Racer). The traditional sedentary video games were rated as sedentary to light physical activity intensity whereas all but one of the AVRGs were classified as vigorous exercise intensity ($\geq$ 6 METs). Compared to older AVRG models such as the Nintendo Wii (Nintendo, Kyoto, Japan) that tracks the use of a single controller and estimates whole body movement from a single point, this study utilized the Xbox Kinect (Microsoft, Redmond, Washington) that uses motion-detecting technology that tracks whole body movements. The majority of Nintendo Wii games have been rated to be equivalent to light-to-moderate exercise intensity which could be due to the single point reference limitation in its design. Because the Xbox Kinect is tracking the entire body it has the potential to create much more challenging movements required by the player to satisfy the goals of the AVRGs as seen in the higher levels of exercise intensity exhibited in the study. A recent study by Monedero and colleagues (2017) examined young adults' (24.8 $\pm$ 1 y) energy expenditure during two different types of AVRGs (entertainment-themed vs. fitness-themed) and during treadmill running. All conditions elicited moderate or vigorous exercise intensity while METs for each of the AVRG conditions were 5.1 ± 0.3 (entertainment-themed) and 6.4 ± 0.2 (fitness-themed). The findings from the study reinforce the point that AVRGs can meet the criteria for moderate-to-vigorous exercise intensity. To date, most of the reviews on the efficacy of AVRGs to raise energy expenditure levels above resting and meeting criteria for established national physical activity guidelines have focused on children and adolescents. The previous studies point to the direction that AVRGs can elicit similar exercise intensity levels and raise their energy expenditure well above resting.

Differences in Physiological Responses Between Settings/Situations

To date, the majority of studies focusing on energy expenditure while playing AVRGs have been performed in laboratory settings. Recent reviews show marked increases in energy expenditure after only 10- to 20-minutes of continuous gameplay in the lab. However, according to the American Time Use Survey, gamers spend on average 2 hours a day playing video games. It would be safe to assume that longer durations of AVRG play can elicit even greater health benefits. On the other hand, acute measurements of energy expenditure in the lab are unlikely to correctly predict the energy expenditure of players in more naturalistic settings such as the home and gym where video game playing is intermittent and unsupervised. With the presence of an investigator during gameplay, it is possible that participants engage in games in an active manner and continue to be active during the acute gameplay session. In addition, players may spend more time resting between levels and stop for random breaks making energy expenditure not uniform across the session. Players may also choose to play different games at home when given the option to self-select the AVRGs being played. Numerous AVRGs exist that can elicit different exercise intensities ranging from 2.2 to 9.8 METs. Therefore, laboratory studies have, for the most part, led to narrow results of energy expenditure of AVRG play in more naturalistic settings where they are usually played. At the moment, it may be better to utilize AVRGs as a way to displace sedentary activities (television, traditional video games, etc.) rather than replace physical activities (sports, exercise, etc.).

Encouraging findings exist from intervention studies that examined AVRGs potential to increase physical activity in free-living settings. The findings suggest that AVRGs may be able to promote increases in physical activity and improve body composition in children when played in more naturalistic settings. One study by Maloney and colleagues allowed unlimited access to an in-home AVRG (Dance Dance Revolution) and saw significant increases in vigorous intensity exercise and significant reductions in sedentary screen time. The 28-week intervention study was successful in promoting 89-minutes per week of AVRG play in children at a high exercise intensity ($\geq$ 6 METs), or an increase of 6-minutes per day of vigorous intensity exercise from their previous physical activity levels. The researchers suggested the interactive dance video game was more appealing to the children compared to bicycling, dancing to music, or other traditional forms of physical activity. That is, the novelty and innately fun components of the AVRG kept the children motivated to continue to engage in the gameplay. However, no comparison group existed in the study to ascertain any differences between AVRG in different settings. Findings reported in a study by Paw and colleagues (2007) focusing on the effects of a home-based AVRG program to promote physical activity in children showed significantly more dropout rate in the home-based AVRG group compared to a AVRG multiplayer group. The home group was allowed to play the AVRG as often as they liked, and the multiplayer group were invited to participate once a week in a 60-minute AVRG group class. Self-reported play duration by the home group decreased from 228-minutes during the first 6-weeks to 0-minutes in weeks 6-12. It was reported that barriers such as space at home, dull music, and boredom may have led to the higher dropout rate in the home group (64%) compared to the multiplayer group (15%). The researchers argued that if the barriers mentioned at home might have been counteracted then there might have been more motivation to play.

A few studies have examined the effect that AVRG social play has on energy expenditure and physical activity. There are numerous implications that a multiplayer game mode or social setting may have on the ways in which someone engages in AVRG gameplay. As Lyons (2014) suggests, players' movements during a virtual dancing rhythm game may have been exaggerated for the humor value of those watching. That is, any of the spontaneous movements that are not required by the game may have been performed by the player due to the social nature of the setting where the game is played. Another factor to consider is the effect that social physique anxiety (SPA) or body image dissatisfaction (BID) has on the way AVRGs are played. Research indicates that the positive effects that group exercise has on certain individuals does not have the same effects on those with high levels of SPA or BID. However, virtual reality serves as an interesting mode of social exercising where a player is transposed as a virtual avatar into a workout environment. A study examining the effects of a single player mode vs a multiplayer mode found a significant increase in METs and heart rate in the multiplayer setting (Wii Sports Boxing). The researchers also noted a potential Hawthorne effect that took place with at least one investigator being present at all conditions. The Hawthorne effect is defined simply as a participant's change in behavior due to their knowledge of being observed. In this case an increase in performance while playing AVRGs. In line with the previous studies were the results from a study by McGuire and Willems (2015) which focused on single and multiplayer modes across different exercise intensity AVRGs (i.e. football, track and field, boxing). Participants had significantly higher energy expenditure in the football (4.7 ± 0.8 METs) and boxing (5.5 ± 1.1 METs) multiplayer modes compared to single player modes of football (4.1 ± 1.0 METs) and boxing (4.7 ± 1.3 METs). The researchers observed a more intense and erratic punching style in the multiplayer modes as participants tried to knock their opponent out as quickly as possible whereas in the single player mode participants included more blocking actions to play at the pace of the computer. As intensity of the exercise went up the amount of time to complete the match went down which raises concerns if participants would lose motivation to play outside of the laboratory setting.

Gender Differences

Gender is a frequent topic surrounding physical activity intervention research with supported notions that PA participation has privileged male experience and sustained gender hierarchies. In general, females participate less in PA than their male counterparts and they do so at a lower exercise intensity (less energy expended). Researchers have argued that the differences observed are due to specific aspects of PA that each gender is attracted to. For instance, females may be more attracted to the positive responses of their peers during PA participation (ex. popularity gained) or improvements in their body image whereas males report being more attracted to the exertional characteristics from participating. As AVRGs are starting to gain popularity as an alternative form of PA many researchers may employ misguided assumptions that these newly digitized forms of PA are 'neutral' in terms of gender when in fact new active video games are designed with recurring male preferences and representations. For example, Williams and colleagues (2009) reported an over-representation of male characters in video games possibly stemming from the male-dominated video game industry leading to a cycle of creation of consumption. Consequently, new virtual reality games coming to market are adrenaline-fuelled gaming experiences with male protagonists following the same male-dominated cycle in other video game platforms. In this context, females are positioned outside of the normal gaming culture consequently leading to influences on game design and practice. Nonetheless, researchers examining AVRGs potential to increase physical activity and energy expenditure discuss potential explanations for observed gender differences in their study.

In a study by Wu and colleagues (2015) young adult males expended more energy compared to young adult females when playing 6 different AVRGs. When looking at the most intense AVRG in the study (boxing) males had a MET score of 8.26 ± 1.91 vs females who had a MET score of 5.84 ± 1.05. This margin of difference was slightly smaller in the less intense AVRG (bowling) where males had a MET score of 3.22 ± 0.79 compared to females who had 2.18 ± 0.38 METs. The investigators argued that perhaps the level of enjoyment experienced by males when playing AVRGs elicited the higher energy expenditure observed. When gender is used to endorse behaviors that characterize males, aggressive and assertive are two behaviors often discussed. This might explain the higher energy expenditure in males when they engage in AVRGs that require a certain level of aggressive actions (punching, jabbing, etc.) to perform well in the game. Similar findings were reported in a study by Howe and colleagues (2015) which examined the differences in intensity between 6 AVRGs in college-aged adults. The participants were given the option to play against one of their peers when measurements were being taken. The pairing of participants with a playmate was to give a sense of a social atmosphere similar to places AVRGs would be played (dorm room, living room, etc.). From the study, energy expenditure was greater in males (4.63 ± 0.3 kcal/min) than in females (2.99 ± 0.2 kcal/min). One such explanation, as argued by the investigators, is that the differences observed is quite probably due to the greater body mass in males. This study built upon previous research with findings that in multiplayer settings the typically observed higher energy expenditure in males still exists. Thus, while there still exists some gaps in the literature pertaining to differences in energy expenditure between genders while playing AVRGs, it is possible that males tend to enjoy AVRGs more due to the inherently masculine themes and genres in the games. Nonetheless, research does suggest that AVRGs have the potential to benefit both genders. Even though females tended to achieve lower energy expenditure, the intensity at which they played AVRGs still met the ACSM guidelines.

Summary

At this point, serious considerations of AVRGs as a way of decreasing sedentary activities and promoting PA should be in place. In several studies, AVRGs have shown the potential of eliciting moderate-to-vigorous intensity exercise and the ability to meet national guidelines for preventative health benefits. Furthermore, health professionals wanting to promote PA can design a program with varying intensities depending on the game chosen with different games requiring unique movements to be successful while playing. The reasons for playing traditional video games have roots in the self-determination theory where players feel a sense of competency, autonomy, and relatedness. Research has shown new virtual reality gaming consoles to achieve the same, if not higher, feelings of these intrinsically motivating factors. However, there exists a certain gap in the literature that fails to answer the efficacy of AVRGs over time on variables such as enjoyment, energy expenditure, and adherence. Therefore, it should not be concluded that AVRGs can replace other forms of conventional PA but rather displace sedentary behaviors or used in conjunction with conventional PA to enhance it. Finally, the realm of AVRGs continues to evolve at a rapid pace, with new games and hardware systems being introduced all the time. Questions regarding the viability of AVRGs to promote PA and raise exercise intensity levels to meet national guidelines will continue to be pertinent as AVRG entertainment continues to advance.

References

Aguiar, M., Bils, M., Charles, K. K., & Hurst, E. (2017). Leisure luxuries and the labor supply of young men.

Ajzen, I. (1991). The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50, 179-211.

Alberti, K. G., Eckel, R. H., Grundy, M. S., Zimmet, Z. P., Cleeman, I. J., Donato, K. A., Fruchart, J-C., James, W. P., Loria, C. M., & Smith, S. C. (2009). Harmonizing the metabolic syndrome. *Circulation*, 120(16), 1640-1645.

Anderson, C. A., Shibuya, A., Ihori, N., Swing, E. L., Bushman, B. J., Sakamoto, A., Rothstein, H. R., & Saleem, M. (2010). Violent video game effects on aggression, empathy, and prosocial behavior in eastern and western counties: A meta-analytic review. *Psychological Bulletin*, 136(2), 151-173.

American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 10th ed. Philadelphia, (PA). Lippincott Williams & Wilkins; 2017.

Astorino, T., Edmunds, R., Clark, A., King, L., Gallant, R., Namm, S., Fishcer, A., & Wood, K. (2017). High-intensity interval training increases cardiac output and vo2max. Medicine and Science in Sport and Exercise, 49(2), 265-273.

Biddiss, E. & Irwin, J. (2010). Active video games to promote physical activity in children and youth: A systematic review. *Archives of Pediatrics and Adolescent Medicine*, 164(7), 664-672.

Butt, J., Weinberg, R. S., Breckon, J. D., & Claytor, R. P. (2011). Adolescent physical activity participation and motivational determinants across gender, age, and race. Journal of Physical Activity and Health, 8, 1074-1083.

Chalabaev, A., Sarrazin, P., Fontayne, P., Boiche, J., & Clement-Guillotin, C. (2013). The influence of sex stereotypes and gender roles on participation and performance in sport and exercise: Review and future directions. Psychology of Sport and Exercise, 14(2), 136-144.

Chen, J. (2007). Flow in games (and everything else). A well designed game transports its players to their personal flow zones, delivering genuine feelings of pleasure and happiness. Communications of the ACM, 50, 31-34.

Chuang, T-Y., Chen, C-H., Chang, H-W., Lee, H-C., Chou, C-L., & Doong, J-L. (2003). Virtual reality serves as a support technology in cardiopulmonary exercise testing. Presence: Teleoperators & Virtual Environments, 12(3), 326-331.

Colbert, A., Yee, N., & George, G. (2016). The digital workforce and the workplace of the future. Academy of Management Journal, 59(3), 731-739.

Crawford, S. & Eklund, R. C. (1994). Social physique anxiety, reasons for exercise, and attitudes toward exercise settings. Journal of Sport and Exercise Psychology, 16(1), 70-82.

Csikszentmihalyi, M. (1988). The flow experience and its significance for human psychology. Optimal Experience: Psychological Studies of Flow in Consciousness, 15-35.

Csikszentmihalyi, M. (1990). Flow: The psychology of optimal experience.

Csikszentmihalyi, M. (1997). Flow and education. North American Montessori Teachers' Association, 22(2), 2-35.

Deurenberg, P., Yap, M., & Staveren, W. A. (1998). Body mass index and percent body fat: a meta-analysis among different ethnic groups. *International Journal of Obesity*, 22, 1164-1171.

Donnelly, J. E., Blair, S. N., Jakicic, J. M., Manore, M. M., Rankin, J. W., & Smith, B. K. (2009). American college of sports medicine position stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Medicine and Science in Sports and Exercises*, 41(2), 459-471.

Dooley, E., Golaszewski, N., & Bartholomew, J. (2017). Estimating accuracy at exercise intensities: a comparative study of self-monitoring heart rate and physical activity wearable devices. Journal of Medical Internet Research, 5(3), 34.

Ferguson, C. J. (2007). The good, the bad and the ugly: A meta-analytic review of positive and negative effects of violent video games. P*sychiatric Quarterly*, 78, 309-316.

Fisher, S. S., Wenzel, E. M., Coler, C., & McGreevy, M. W. (1988). Virtual interface environment workstations. Proceedings of the Human Factors Society, 32nd annual meeting.

Focht, B. (2009). Brief walks in outdoor and laboratory environments: Effects on affective responses, enjoyment, and intentions to walk for exercise. Research Quarterly for Exercise and Sport, 80(3), 611-620.

Foley, L. & Maddison, R. (2010). Use of an active video game to increase physical activity in children: A (virtual) reality? Pediatric Exercise Science, 22(1), 7-20.

Gao, Z., Chen, S., Pasco, D., & Pope, Z. (2015). A meta-analysis of active video games on health outcomes among children and adolescents. Obesity Reviews, 16, 783-794.

Gao, Z., Pope, Z., Lee, E. J., Stodden, D., Roncesvalles, N., Pasco, D., Huang, C. C., & Feng, D. (2017). Impact of exergaming on young children's school day energy expenditure and moderate-to-vigorous physical activity levels. *Journal of Sport and Health Science*, 6, 11-16.

Gauvin, L., & Spence, J. (1996). Physical activity and psychological well-being: Knowledge base, current issues, and caveats. Nutrition Reviews, 54(4), 553-565.

Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Computers in Entertainment*, 1(1), 20-20.

Gee, J. P. (2008). Video games and embodiment. *Games and Culture*, 3(4), 253-263.

Gomez, D., Bagley, J., Bolter, N., Kern, M., & Lee, C. (2018). Metabolic cost and exercise intensity during active virtual reality gaming. Games for Health Journal, 7(5), 310-316.

Harris, K. C., Kuramoto, L. K., Schulzer, M., & Retallack, J. E. (2009). Effect of school-based physical activity interventions on body mass index in children: A meta-analysis. *Canadian Medical Association Journal*, 180(7), 719-726.

Heisz, J., Tejada, M., Paolucci, E., & Muir, C. (2016). Enjoyment for high-intensity interval exercise increases during the first six weeks of training: Implications for promoting exercise adherence in sedentary adults. PLoS ONE, 11(12).

Henderson, K. & Ainsworth, B. (2002). Enjoyment: A link to physical activity, leisure, and health. Journal of Park and Recreation Administration, 20(4), 130-146.

Howe, C. A., Barr, M. W., Winner, B. C., Kimble, J. R., & White, J. B. (2015). The physical activity energy cost of the latest active video games in young adults. Journal of Physical Activity and Health, 12, 171-177.

Huang, G., Gibson, C., Tran, Z., & Osness, W. (2005). Controlled endurance exercise training and vo2max changes in older adults: A meta-analysis. Preventative Cardiology, 217-225.

Hunter, G. R., Kekes-Szabo, T., Snyder, S. W., Nicholson, C., Nyikos, I., & Berland, L. (1997). Fat distribution, physical activity, and cardiovascular risk factors. *Medicine and Science in Sports and Exercise*, 29(3), 362-369.

Jackson, S. & Marsh, H. (1996). Development and validation of a scale to measure optimal experience: the flow state scale. Journal of Sport and Exercise Psychology, 18, 17-35.

James, I. D. & Kalyanaraman, S. (2007). The effects of technological advancement and violent content in video games on players' feelings of presence, involvement, physiological arousal, and aggression. *Journal of Communication*, 57(3), 532-555.

Jin, K. & Igarashi, T. (2016). The effects of narcissism and self-esteem on immersion in social network games and massively multiplayer online role-playing games. *The Japanese Journal of Psychology*, 87(1), 1-11.

Kahn, E. B., Ramsey, L. T., Brownson, R. C., Heath, G. W., Howze, E. H., Powell, K. E., Stone, E. J., Rajab, M. W., & Corso, P. (2002). The effectiveness of interventions to increase physical activity. American Journal of Preventative Medicine, 22(4), 73-107.

Kent, Steven. *The Ultimate History of Video Games: Volume Two: from Pong to Pokemon and Beyond - The Story Behind the Craze That Touched Our Lives and Changed the World.* Three Rivers Press, 2001.

Kilteni, K., Groten, R., & Slated, M. (2012). The sense of embodiment in virtual reality. *Presence*, 21(4), 373-387.

Laver, K., George, S., Thomas, S., & Crotty, M. (2015). Virtual reality for stroke rehabilitation. Cochrane Database of Systematic Reviews, 2.

Lenhart, A., Jones, S., Macgill, A. [Internet]. Adults and video games. In Pew Internet and American Life Project. 2008. [cited 2019 May 22] Available from: http://www.pewinternet.org/Reports/2008/Adults- and-Video-Games.aspx.

Lombard, M & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication* , 3(2), 5-12.

Lyons, E. J., Tate, D. F., Ward, D. S., Ribisl, K. M., Bowling, J. M., & Kalyanaraman, S. (2014). Engagement, enjoyment, and energy expenditure during active video game play. Health Psychology, 33(2), 174-181.

Maivorsdotter, N. & Quennerstedt, M. (2018). Exploring gender habits: A practical epistemology analysis of exergaming in school. European Physical Education Review, 4, 1-17.

Maloney, A. E., Bethea, C., Kelsey, K. S., Marks, J. T., Paez, S., Rosenberg, A. M., Catellier, D. J., Hamer, R. M., & Sikich, L. (2008). A pilot of video game (DDR) to promote physical activity and decrease sedentary screen time. *Obesity*, 16, 2074-2080.

Matthews, C. E., Chen, K. Y., Freedson, P. S., Buchowski, M. S., Beech, B. M., Pate, R. R., Trojano, R. (2008). Amount of time spent in sedentary behaviors in the united states, 2003-2004. *American Journal of Epidemiology*, 167(7):875-881.

Maurer, T. & Pierce, H. (1998). A comparison of likert scale and traditional measures of self-efficacy. Journal of Applied Psychology, 83(2), 324-329.

McGuire, S. & Willems, M. (2015). Physiological responses during multiplay exergaming in young adult males are game-dependent. Journal of Human Kinetics, 46, 263-271.

Melton, B., Bigham, L., Bland, H., Bird, M., & Fairman, C. (2014). Health-related behaviors and technology usage among college students. American Journal of Health Behavior, 38(4), 510-518.

Messinger, P. R., Stroulia, E., & Lyons, K. (2008). A typology of virtual worlds: Historical overview and future directions. *Journal of Virtual Worlds Research*, 1(1), 1-18.

Milanez, V., Lima, M., Gobatto, C., Perandini, L., Nakamura, F., & Ribeiro, L. (2011). Correlates of session-rate of perceived exertion (rpe) in a karate training session. Science and Sports, 26(1), 38-43.

Miller, K. J., Adair, B. S., Pearce, A. J., Said, C. M., Ozanne, E., & Morris, M. M. (2014). Effectiveness and feasibility of virtual reality and gaming system use at home by older adults for enabling physical activity to improve health-related domains: A systematic review. Age and Ageing, 43(2), 188-195.

Millar, A. & Navarick, D. J. (1984). Self-control and choice in humans: Effects of video game playing as a positive reinforcer. *Learning and Motivation*, 15(2), 203-218.

Mokdad, A. H., Ford, F. S., Bowman, B. A., Vinicor, F., Bales, V. S., & Marks, J. S. (2003). Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. *The Journal of the American Medical Association*, 289(1), 76-79.

Monedero, J., Murphy, E, E., & O'Gorman, D. J. (2017). Energy expenditure and affect responses to different types of active video game and exercise. PLOS one.

Montano, D. & Kasprzyk, D. (2007). Theory of reasoned action, theory of planned behavior, and the integrated behavioral model. Health Behavior and Health Education, 95-124.

Nieman, D., Austin, M., Dew, D., & Utter, A. (2013). Validity of cosmed's quark cpet mixing chamber system in evaluating energy metabolism during aerobic exercise in healthy male adults. Research in Sports Medicine, 21, 136-145.

O'Donovan, C., Hirsch, E., Holohan, E., McBride, I., McManus, R., & Hussey, J. (2012). Energy expended playing xbox kinect and wii games: A preliminary study comparing single and multiplayer modes. Physiotherapy, 98, 224-229.

Okorodudu, D. O., Jumean, M. F., Montori, V. M., Romero-Corral, A., Somers, V. K., Erwin, P. J., & Lopez-Jimenez, F. (2010). Diagnostic performance of body mass index to identify obesity as defined by body adiposity: A systematic review and meta-analysis. *International Journal of Obesity*, 34, 791-799.

Pasco, D., Roure, C., Kermarrec, G., Pope, Z., & Gao, Z. (2017). The effects of a bike active video game on players' physical activity and motivation. *Journal of Sport and Health Science*, 6(1), 25-32.

Parsons, Thomas D. and Albert A. Rizzo. (2008). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: a meta-analysis. *Journal of behavior therapy and experimental psychiatry,* 39(3), 250-61.

Paw, M., Jacobs, W. M., Vaessen, E., Titze, S., & van Mechelen, W. (2008). The motivation of children to play an active video game. Journal of Science and Medicine in Sport, 11, 163-166.

Peng, W., Crouse, J., & Lin, J-H. (2012). Using active video games for physical activity promotion: A systematic review of the current state of research. Health Education and Behavior, 40(2), 171-192.

Prensky, M. (2003). Digital game-based learning. ACM Computers in Entertainment, 1(1), 1-4.

Przybylski, A. K., Scott, R. C., & Ryan, R. M. (2010). A motivational model of video game engagement. *Review of General Psychology*, 14(2), 154-166.

Reynolds, C., Benham-Deal, T., Jenkins, J. M., & Wilson, M. (2018). Exergaming: Comparison of on-game and off-game physical activity in elementary physical education. *The Physical Educator*, 75, 64-76.

Ryan, R. M. & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1), 68-78.

Ryan, R. M., Rigby, S. C., & Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion*, 30(4), 344-360.

Salmon, J., Owen, N., Crawford, D., Bauman, A., & Sallis, J. F. (2003). Physical activity and sedentary behavior: A population-based study of barriers, enjoyment, and preference. Health Psychology, 22(2), 178-188.

Schilling, M. A. (2003). Technical leapfrogging: Lessons from the U.S. video game console industry. *California Management Review*, 45(3), 6-32.

Sheldon, K. M. & Filak, V. (2008). Manipulating autonomy, competence, and relatedness support in a game-learning context: New evidence that all three needs matter. *British Journal of Social Psychology, 47, 267-283.*

Sherry, J. L., Greenberg, B. S., Lucas, K., & Lachlan, K. A. (2006). Video game uses and gratifications as predictors of use and game preference. *International Journal of Sports Marketing and Sponsorship*, 8, 213-224.

Slattery, M. L., McDonald, A., Bild, D. E., Caan, B. J., Hilner, J. E., Jacobs, D. R., & Liu, K. (1992). Associations of body fat and its distribution with dietary intake, physical activity, alcohol, and smoking in blacks and whites. *The American Journal of Clinical Nutrition*, 55(5), 943-949.

Song, H., Kim, J., & Lee, K. M. (2014). Virtual vs. real body in exergames: Reducing social physique anxiety in exercise experiences. Computers in Human Behavior, 36, 282-285.

Stanney, M. Kay. *Handbook of Virtual Environments - Design, Implementation, and Applications.* Lawrence Erlbaum Associates, 2002.

Sturm, R. (2013). Morbid obesity rates continue to rise rapidly in the US. International Journal of Obesity, 37(6), 889-891.

Sween, J., Wallington, S. F., Sheppard, V., Taylor, T., Llanos, A. A., Adams-Campbell, L. L. (2014). The role of exergaming in improving physical activity: A review. Journal of Physical Activity and Health, 11, 864-870.

Tamborini, R., Bowman, N. D., Eden, A., Grizzard, M., & Organ, A. (2010). Defining media enjoyment as the satisfaction of intrinsic needs. *Journal of Communication*, 60, 758-777.

United States. (2015). American time use survey. Washington, D.C: U.S. Bureau of Labor Statistics.

Vandewater, E. A., Shim, M-S., & Caplovitz, A. G. (2004). Linking obesity and activity level with children's television and video game use. *Journal of Adolescence*, 27, 71-85.

Vescovi, J., Hildebrandt, L., Miller, W., Hammer, R. (2002). Evaluation of the bod pod for estimating percent fat in female college athletes. The Journal of Strength and Conditioning Research, 16(4), 599-605.

Wack, E. & Stacey, T. (2009). Relationships between electronic game play, obesity, and psychosocial functioning in young men. Cyberpsychology and Behavior, 12(2), 241-244.

Warden, C. A., Stanworth, J. O., & Chang, C-C. (2016). Leveling up: Are non-gamers and women disadvantaged in a virtual world classroom? Computers in Human Behavior, 65, 210-219.

Wang, C. K. J., Khoo, A., Liu, W. C., & Divaharan, S. (2008). Passion and intrinsic motivation in digital gaming. *CyberPsychology & Behavior*, 11(1), 39-45.

Wankel, L. (1993). The importance of enjoyment to adherence and psychosocial benefits from physical activity. International Journal of Sport Psychology, 24(2), 151-169.

Weinstein, N., Przybylski, A. K., & Ryan, R. M. (2009). Can nature make us more caring? Effects of immersion in nature on intrinsic aspirations and generosity. *Personality and Social Psychology Bulletin*, 35(10), 1315-1329.

Williams, D., Martins, N., Consalvo, M., & Ivory, J. I. (2009). The virtual census: Representations of gender, race and age in video games. New Media and Society, 11(5), 815-834.

Witmet, B. G. & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence*, 7(3), 225-240.

Whittaker, Jason. *The Cyberspace Handbook*. Routledge, 2003.

Wolf, Mark. *The Video Game Explosion: A History From Pong to Playstation and Beyond*. Greenwood Press, 2008.

Wu, P-T., Wu, W-L., & Chu, I-H. (2015). Energy expenditure and intensity in healthy young adults during exergaming. American Journal of Health Behavior, 39(4), 556-561.

Yoo, S., Heywood, T., Tang, L., Kummerfield, B., & Kay, J. (2017). Towards a long term model of virtual reality exergame exertion. The Journal of Undergraduate Mathematics and Its Applications, 247-255.

Zyda, M. (2005). From visual simulation to virtual reality to games. *IEEE Computer Society*, 3(5), 25-32.

Pre-Test Instructions

If an individual agrees to participate in this research. (using standardized instructions for body composition and graded exercise test).

a. No food or drink at least 3 hours prior to testing (except for water)

b. Use the restroom within 30 minutes of testing

c. Should not consume alcohol 24 hours prior to testing

d. Should not exercise at least 12 hours prior to testing

e. Arrive with appropriate attire- minimal, form-fitting clothing:

i. Men: Thin fabric shorts, lycra/spandex type swimsuit or single layer compression bike style shorts (no padding).

ii. Women: lycra/spandex type swimsuit or bike style shorts and sports bra (no wire or padding).

iii. They will come to the lab in active wear (shorts and t-shirt) to avoid differences in thermoregulation from clothes during data collection for the graded exercise test and familiarization of HTC VIVE® equipment and VR games.

Permission to Recruit Letter

SAN FRANCISCO STATE UNIVERSITY

DEPARTMENT OF KINESIOLOGY
COLLEGE OF HEALTH & SOCIAL SCIENCES
1600 Holloway Avenue - Gym 139
San Francisco, CA 94132-4161

July 9, 2018

Office of Human and Animal Protections (OHAP)
San Francisco State University
471 Administration Building
1600 Holloway Avenue,
San Francisco, CA 94132

To The Office of Human and Animal Protections,

Mr. Trenton Stewart has the permission of **the Department of Kinesiology** to recruit subjects and/or conduct research for his study on ***Virtual Reality Exercise Gaming to Promote Physical Activity and Health*** through this agency. The details of this study have been explained to us and we support the research.

Please contact me for any further questions at (415) 338-2709.

Sincerely,

Marialice Kern

Marialice Kern, PhD
Department Chair of Kinesiology
San Francisco State University

Informed Consent Documents

San Francisco State University
Informed Consent to Participate in a Research Study
Virtual Reality Exercise Gaming to Promote Physical Activity and Health

A. PURPOSE AND BACKGROUND

The purpose of this research study is to assess the energy expenditure and levels of enjoyment of active virtual reality gaming (AVRGs) in three different settings [in the lab, at the gym, and at home (optional)]. The researcher, Trenton Stewart, a graduate student at San Francisco State University, is conducting research for a master's degree in Kinesiology. You are being asked to participate in this study because you are an apparently healthy individual between the ages of 18 and 39 years of age.

B. PROCEDURES

If you agree to participate in this research study, you will be asked to make two visits to the Exercise Physiology Laboratory in the Gymnasium Building at SFSU (GYM 111), together lasting approximately 2 hours. Additionally, two workout sessions lasting approximately 45 mins each, one at home (optional depending on your access to an HTC VIVE®) and one at SFSU's Mashouf Wellness Center. Overall time commitment is approximately **3 hours (~4 hours** if an HTC VIVE® is available for use at home).

Visit One: [Exercise Physiology Lab (GYM 111) San Francisco State University]

- You will be asked to read and sign the informed consent document.
- You will be asked to complete a questionnaire regarding current physical activity levels, previous experience with video games, and affiliation with San Francisco State University.
- You will be assessed for your body composition (height, weight, and body density – via air displacement plethysmography).
  - *Air Displacement Plethysmography (Bod Pod):* You will be seated in the Bod Pod chamber wearing appropriate test clothing. There will be two ~30-second measurements of air displacement while you sit quietly.
- You will be assessed for your maximal oxygen consumption (VO2max) via a graded exercise test (GXT). You have the option of completing a treadmill or cycle ergometer GXT.
  - *Graded Exercise Test (GXT):* You will be given an overview of the test which includes familiarization with the Borg Scale that rates your perceived level of exertion. The researcher will then place a facemask (covers the nose and mouth) on you to measure amount of gas (oxygen, carbon dioxide, and respiratory exchange ratio [RER]) consumed and produced by you during the exercise. A heart rate strap (Polar) will be placed around your torso area to monitor heart rate (HR) during the test. You will be asked to complete 10-minutes of resting data sitting in a chair followed either by the treadmill VO2max test in which you will jog at a speed you feel comfortable with while the researcher changes the grade of the treadmill and have cool down for 3 minutes to maintain the circulation of blood throughout the body, followed by a 2-minute warmup on the cycle ergometer cycling at 50 Watts. After warmup, you will be cycling a target wattage while increasing the wattage by 30 Watts every 2-minutes until termination of the test followed by a 3-minute cooldown to maintain circulation of blood throughout the body. The test will be terminated at any point if you wish to stop the test or; if your VO2 or HR decreases with an increase in workload, RER > 1.14, or RPE ≥ 18.
- You will partake in a 15-minute AVRG familiarization session of games and HTC VIVE® equipment (5 mins each game).

Visit Two: [Exercise Physiology Lab (GYM 111) San Francisco State University]

- You will visit the Exercise Physiology Lab (Gym 111) at San Francisco State University at least 2 days and no more than 14 days after visit one.
- You will be assessed for your resting energy expenditure by wearing a heart rate monitor and facemask while lying supine for 10-minutes.
- You will be assessed for your energy expenditure while playing 3 AVRGs.
    - *Energy Expenditure During AVRGs:* While standing, the researcher will place the head-mounted display and hand controllers with straps on you. The order of games played will be randomized and you will play each game for 10-minutes. At minutes 4, 6, and 8 the researcher will ask you to rate your perceived exertion (RPE) using the Borg Scale. You will have 5 minutes of rest between each game for a total of 45-minutes of gameplay including rest.

Active Virtual Reality Gaming at Home:

- You will exercise at home with AVRGs after completing visits one and two in the lab.
- You will be assessed for your heart rate while exercising at home by wearing a heart rate strap synced to a smartphone application (Polar).
- You will be asked to play three different AVRGs (10-minutes each with 5-minutes of rest between games for a total of 45-minutes).

Active Virtual Reality Gaming in Gym: (Mashouf Wellness Center at San Francisco State University)

- You will visit the Mashouf Wellness Center at a predetermined time after completing visits one and two in the lab.
- You will be assessed for your heart rate while exercising in the gym by wearing a heart rate strap synced to a smartphone application (Polar).
- You will be asked to play three different AVRGs (10-minutes each with 5-minutes of rest between games for a total of 45-minutes). During this time an instructor will periodically ask you to rate your perceived exertion (RPE).

C. RISKS

There exist certain risks associated with treadmill and cycle ergometer exercise. The risks include, but are not limited to muscular and joint injury/soreness and cardiovascular abnormalities/injury such as shortness of breath, chest pain, and light-headedness. However, the risk of a serious cardiovascular complication during any physical exertion such as treadmill exercise only increases in those with underlying pathologies. In fact, there is a relatively small (.06% in mixed populations including those with documented disease) risk of cardiovascular complications occurring. To minimize these risk, you will have a warm-up period prior to initiation of exercise and have your heart rate monitored throughout the protocol. At your request, the test will be terminated at any point or any abnormal responses to the exercise occur.

There is the physical risk of tripping over power cords attached to the VR console while playing AVRGs. This risk will be minimized in the laboratory by having a research assistant hold the cords while following behind you during exercise. Additionally, there is some discomfort while wearing the head-mounted display along with the facemask, but proper fitting can minimize discomfort experienced. You are free to withdraw from the study at any time without penalty.

D. CONFIDENTIALITY

There is a risk of potential loss of privacy. The records for this study will be kept as confidential as possible. However, no names or identities will be used in any reports or publications resulting from this study. All research data will be kept in a locked desk in Professor Jimmy Bagley's office. Only the researchers and the faculty advisor will have access to the data and will be kept for 3 years after which de-identified data will be retained indefinitely.

E. DIRECT BENEFITS

There are no direct benefits to you for participating in this study.

F. COSTS

The only cost to you will be transportation to San Francisco State University

G. COMPENSATION

There will be no compensation for participating in this study.

H. ALTERNATIVES

The alternative is not to participate in this research.

I. QUESTIONS

You have spoken with the researcher about this study and have had your questions answered. If you have any further questions about the study, you may contact the researcher by email at tstewar1@mail.sfsu.edu or by phone at 626-807-7642 or you may contact the researcher's advisor, Professor James Bagley, Ph. D. at jbagley@sfsu.edu or by phone at 415-338-3363.

Questions about your rights as a study participant, or comments/complaints about the study, may also be addressed to the Human and Animal Protections at 415-338-1093 or protocol@sfsu.edu

J. CONSENT

You have been given a copy of this consent form to keep.

PARTICIPATION IN THIS RESEARCH IS VOLUNTARY. You are free to decline to participate in this research study, or to withdraw your participation at any point, without penalty. Your decision whether or not to participate in this research study will have no influence on your present or future status at San Francisco State University.

Signature______________________________ Date:____________________
Research Participant

Signature______________________________ Date:____________________
Researcher

San Francisco State University
Institutional Review Board
Approval Date 2/19/2019
Expiration Date 8/27/2019
Protocol No. X18-540
(415) 338-1093

VR Questionnaire

VR-Questionnaire

Q1: Participant ID? _______

Q2: I describe myself as:
- ❍ Asian or Asian American (Including Chinese, Japanese, and others)
- ❍ Pacific Islander (Including Filipino, Native Hawaiian, Samoan, and others)
- ❍ Black or African American
- ❍ Hispanic or Latino (Including Mexican American, Central American, and others)
- ❍ White, Caucasian, Anglo, European American; Not Hispanic
- ❍ American Indian/Native American
- ❍ East Asian (Including Indian, Pakistani, Nepalese, Sri Lankan)
- ❍ A member of more than one of these ____________________

Q3: What sex were you assigned at birth?
- ❍ Male
- ❍ Female

Q4: Current status at San Francisco State University:
- ❍ Freshman
- ❍ Sophmore
- ❍ Junior
- ❍ Senior
- ❍ Graduate Student
- ❍ Faculty member at SFSU
- ❍ Community member

Q5: Do you play video games?
- ❍ Yes
- ❍ No

Q7: If you answered "Yes" on Q5, how often do you play video games a week:

____

Q8: Have you ever participated in Virtual Reality before?
- ❍ Yes
- ❍ No

Q9: If you answered "Yes" on Q8, what type of game interaction was involved:
- ❍ Sitting or standing but did not require much active movement from my part
- ❍ Standing and moving to accomplish a task (including boxing, tennis, archery, dancing, etc.)
- ❍ I do not remember

Q10: Which type of physical activity do you enjoy participating in? Please select all that apply.

- ❍ Walking/Hiking
- ❍ Swimming
- ❍ Weight-training
- ❍ Aerobics/Steps
- ❍ Jogging/Running
- ❍ Rowing
- ❍ Cycling
- ❍ Step Machine
- ❍ Dancing
- ❍ Yoga
- ❍ None
- ❍ Other (please specify) ______________________________

Q11: For the physical activity/activities that you chose please circle your overall level of enjoyment of the activity. (1 = no enjoyment. 10 = high level of enjoyment)

1. Walking/Hiking	1	2	3	4	5	6	7	8	9	10
2. Swimming	1	2	3	4	5	6	7	8	9	10
3. Weight-training	1	2	3	4	5	6	7	8	9	10
4. Aerobics/Steps	1	2	3	4	5	6	7	8	9	10
5. Jogging/Running	1	2	3	4	5	6	7	8	9	10
6. Rowing	1	2	3	4	5	6	7	8	9	10
7. Cycling	1	2	3	4	5	6	7	8	9	10
8. Step Machine	1	2	3	4	5	6	7	8	9	10
9. Dancing	1	2	3	4	5	6	7	8	9	10
10. Yoga	1	2	3	4	5	6	7	8	9	10
Other	1	2	3	4	5	6	7	8	9	10

Q12: How many times in a normal week do you participate in this/these physical activity/physical activities? If you have chosen more than one physical activity, please indicate which number it is from the list.

Physical activity # _______
- ❍ Never
- ❍ 1-2 times
- ❍ 3-4 times
- ❍ 5-6 times
- ❍ 7 or more times

Physical activity # _______
- ❍ Never
- ❍ 1-2 times
- ❍ 3-4 times
- ❍ 5-6 times
- ❍ 7 or more times

Physical activity # _______

- ❍ Never
- ❍ 1-2 times
- ❍ 3-4 times
- ❍ 5-6 times
- ❍ 7 or more times

Physical activity # _______

- ❍ Never
- ❍ 1-2 times
- ❍ 3-4 times
- ❍ 5-6 times
- ❍ 7 or more times

Physical activity # _______

- ❍ Never
- ❍ 1-2 times
- ❍ 3-4 times
- ❍ 5-6 times
- ❍ 7 or more times

Q13: Given the opportunity how often would use VR to exercise in a normal week?

- ❍ Never
- ❍ 1-2 times
- ❍ 3-4 times
- ❍ 5-6 times
- ❍ 7 or more times

Recruitment Script for Undergraduate and Graduate Classes

Hello, my name is Trenton Stewart. I am a Masters student at San Francisco State University, in the Department of Kinesiology. I am conducting research in the kinesiology department, and I am inviting you to participate. We are inviting any SFSU undergraduate, graduate, or community member between the ages of 18 to 39 years with no metabolic diseases, musculoskeletal injuries, or history of motion sickness to participate in this research. I am interested in looking at if the setting of where someone plays virtual reality games influences energy expenditure and levels of enjoyment. As a participant, you will be asked to complete a questionnaire, body composition (BodPod), graded exercise test (GXT), and play 3 different VR games in 3 different settings. If you partake in the study it will require a two-day visit to the exercise physiology laboratory, an exercise session at the Mashouf Wellness Center, and at home. This study will be free of charge. The duration of visit 1 and 2 in the lab will be about an hour each. Exercise sessions in the gym and at home will be about 45-minutes each.

Your participation is completely voluntary and any information you provide will remain confidential. Your decision to participate or not participate will not affect your future with the Kinesiology Department or San Francisco State University.

If you have any questions or would like to participate in this research, please contact me at tstewar1@mail.sfsu.edu

Game Synopsis and Procedure

Beat Saber

Beat Saber is a rhythm game centered around slashing beats (represented by small cubes) as they come at you. The cubes will either be red or blue with a direction that they need to be slashed. In each of your hands will be a light saber. Your right hand will be a blue light saber and your left hand will be a red light saber. Correctly slashing a beat will be accomplished by slashing with the correct saber and direction indicated on the beat. Cubes that have a colored circle on them only need to be slashed with the correct saber. Additionally, barriers will appear periodically that you will need to dodge to the left or right or duck under to avoid being hit. Avoid touching or slashing bombs at any cost and rack up combo points by slashing beats consecutively.

Holopoint

Holopoint is an intense archery simulator that requires players to shoot arrows at targets around a room. Targets are represented as blue cubes and will appear in random areas around the room. Once you have your bow in the hand you wish to aim with, nocking your bow with an arrow requires you to reach over your shoulder with the other hand while pressing the trigger on the controller. An arrow will appear in your hand which you will bring together with the bow and be ready to fire. Simply release the trigger on the controller and aim at the targets to break them. Once broken, targets will shoot a blue laser in your direction that must be dodged or can be hit with an arrow to avoid them. If you fail to dodge the blue laser in time you will lose one of your three lives. The game will end if you exhaust your lives. In the later levels, blue cubes are replaced with moving ninjas that move towards you that must be avoided in the same fashion.

Fruit Ninja VR

Fruit Ninja VR is a fruit-slicing arcade game where you test your ninja skills in the virtual world. The main objective is to rack up as many points as possible in 2-minutes by connecting combos while slicing fruit. With a sword in each hand, you will have 2-minutes to slice through as many fruits as you can. Slicing glowing peaches will add 2-seconds to your overall round time.

Enjoyment Likert Scale and Flow State Scale

Q1: Please rate your overall level of enjoyment by circling the number that best represents your experience of exercising in virtual reality.

(1 = no enjoyment, 10 = high level of enjoyment)

1 2 3 4 5 6 7 8 9 10

Please answer the following questions in relation to your experience exercising with virtual reality. These questions relate to the thoughts and feelings you may have experienced during the exercise session. There are no right or wrong answers. Think about how you felt during the workout and answer the questions using the rating scale below. Circle the number that best matches your experience from the options to the right of each question.

Rating Scale:

Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree

1 2 3 4 5

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1. I was challenged but I believe my skills would allow me to meet the challenge.	1	2	3	4	5
2. I made the correct movements without thinking about trying to do so.	1	2	3	4	5

3. I knew clearly what I wanted to do	1	2	3	4	5
4. It was really clear to me that I was doing well.	1	2	3	4	5
5. My attention was focused entirely on what I was doing.	1	2	3	4	5
6. I felt in control of what I was doing.	1	2	3	4	5
7. I was not concerned with what others may have been thinking of me.	1	2	3	4	5
8. Time seemed to alter (either slowed down or sped up).	1	2	3	4	5
9. I really enjoyed exercising in virtual reality.	1	2	3	4	5
10. My abilities matched the high challenge of the situation.	1	2	3	4	5
11. Things just seemed to be happening automatically.	1	2	3	4	5
12. I had a strong sense of what I wanted to do.	1	2	3	4	5
13. I was aware of how well I was performing.	1	2	3	4	5
14. It was no effort to keep my mind on what was happening.	1	2	3	4	5
15. It felt like I could control what I was doing.	1	2	3	4	5
16. I was not worried about my performance during the gameplay.	1	2	3	4	5
17. The way time passed seemed to be different from normal.	1	2	3	4	5
18. I love the feeling of exercising in virtual reality and want to capture it again.	1	2	3	4	5
19. I felt I was competent enough to meet the high demands of exercising in virtual reality.	1	2	3	4	5

20. I performed automatically.	1	2	3	4	5
21. I knew what I wanted to achieve.	1	2	3	4	5
22. I had a good idea while I was exercising about how well I was doing.	1	2	3	4	5
23. I had total concentration.	1	2	3	4	5
24. I had a feeling of total control.	1	2	3	4	5
25. I was not concerned with how I was presenting myself.	1	2	3	4	5
26. It felt like time stopped while I was exercising.	1	2	3	4	5
27. The experience left me feeling great.	1	2	3	4	5
28. The challenge and my skills were at an equally high level.	1	2	3	4	5
29. I did things spontaneously and automatically without having to think.	1	2	3	4	5
30. My goals were clearly defined.	1	2	3	4	5
31. I could tell by the way I was performing how well I was doing.	1	2	3	4	5
32. I was completely focused on the task at hand.	1	2	3	4	5
33. I felt in total control of my body.	1	2	3	4	5
34. I was not worried about what others may have been thinking of me.	1	2	3	4	5
35. At times, it almost seemed like things were happening in slow motion.	1	2	3	4	5
36. I found the experience extremely rewarding.	1	2	3	4	5

Physical Activity Readiness Questionnaire (PAR-Q)

Thank you for your interest in participating in this Masters Thesis. We are interested in looking at Active Virtual Reality Games (AVRG) as a new avenue of physical activity and if the setting of virtual reality-based exercise influences energy expenditure and levels of enjoyment. Before being scheduled to participate we would appreciate if you filled out this questionnaire about your health history to know your risk factors and decide if you can partake in the other components of the study.

Name: ______________________ **Age:** ______ **Date:** ___________

Ethnicity: ______________________

Directions: Write "Yes" next to any true statements below. Otherwise, leave it blank.

___ Are you a male older than 45 or a female older than 55 years?

___ Have you ever experienced any abnormal events during physical exertion?

___ Have you ever had a heart attack, heart surgery, stroke, or any other cardiovascular event?
(example: fainting, chest pain, unreasonable breathlessness)?

___ Have you ever been prescribed heart or blood pressure medications?

___ Have you ever been told by a medical professional that you have diabetes?

___ Do you have joint or musculoskeletal problems that limit your physical activity?

___ Have you ever been told by a medical professional that you have high blood pressure?

___ Have you ever been told by a medical professional that you have high cholesterol?

___ Have you ever been prescribed heart or blood pressure medications?

___ Have you ever been told by a medical professional that you have asthma or other lung disease?

___ Do you currently smoke, or have you quit within the previous 6 months

___ Are you physically inactive (i.e., you get less than 30 min. of physical activity on at least 3
days per week)?

___ Do you have a close blood relative who had a heart attack before age 55 (father or brother)
or age 65 (mother or sister)?

___ Do you think you are at least 20lbs overweight?

___ Do you currently have concerns about the safety of exercise?

Thank you for answering the questions on this survey! You will be contacted back with more information about scheduling and consent forms! If you have any questions, feel free to send me an email at tstewar1@mail.sfsu.edu