2019-05-01

The Influence Of Exergaming On Heart Rate, Perceived Exertion, Motivation To Exercise, And Time Spent Exercising

Tuong Thai

THE INFLUENCE OF EXERGAMING ON HEART RATE, PERCEIVED EXERTION, MOTIVATION TO EXERCISE, AND TIME SPENT EXERCISING

Honors Thesis

Presented in Partial Fulfillment of the Requirements
For the Degree of Bachelor of Sports & Movement Science – Exercise Science Concentration

In the School of Sports & Movement Science
at Salem State University

By

Tuong Thai

Professor Christopher Schoen
Faculty Advisor
Department of Sports & Movement Science

***

Commonwealth Honors Program
Salem State University
2019

Abstract:

Objective:

With the technological advances in today's society, active videogames (or exergames) have become more commonplace. Virtual reality (VR) exergames have begun to emerge with more readily available, affordable technology that can be bought online and in stores. This study focused on the popular VR game *Beat Saber* (Beat Games 2018) and its overall effectiveness in getting individuals to exercise in comparison to a treadmill condition one can do at a gym. It was hypothesized that participants will have similar heart rates, equally high perceived exertion, higher intrinsic motivation to exercise, and have more time spent exercising in *Beat Saber* than on the treadmill.

Methods:

Twenty young adults (male or female) were asked to participate in this two non-consecutive day study. Participants underwent two conditions in a balanced order, with half completing the exergame condition first, and the other half completing the treadmill condition first. Participants completed the remaining test condition during their second visit. The participants were evenly divided into two different groups (Group A and Group B). Those in Group A started with an exergame protocol while those in Group B started with a treadmill protocol. All participants had their heart rates, perceived exertion levels (RPE), motivation to exercise, and time spent exercising measured in both conditions.

Results:

A paired t-test ($p < 0.05$) found significant differences in mean heart rate ($p = 0.003$), in the intrinsic motivation subgroups of Interest/Enjoyment ($p < .05$) and Perceived Choice ($p < .05$),

and in average time spent exercising ($p < 0.001$). The paired t-test also found no significant differences in the most active twenty-minute period mean heart rate ($p = 0.92$), in mean RPE ($p = 0.53$), or in the intrinsic motivation subgroups of Perceived Competence ($p = 0.37$), Effort/Importance ($p = 0.48$), and Value/Usefulness ($p = 0.21$).

Conclusion:

As hypothesized, the exergame *Beat Saber* can be considered a viable, alternative form of exercise that is also more engaging than running on the treadmill.

TABLE OF CONTENTS

Background:

According to a study from 2015-2016 done by the Centers of Disease Control and Prevention (CDC), 39.8% of all Americans over the age of 20 are clinically obese and 71.6% of all Americans over the age of 20 are clinically overweight (CDC, 2017). One of the reasons as to why obesity in America is so prevalent is due to the rising sedentary behavior instilled in many Americans today. As reported by the CDC, only 21% of all adults in America meet the 2008 Physical Activity Guidelines (150 minutes of moderate intensity aerobic exercise and at least two days of muscle strengthening activities, or 75 minutes of vigorous intensity aerobic exercise, and at least two days of muscle strengthening activities each week) (CDC, 2018). According to clinical psychologist Sherry Pagoto, the reason as to why people don't exercise is due to a lack of motivation to feel any form of discomfort (Pagoto, 2014). Pagoto explains her reasoning by stating that "maybe our everyday lives are a little too comfortable" and goes on to explain this by listing off the luxuries today's society has, such as houses having controlled temperatures year round, comfortable clothes, soap and hot water, and so on (Pagoto, 2014). In order to counteract the rising levels of both obesity and sedentary behavior in the United States, active video-gaming (or exergames) can potentially serve as a solution. However, at present, few researchers have tested the effectiveness of virtual reality exergaming on adult physical activity levels in comparison to typical aerobic exercise one can do at a gym.

The purpose of this study is to determine the effectiveness of exergaming in motivating individuals to exercise more and to help determine whether virtual reality (VR) exergames can be used in lieu of going to a gym. Exergames, or active videogames, can be defined as videogames that require players to undergo some form of physical activity in order to be able to play. With the advances in technology in today's world, exergames have become more

prominent in terms of availability and have becoming increasingly popular. For example, the popular VR exergame *Beat Saber* (used for the present study), has received an "overwhelmingly positive" review from an overall six thousand individual reviews on the popular digital distribution platform for video games, Steam (Valve 2019). *Beat Saber* is a popular VR rhythm game released on May 1, 2018 that has its players slash the incoming "beats" with two controllers representing two virtual swords (one red and one blue) that the player will use in game. The "beats" will come in one of the two aforementioned colors with a direction in which the player must swing in order to proceed further in the game. In addition to this (depending on the choice of difficulty) players will have to dodge incoming obstacles and avoid hitting spikes that will result in a "game over" screen if the player ends up failing. One review on VR Fitness Insider said that *Beat Saber* was a "physical and mental challenge that's going to immerse you in a cutting edge and music inspired workout" (Hoalst, 2018). Though research on exergaming is still scarce, many have shown positive results in relation to exergaming on children, adolescent, and adult physical activity levels.

According to a study by Gao, Hannan, Xiang, Stodden, and Valdez (2013), children's motivation towards physical activity and overall physical fitness increased via exergaming. The study examined the impact of Dance Dance Revolution (DDR) on children's physical activity levels and academic scores. Two-hundred and eight students from an urban elementary school were asked to participate, where each child completed a baseline test consisting of a timed 1-mile run, had their Body Mass Index (BMI) measurements, and their reading and math scores measured. After nine months had passed after partaking in the DDR based exercises, the children would then complete their baseline tests once again in order to see if there was any significant difference. The results showed that the children's cardiorespiratory endurance and math scores

had improved. The study concluded that the DDR game had a positive effect on children's physical fitness and academic achievements and that schools should consider incorporating exergames in physical education courses in school to counter sedentary behavior and promote academic success in children.

Another study by Staiano, Beyl, Hsia, Katzmarzyk, and Newton (2016) explored the use of a 12-week long exergaming study on overweight and obese adolescent girls. Thirty-seven obese or overweight girls ranging from the ages of 14 to 18 years were recruited for the study, where they were split up into either a 12-week exergaming group or a control group. Results showed higher levels of physical activity, increased self-efficacy, and decreased television viewing and sedentary behavior for participants in the dance exergaming group in comparison to the control group. The study concluded that the twelve weeks of exergaming had a positive impact on the participants and argued that exergaming serves as a good alternative form of exercise that can be enjoyable, motivating, and effective in raising physical activity levels.

Moholdt, Weie, Chorianopoulos, Wang, and Hagen (2017) did a research study that examined the exercise intensity of a biking exergame that was new at the time of this study. The study consisted of eight adult males who over the course of three days underwent both the exergame and a control exercise (walking). Heart rate, caloric expenditure, and activity duration were recorded for all eight participants for both parts of the studies. Results concluded that the average intensity and average energy expenditure was higher in the exergame than in the walking exercise. The study concluded that exergaming stands as an innovative form of exercise that can vary from light, moderate, and high intensity and can coincide as an enjoyable form of physical activity.

Research Question:

In comparison to treadmill running, what effects does playing the VR game *Beat Saber* have on adults in terms of: heart rate, rated perceived exertion, motivation to exercise, and time spent exercising?

Hypothesis:

Participants will have higher heart rates, less perceived exertion, more motivation to exercise, and spend more time exercising in Beat Saber in comparison to the treadmill exercise.

Methods:

Participant Description:

This study was approved by the Salem State University Institutional Review Board. Twenty adults (10 male, 10 female) with a mean (SD) of 22.5 (3.86) (age range 18 to 35 years) provided informed consent to take part in testing.

Study design:

This study was a two-condition balanced, controlled trial using a within subject design and took place in the Human Performance Lab in the O'Keefe Center at Salem State University. Twenty students (male or female) from Salem State University were asked to participate in this two non-consecutive day study. Each participant was briefly interviewed to determine whether said participant was eligible to participate. Participants who have physical injuries, motion sickness, sensitivity to flashing lights, or any other form of disability that would impede said participant(s) from performing this study competently were asked not to participate. Once all eligible participants signed their forms of consent, the study commenced.

Participants underwent two conditions in a balanced order, with half completing the exergame condition first, and half completing the treadmill condition first. Participants completed the remaining test condition during their second visit. The participants were evenly divided into two different groups (Group A and Group B). Participants in Group A started with an exergame protocol while participants in Group B started with a treadmill protocol. Participants in group A started by learning about VR and how to use the VR equipment. After being briefed, participants began to play *Beat Saber* for a minimum of twenty minutes on increasing difficulty levels ranging from easy, normal, hard, expert, and expert+. Once twenty minutes had passed, participants could continue to play on any difficulty up until they decided whenever they wanted to stop or when they had reached the sixty minute maximum period. Participants in Group B first did the treadmill condition where participants were asked to complete a minimum of twenty minutes of light running where participants started at a speed of 3.0 and then increase incrementally up to a speed of 7.0. Once twenty minutes had passed, participants could continue to run at any speed up until whenever they decided to stop or when they had reached the sixty minute maximum period. All participants had their heart rates, perceived exertion levels, motivation to exercise, and time spent exercising measured in both conditions (See Fig. 1 Study Design).

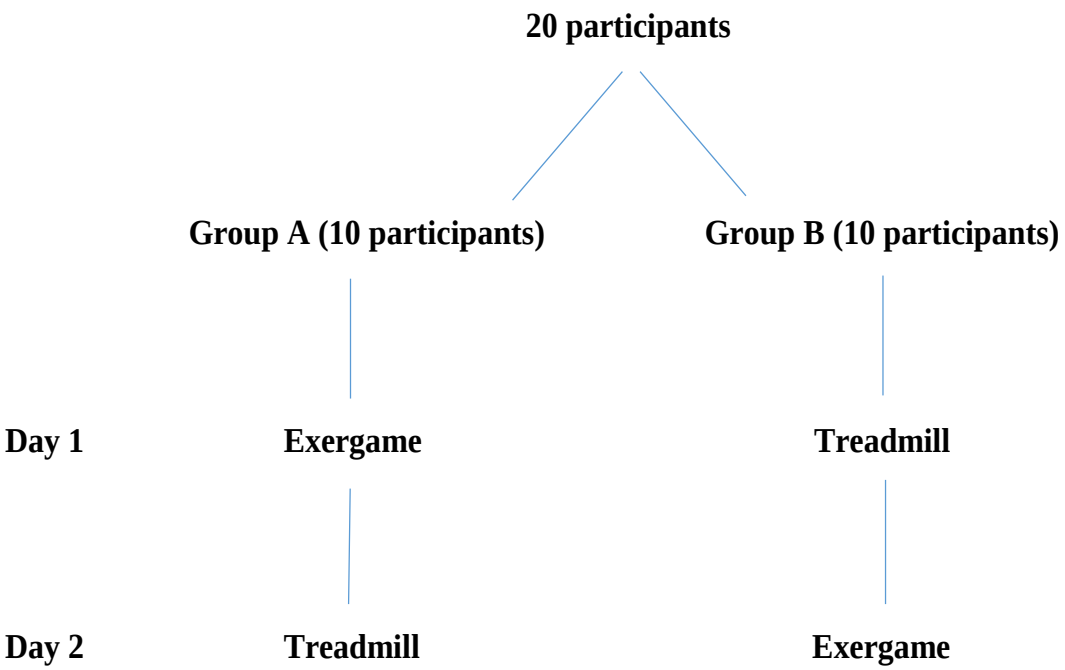

Fig.1 Study Design: Participants underwent two conditions in a balanced order, with half completing the exergame condition first, and half completing the treadmill condition first. Participants completed the remaining test condition during their second visit.

Measurements:

Heart Rate: Resting heart rates and heart rates after every five minutes in both conditions were measured using a heart rate monitor (beats per minute) (Polar T31 Non-Coded Transmitter and Belt Set., Polar USA, Bethpage, New York).

Rated Perceived Exertion (RPE): Using the Borg Rating of Perceived Exertion scale (Borg, 1998), participants in both conditions rated their perceived exertion every five minutes they exercised in total.

Motivation to Exercise: Upon completion of either condition, participants were asked to complete a fourteen-item questionnaire selected from the Intrinsic Motivation Inventory (IMI) (McAuley et al.,1989). Of the fourteen items, participants were asked to rate how true each statement was in relation to the condition that was completed on a scale of 1-7 (1 being Not True at All and 7 being Very True) (See Appendix).

Amount of time spent exercising was recorded for each individual in both conditions.

Data analysis:

A paired t-tests was used to detect differences between time, mean heart rate, rated perceived exertion, and intrinsic motivation, along with each associated sub-scale, between both conditions (alpha=0.05). All calculations were done in Excel.

Results:

Heart Rate Results:

Participants exhibited a lower mean heart rate on the exergame (Exergame Mean HR = 133.43, SD = 15.23) than on the treadmill (Treadmill Mean HR = 144.41, SD = 12.65) ($t(19) = 3.34$, $p = 0.003$) (See Fig. 2.A Overall Mean Heart Rate Results). However, when the most active twenty-minute period of the exergame for each participant was compared to that of the treadmill, both conditions produced similar mean heart rates (Exergame mean HR = 148.61, SD = 15.91) (Treadmill mean HR = 148.17, SD = 12.65) ($t(19) = 0.11$, $p = 0.92$) (See Fig. 2.B Most Active period Heart Rate Results).

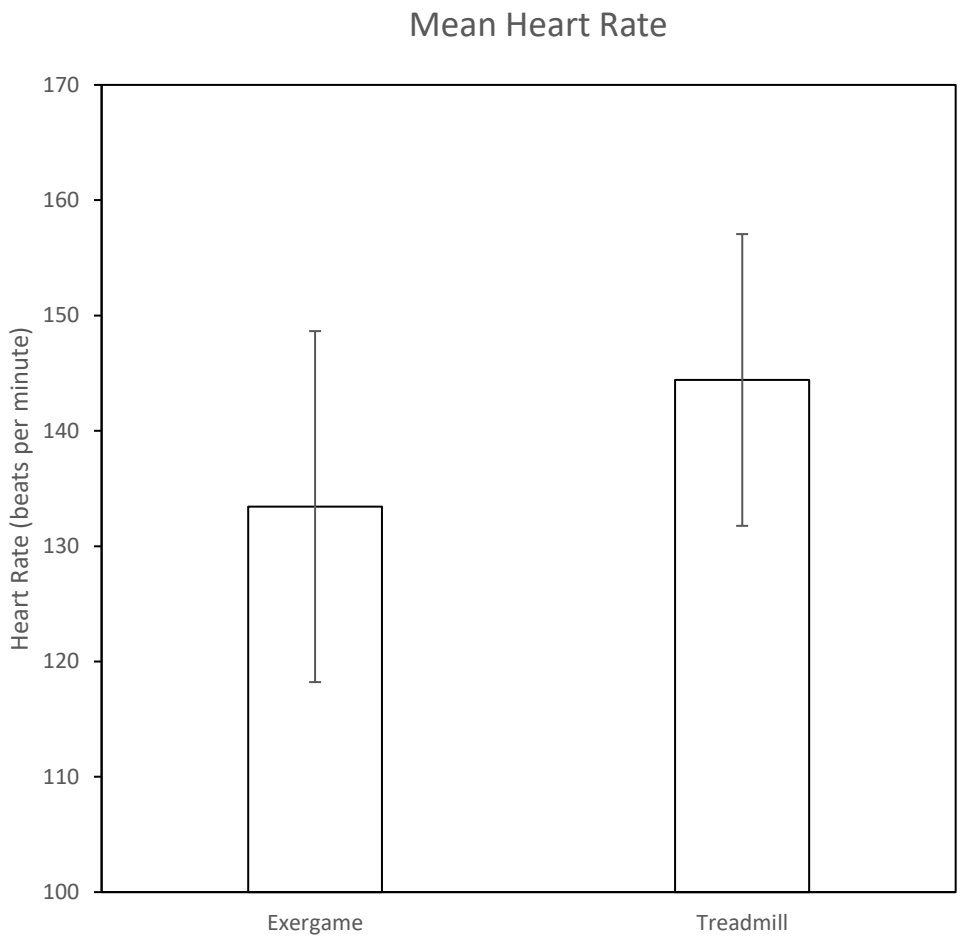

Fig. 2.A Overall Mean Heart Rate Results (Error bars indicate ±1 SD): Participants exhibited a lower mean heart rate on the exergame (Exergame Mean HR = 133.43, SD = 15.23) than on the treadmill (Treadmill Mean HR = 144.41, SD = 12.65) ($t(19) = 3.34$, $p = 0.003$).

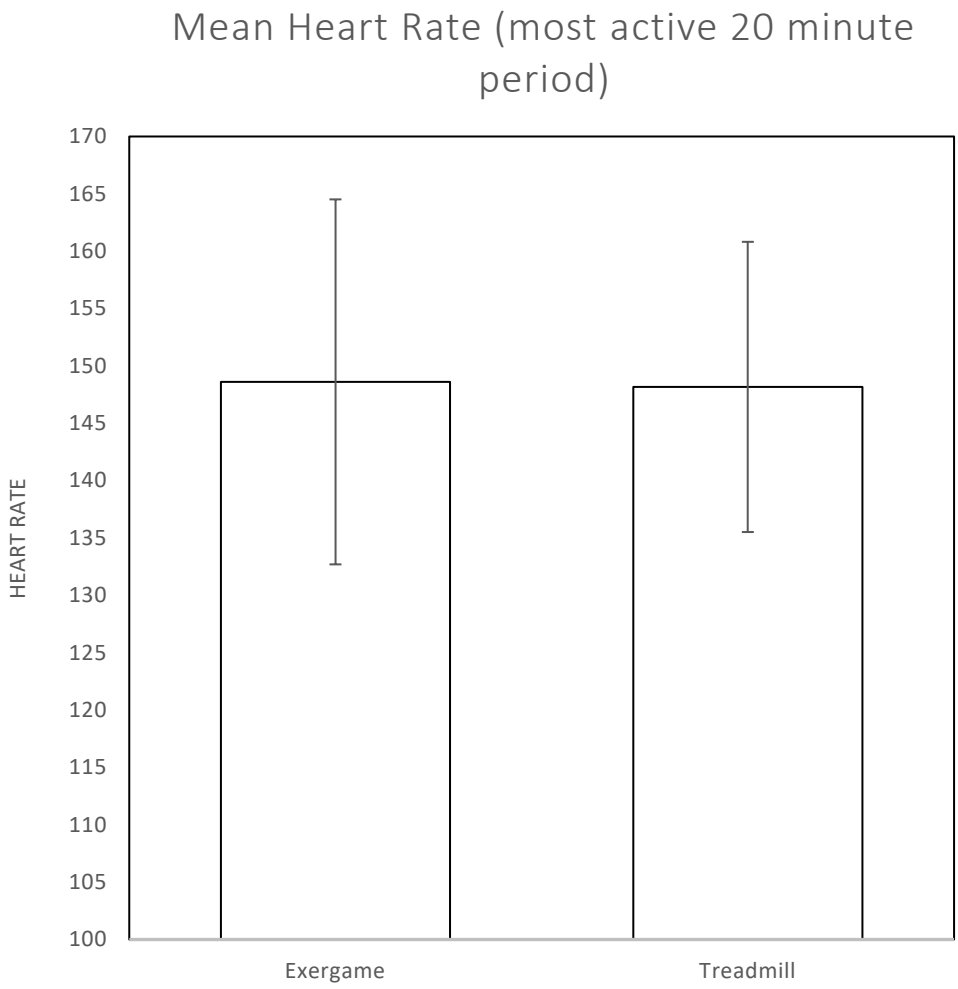

Fig. 2.B Most Active period Heart Rate Results (Error bars indicate ±1 SD): When the most active twenty-minute period of the exergame for each participant was compared to that of the treadmill, both conditions produced similar mean heart rates (Exergame mean HR = 148.61, SD = 15.91) (Treadmill mean HR = 148.17, SD = 12.65) ($t(19) = 0.11$, $p = 0.92$).

Rated Perceived Exertion (RPE) Results:

Mean was not reliably significantly different between both conditions, suggesting that participants experienced similar RPE ratings between both conditions (Exergame = 9.54, SD = 2.13; Treadmill = 9.85, SD = 1.49) (t (19) = 0.64, p = 0.53). (See Fig. 3 Mean RPE).

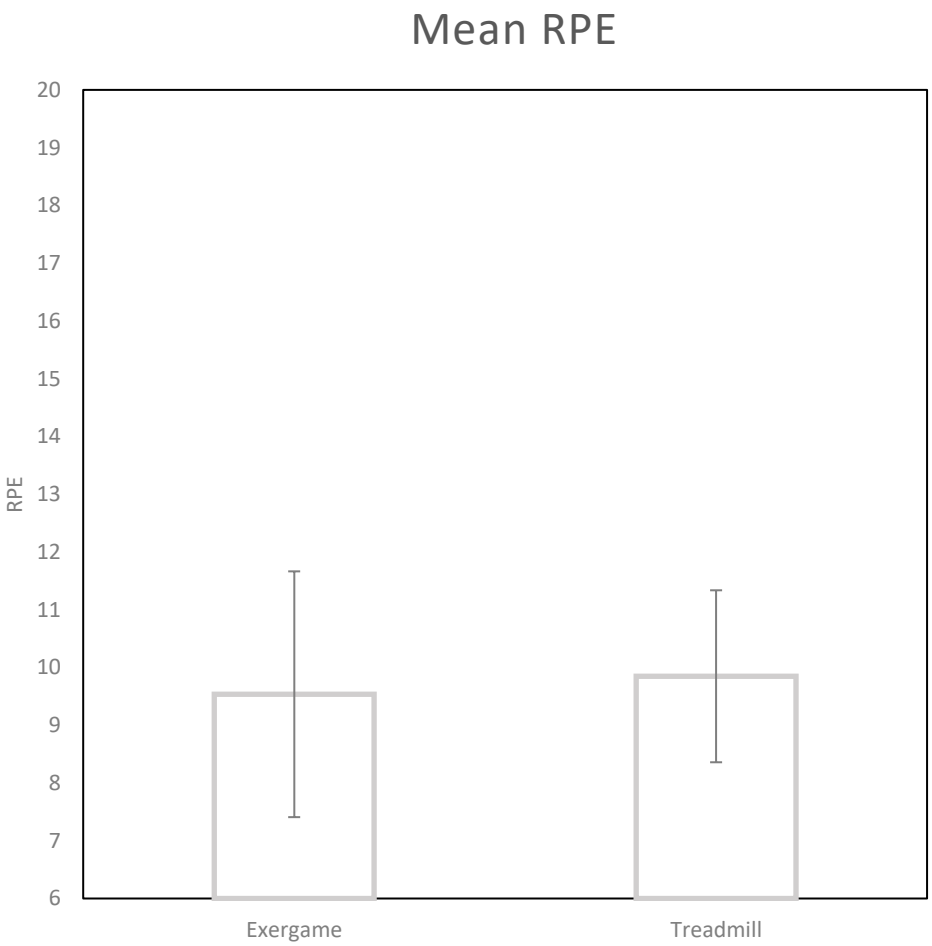

Fig. 3 Mean RPE (Error bars indicate ±1 SD): Participants experienced similar RPE ratings between both conditions (Exergame = 9.54, SD = 2.13; Treadmill = 9.85, SD = 1.49) (t (19) = 0.64, p = 0.53). (See Fig. 3 Mean RPE).

Intrinsic Motivation Inventory (IMI) Results:

For the IMI-based questionnaire used in this study, the fourteen items used in said questionnaire were divided into five sub-groups that assessed participant's intrinsic motivation. Said sub-groups were: Interest/Enjoyment, Perceived Competence, Effort/Importance, Perceived Choice, and Value/Usefulness. Upon completion of data collection, results were averaged into Fig. 4 Intrinsic Motivation Inventory (IMI) Results (See Fig. 4 Intrinsic Motivation Inventory (IMI) Results).

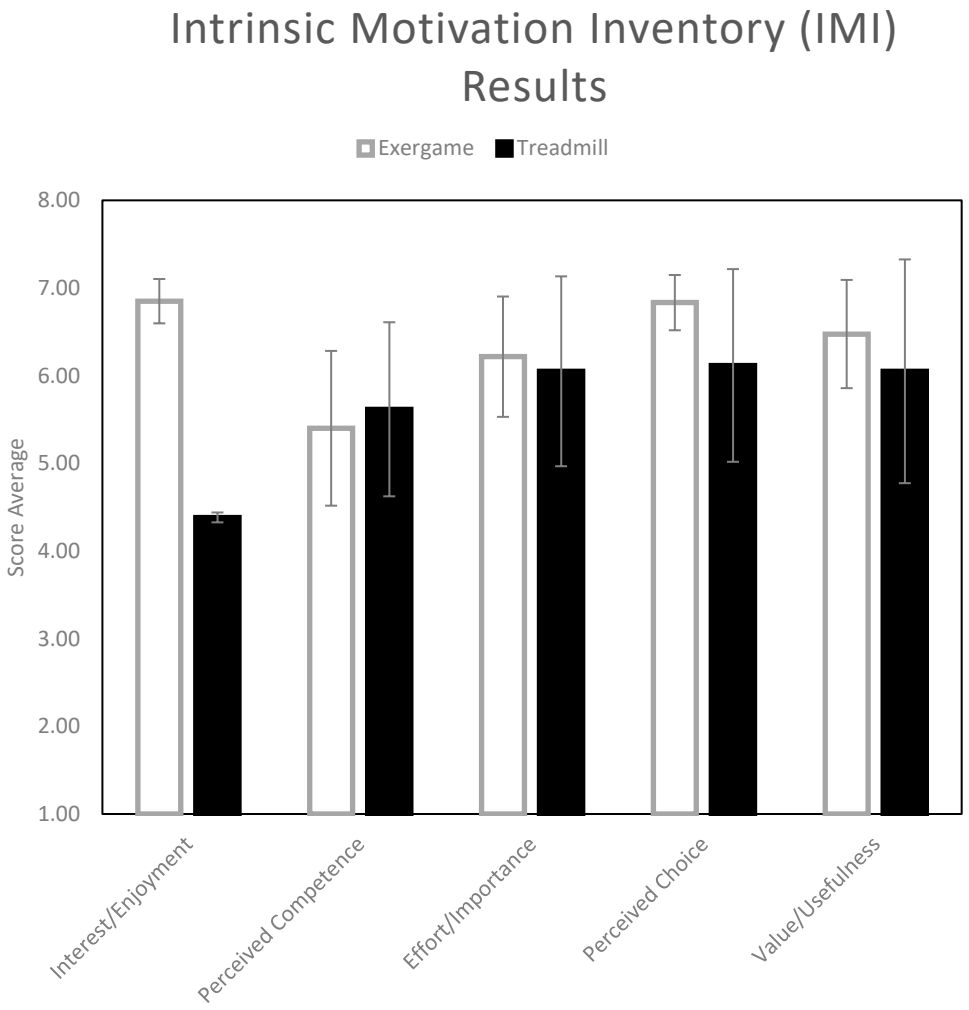

Fig. 4 Intrinsic Motivation Inventory (IMI) Results (Error bars indicate ±1 SD): Participants reported higher ratings on the exergame than on the treadmill for Interest/Enjoyment (Exergame = 6.85, SD = 0.25; Treadmill = 4.38, SD = 1.82) ($t(19) = 6.19$, $p < .05$) and on Perceived Choice (Exergame = 6.83, SD = 0.32; Treadmill = 6.12, SD = 1.1) ($t(19) = 2.81$, $p < .05$) (See Fig. 4 Intrinsic Motivation Inventory (IMI) Results). Participants reported not statistically different results for Perceived Competence (Exergame = 5.4, SD = 0.88; Treadmill = 5.62, SD = 0.99) ($t(19) = 0.91$, $p = 0.37$), for Effort/Importance (Exergame = 6.26, SD = 0.69; Treadmill = 6.05, SD = 1.08) ($t(19) = 0.72$, $p = 0.48$), and for Value/Usefulness (Exergame = 6.48, SD = 0.62; Treadmill = 6.05, SD = 1.28) ($t(19) = 1.3$, $p = 0.21$).

Time Results:

Average time spent on the exergame was significantly greater than that of the treadmill (Exergame = 48.64, SD = 8.26; Treadmill = 23.24, SD = 7.42) ($t(19) = 13.06$, $p < 0.001$) (See Fig 5 Time Results)

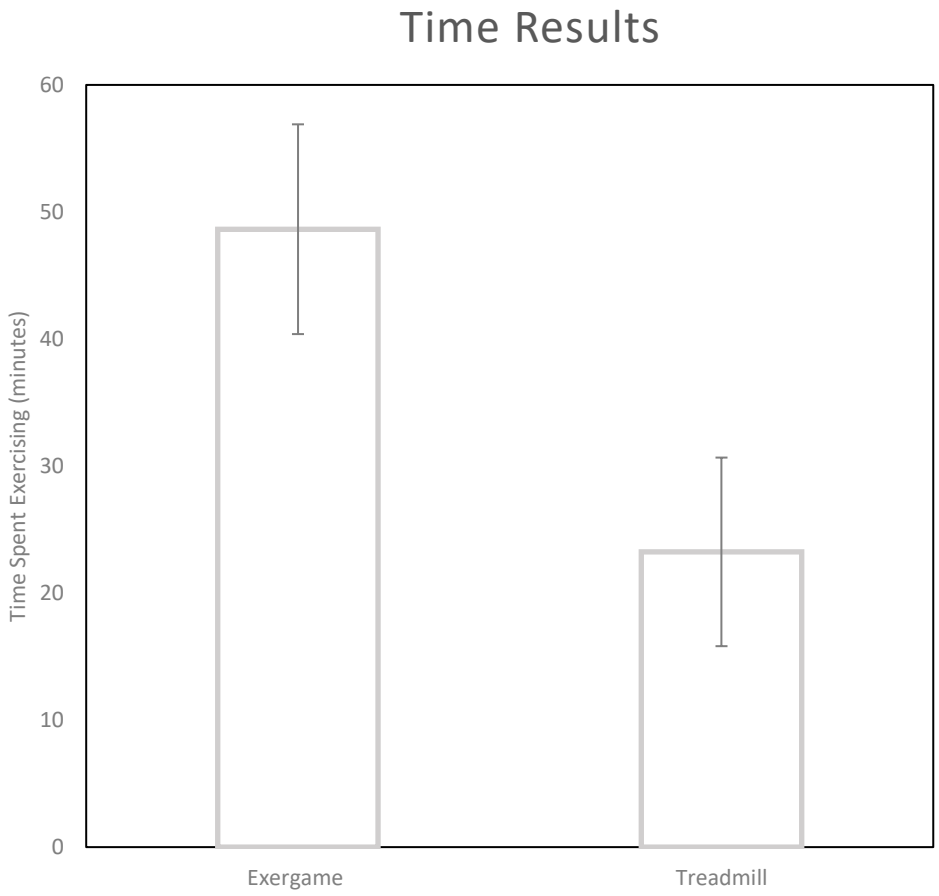

Fig. 5 Time Results (Error bars indicate ±1 SD): Average time spent on the exergame was significantly greater than that of the treadmill (Exergame = 48.64, SD = 8.26; Treadmill = 23.24, SD = 7.42) ($t(19) = 13.06$, $p < 0.001$).

Discussion:

This study focused on determining whether or not the VR exergame *Beat Saber* could be considered a viable, alternative form of cardio exercise. The protocol used in this study was effective in measuring the four variables (heart rate, RPE, intrinsic motivation, and time spent exercising), which in turn allowed for testing of the experimental hypothesis. More specifically,

by requiring participants to exercise for a minimum of twenty minutes, participants were able to provide sufficient heart rate and RPE data that helped in determining the accuracy of the hypothesis. For said twenty minutes, in the exergame condition, participants played on increasingly difficult levels (easy, normal, hard, expert, and expert+) while in the treadmill condition, participants ran on increasing speed intervals (starting at 3.0 and going up to 7.0). In doing so, heart rate and RPE data were able to be compared between both conditions in order to determine if the exergame was able to induce the same amount of exertion as if one was running on a treadmill. In addition, by allowing the participants to continue for as long as they liked (and on any difficulty level in the exergame and on any speed on the treadmill) up until a maximum of sixty minutes, intrinsic motivation data and overall time spent exercising were able to be measured accurately, considering how participants were allowed to stop whenever they chose in either condition. When comparing the most active twenty-minute periods in both conditions, the mean heart rate for both were not statistically different (Exergame mean HR = 148.61 beats per minute, Treadmill mean HR = 148.17 beats per minute) (See Fig. 2.B Most Active period Heart Rate Results), suggesting that participants experience similar heart rates between both conditions. Mean RPE between both conditions were not statistically different (Exergame = 9.54, Treadmill = 9.85) (See Fig. 3 Mean RPE), suggesting that participants experienced similar RPE ratings between both conditions. Results on the IMI-based questionnaire had shown that participants experienced higher levels of intrinsic motivation in the sub-groups of Interest/Enjoyment (Exergame = 6.85, Treadmill = 4.38) and on Perceived Choice (Exergame = 6.83, Treadmill = 6.12), while also showing similar levels of intrinsic motivation in the sub-groups of Perceived Competence (Exergame = 5.4, Treadmill = 5.62), Effort/Importance (Exergame = 6.26, Treadmill = 6.05), and Value/Usefulness (Exergame = 6.48, Treadmill =

6.05) (See Fig. 4 Intrinsic Motivation Inventory (IMI) Results). The results here suggest that participants felt more interest/enjoyment and perceived choice in *Beat Saber* than on the treadmill, while also showing that they felt similar perceived competence, effort/importance, and value/usefulness between both *Beat Saber* and the treadmill. In addition, the overall average time spent on the exergame (about 48.64 minutes) was more than double that of the overall average time spent on the treadmill (23.24 minutes) (See Fig 4 Time Results), suggesting that participants were more willing to spend more time exercising in *Beat Saber* than on the treadmill. The findings from this study showed positive results for exergaming in terms of whether it might be considered a viable, alternative form of exercise in comparison to typical aerobic exercise that could be done at a gym i.e. treadmill running. Similarly, to the study done by Gao, Hannan, Xiang, Stodden, and Valdez (2013), motivation to exercise had increased with the use of exergames, and much like the studies done by Staiano, Beyl, Hsia, Katzmarzyk, and Newton, Jr. (2016) and Moholdt, Weie, Chorianopoulos, Wang, and Hagen (2017), exergaming was considered to be a viable, alternative form of cardio exercise. However, more research is recommended in the field of exercise videogaming in order to better determine the effectiveness of exergaming on adult physical activity levels.

The results of the present study should be interpreted in light of several limitations. For example, the study was limited to a small sample size (twenty). In addition, heart rate measurements could have potentially been altered since the Polar heart rate monitor needed to be wettened and strapped onto a participant's chest in order to properly calculate and estimate said participant's heart rate. If strapped on incorrectly or if the strap was not wet enough, the recordings potentially could've been different than what they actually were. That said, heart rate readings from the heart rate monitor potentially could've been lower than they were, however, this is not a concern

since the readings would've been lower for all participants and in both conditions due to randomization. Rating of perceived exertion measurements may also be faulty since each participant's sense of fatigue may have varied, leading to higher and lower ratings than what was perceived. Participation in this study was entirely voluntary, which potentially could have skewed intrinsic motivation in comparison to if participants who did not want to participate had joined the study. And participants rating of motivation and the associated subscales can differ widely, both between participants, and repeated measurements taken within participants. If there wasn't a twenty-minute minimum or a sixty-minute maximum placed in both conditions, participants may have wanted to stop earlier or continue for longer than they did, which in turned potentially could've altered the data for intrinsic motivation and overall time spent exercising. If this study were to be reproduced, it is recommended to increase the sample size and to include more measurements such as blood pressure, oxygen consumption (VO_2), and carbon dioxide production (VCO_2).

Further research is recommended to determine whether the results will be similar when different age groups (i.e. children, teenagers, older adults) and when at-risk population (i.e. overweight/obese individuals) undergo this study. With the prevalence of obesity in the world today, as stated by the CDC's study (2018), it is important to determine whether or not exergaming can be a potential solution to countering rising obesity rates. More research to determine if different forms of cardio exercise (i.e. cycling) will yield similar results would be beneficial in further determining the effectiveness of exergaming as a viable alternative form of cardio exercise. Future research could be conducted as newer, more technologically advanced forms of exergaming are created as well.

Conclusion:

As hypothesized, the exergame *Beat Saber* can be considered a viable, alternative form of exercise that is also more engaging than running on the treadmill.

References

Beat Games. (2018, May 1). Beat Saber (Version 0.13.2) [Computer software]. Retrieved December 31, 2018, from https://store.steampowered.com/app/620980/Beat_Saber/

Borg, G. (1998). Borg's perceived exertion and pain scales. Human kinetics.

Valve Corporation. (2003, September 11). Steam (Version 2019) [Computer software]. Retrieved December 31, 2018, from https://store.steampowered.com/

Centers for Disease Control and Prevention: Facts about Physical Activity. (2018, September 12). Retrieved October 24, 2018, from https://www.cdc.gov/physicalactivity/data/facts.htm

Hoalst, S. (2018, May 14). Beat Saber Game Review - A Jedi Samurai Rhythm Game. Retrieved August 25, 2018, from https://www.vrfitnessinsider.com/review/beat-saber-game-review-a-jedi-samurai-rhythm-game/

McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. Research quarterly for exercise and sport, 60(1), 48-58.

Moholdt, T., Weie, S., Chorianopoulos, K., Wang, A. I., & Hagen, K. (2017). Exergaming can be an innovative way of enjoyable high-intensity interval training. BMJ open sport & exercise medicine, 3(1), e000258. doi:10.1136/bmjsem-2017-000258

National Center for Health Statistics. (2017, January 20). Retrieved October 24, 2018, from https://www.cdc.gov/nchs/fastats/exercise.htm

Pagoto, S. (2014, November 10). The Real Reason We Don't Exercise. Retrieved October 24, 2018, from https://www.psychologytoday.com/us/blog/shrink/201411/the-real-reason-we-dont-exercise

Ryan, R. M., & Deci, E. L. (n.d.). Intrinsic Motivation Inventory (IMI). Retrieved November 20, 2018, from https://webcache.googleusercontent.com/search?q=cache:BIq9LUtoBiEJ:https://gih.instructure.com/files/2040/download?download_frd=1 &cd=3&hl=en&ct=clnk&gl=us

Staiano, A. E., Beyl, R. A., Hsia, D. S., Katzmarzyk, P. T., & Newton, R. L. (2016). Twelve weeks of dance exergaming in overweight and obese adolescent girls: Transfer effects on physical activity, screen time, and self-efficacy. *Journal of sport and health science*, *6*(1), 4-10.

Zen, G., Hannan, P., Xiang, P., Stodden, D. F., & Valdez, V. E. (2013, February 14). Video Game–Based Exercise, Latino Children's Physical Health, and Academic Achievement. Retrieved October 29, 2018, from https://www.sciencedirect.com/science/article/pii/S0749379712009063?via=ihub#

Appendix A

Borg Rating of Perceived Exertion Scale

Intrinsic Motivation Inventory based Questionnaire

Borg Rating of Perceived Exertion Scale

Rating	Perceived Exertion
6	No exertion
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Intrinsic Motivation Inventory based Questionnaire

For each of the following statements, please indicate how true it is for you, using the following scale:

1	2	3	4	5	6	7

Not true at all **Somewhat True** **Very True**

Questions (14):

1. I enjoyed doing this exercise very much.

2. After working at this activity for a while, I felt pretty competent.

3. This activity was fun to do.

4. I put a lot of effort into this exercise.

5. I thought this was a boring activity.

6. I am satisfied with my performance at this exercise.

7. I think I am pretty good at this activity.

8. I didn’t put much energy into this exercise.

9. It was important to me to do well at this task.

10. I believe that doing this activity could be of some value for me.

11. I felt like it was not my own choice to do this exercise.

12. I did this exercise because I wanted to.

13. I believe I had some choice about doing this activity.

14. I would be willing to do this activity again because it has some value for me.