The Impact of Exergaming Competitions on Affective and Performance Variables

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CHAPTER I: INTRODUCTION

Across the United States, there's an increasing concern regarding physical inactivity. According to the 2008 Physical Activity Guidelines for Americans, 44% of US adults are aerobically active (Miller et. al, 2016). This includes individuals who participate in a variety of aerobic activities and those who do not meet the Centers for Disease Control and Prevention (CDC) guidelines. With this, obesity continues to increase, national cholesterol and diabetes levels continue to increase, and earlier morbidity rates have become more prominent. Researchers and exercise specialists have desperately begun to work to find a solution to these growing problems with physical inactivity. Technology experts and specialists have developed the concept of exergaming in considering methods that could enhance exercise's enjoyability and motivation. Through this concept, researchers hope to take a key variable in increased sedentary behavior—gaming—and transform it into a form of exercise.

Researchers have found exergaming to have a remarkable ability to transport individuals from the reality of the present to an alternate environment and space. Exergaming's impact on culture and humans across the globe continues to grow and has become an increasing phenomenon within today's society. Exergaming can significantly increase the dissociation from the environment and surroundings and increase immersion into a virtual world through exercise (Aardema et al., 2010). Understanding the impact that exergaming can have on one's ability to dissociate from their current circumstances and environment has become integral in understanding the many different methods and uses for these exergaming systems.

Both immersive and non-immersive virtual reality continue to grow in popularity and scholars have hypothesized that both of these systems have the opportunity to become one of the most educational new technologies to exist (Hamad, 2022). Scientists, educators, exercisers, and practitioners have begun to seek the usage of a particular branch of virtual reality, exergaming, to transport them from a current environment into an alternate universe that can increase personal dissociation and decrease present emotions and psychological feelings (Cipresso, 2018).

Exercise is one field in particular that exergaming has begun to vastly transform. Researchers have studied both the physiological and psychological effects of exercise on an individual for years and have continued to discover the benefits of exercise and physical activity on an individual's well-being. Scholars have found that enjoyable distractions such as watching TV while exercising can increase an individual's enjoyment of their own exercise experience and lead to increased positive affect post-workout (Privitera, 2014). While exercise itself has the ability to increase positive mood post-working out, the combination of a distracting and enjoyable experience with exercise has shown to significantly have greater increases in positive mood post-exercising. These enjoyable distractions have the capacity to improve an individual's physiological and psychological workout experience which can ultimately lead to an increased motivation to adhere to an exercise routine.

Exergaming can have vast physiological benefits for one's exercise experience and performance. While it holds many positive benefits, exercise can become repetitive, boring, and fatigue provoking for individuals which can cause people to become less motivated and driven to participate in exercise. Therefore, researchers, medical professionals, and scientists have continued to collaborate in order to find alternative measures to increase exercise adherence and motivation to exercise. Exergaming has the potential to become a solution for the unmotivated to adhere to the exercise phenomenon. When using exergaming systems as an enjoyable distraction while exercising, individuals have been able to significantly increase muscle strength, physical fitness, and balance (Qian, 2020). Both fully immersive and non-immersive exergame systems can provide positive distractions that offer environments where individuals can more willingly exert themselves while distracted from their physical fatigue. Researchers have found that the use of competitive exergaming has increased participants' levels of physical activity (Hamad, 2022). This personal motivation and exciting environment while exercising can lead an individual to higher physical exertion, greater cardiac output, and increased joint mobility. The incorporation of exergames into exercise can create a motivating and transformational system that can decrease sedentary behavior and improve physiological benefits of one's exercise experience.

Through providing a dissociative opportunity for an exerciser, exergaming can decrease an individual's negative emotions both during and after exercise. This dissociation can shift attentional focus and allow one's present attention on their breathing and how their physical body feels to a more dissociative feeling of a game that they are playing. Researchers have found that when one engages in an enjoyable form of exergaming, they will later be more likely to experience calmness, less depressive symptoms, and enhance one's quality of life (Qian, 2020). By undergoing a dissociative environment, the exerciser's focus shifts from their own personal exertion and physiological stress to the focus of the exergame (Lind et al., 2009). Dissociation can not only decrease perception of exertion but can also enhance an individual's affective psychological state during and after exercising. (Lind et al., 2009). Not only does exergaming provide distractive video stimuli to draw one's attention away from their exercise experience, but it also provides an interactive environment that allows an individual to choose a self-paced yet interactive exercise program for themself. Researchers have found that unpleasant feelings of exercise can be improved through individualized and self-paced exercise programs (Miller et al., 2016). Therefore, exergaming has the ability to provide both video dissociation, but also allow an individual to monitor their own exercise routine, which can ultimately decrease a person's negative feelings and improve their affective states while exercising.

When examining the impacts of an exergaming system on one's psychological perspective of exercise, researchers and scientists first look at an individual's own perception of their exertion during exercise. "Perceived exertion is the subjective experience of fatigue, strain, effort, and discomfort during exercise" (Borg & Noble, 1974, p. 17). An individual's perception of their exercise plan and routine becomes key in analyzing how psychological components of exercise may be altered through exergaming. Borg developed the Rating of Perceived Exertion (RPE) scale to measure this psychophysiological variable. Further, researchers hypothesize that by providing distractions, such as exergaming, that positively dissociate an exerciser from their present reality, the exerciser will focus less on their present feelings causing a lower report of rating of perceived exertion. Exergaming can lower one's perception of fatigue, negative emotions, and physical exertion, which can increase their positive psychological experience while exercising.

Along with RPE, an exerciser's feelings while exercising are a key variable in whether they will feel motivated to continue their pattern of exercise. If one exercises with a 'good feeling' through the duration of their exercise, they will be more likely to enjoy their session and feel a greater desire to participate in this exercise again. Exergames have the ability to take an individual's focus, allow them to dissociate, and therefore feel a more positive feeling and emotional high than they would while exercising without an exergame.

Further, data regarding the extension of benefits and uses of competitive exergame systems can continue to remain minimal (Hamad & Jia, 2022). The Centers for Disease Control and Prevention's (CDC) physical activity guidelines continue to be inadequately met, causing growing concern for a national crisis in obesity, unhealthy behavior, and, ultimately, a lack of regular exercise. Advanced research regarding exergaming as a solution to the lack of exercise within American adults is extremely relevant as exercise-related health risks continue to grow. Incorporating an enjoyable and dissociative experience into exercise has been found to not only increase an individual's affective states but to increase their likelihood to adhere to exercise (Qian et al., 2020).

Purpose statement

The purpose of this study was to examine how competitive exergaming impacts an individual's performance and affective responses during a rowing exercise task.

CHAPTER II: LITERATURE REVIEW

A literature review of published works and data regarding the usage of virtual reality and competition during exercise will be discussed. Exergaming has positively transformed the exercise experience of an individual in both psychological and physiological mechanisms. Through analyzing standing published literature on exergaming and exercise, an understanding of how virtual reality competition exergame could impact one's exercise experience and enjoyment can be established. The topics discussed in this review include (1) theories that discuss how exergames through virtual reality are processed and used, (2) physiological effects of the use of exergames during exercise, and (3) the psychological effects of using virtual reality exergames during exercise.

Theories and Models

A significant amount of research exists in defining theories and models that describe how one's perception, integration, and attentional allocation impact both physical and psychological components of performance, specifically within exercise. Theories and models adequately elaborate and support this research on both general virtual reality within exercise as well as competition-based exercise programs.

Self-Determination Theory

The self-determination theory, developed by Ryan and Deci, is a theory that examines how social environments and an individual's personality will impact their own motivation. Researchers use this theory in order to predict how one's psychological motivation may be affected in differing social contexts and environments. The theory suggests that humans have three innate needs including competence, autonomy, and relatedness and that through meeting these needs, an individual can achieve greater internal and task specific motivation (Deci & Ryan, 2015). This theory can offer predictions of how a human's motivation may be affected through a non-immersive virtual reality exercise system.

The first innate human need that the self-determination theory suggests is competence. In a research report released by Cambridge University, researchers define competence as "the ability to integrate and apply contextually appropriate knowledge, skills and psychosocial factors (e.g., beliefs, attitudes, values and motivations) to consistently perform successfully within a specified domain" (Vitello, Greatorex, & Stuart Shaw, 2021). In stating this concept to be a vital human need in order to achieve motivation, Deci and Ryan offer implications that an exerciser must believe that they themself can successfully interpret and understand a context in order to overcome or achieve a specific task (Deci & Ryan, 2015).

The second need that Deci and Ryan suggest humans desire in order to achieve personal motivation is autonomy. For years researchers have debated what exactly defines this term of autonomy. In a chapter discussing ethical foundations, researcher Ron Scott defines autonomy as “self governance” (Scott, 2009). Therefore, in order to develop internal and effective motivation, a human needs to first feel as if they have self-governance and autonomy within their own circumstances. In having the ability to manipulate their surroundings and effort, exercisers achieve autonomy and motivation (Deci & Ryan, 2015).

The third need that Deci and Ryan suggest is relatedness. This need implies that through connecting with one’s surroundings and environment, a social motivation can begin to exist that fosters motivation (Deci & Ryan, 2015). In interacting with alternative environments and social contexts, exercisers find motivation in relatedness. The theory as a whole incorporates both extrinsic and intrinsic motivation. It incorporates extrinsic motivation through an external environment and includes intrinsic motivation in motivating an individual to internally feel motivated and have a desire to push themselves during exercise.

Dual Process Theory

This theory suggests that humans often make decisions and rationalize as a result of two correlational variables. One of these is based on a fast, intuitive decision-making system and the other is rooted in a more deliberate and slow system. Researchers consider the first system to be a system used with little to no attentional control, while system two requires attentional control and working memory. This theory can explain both physical and psychological changes to an individual’s exercise performance (Bellini-Leite, 2022).

In researching the dual process theory within sports, researchers have developed a specific model within this theory referred to as the default interventionist model. This model carries the ideas of two systems, system 1 and 2, within the dual process theory. The default interventionist model explains type 1 processes more specifically as “those whose execution is mandatory in the presence of their triggering conditions” (Furley et al., 2015). The model further defines type 2 processes as “needed either to override the triggered response that is part of a representation/problem space or for a response that has never become part of a representation/problem space” (Furley et al., 2015). The default interventionist model often interprets the type 1 process as an automatic mode that an individual enters as a default that is only inactivated when type 2 processing kicks in.

A false assumption often gained from this model is that these processes simply exist as one or the other. However, in most circumstances and environments, such as exercise, both of these processes coexist. Therefore, an exerciser's performance and behavior can be affected by both type 1 and type 2 processing (Furley et al., 2015).

Social Cognitive Theory

This theory helps to explain how individuals develop and maintain trends of behavior. The theory incorporates variables including peer feedback, environmental factors, and contextual interaction in determining how one's self-esteem and behavior patterns are developed. It further provides research that has led to the designs of exercise programs, including exergames. The background information that researchers have uncovered surrounding this theory is that individuals learn most from others and their environments and ultimately use this acquired knowledge to manipulate and facilitate behavior patterns. The positive effects of these interactions can provide internal motivation for individuals in many areas of their lives (Kooiman & Sheehan, 2015).

Flow Theory

Flow theory involves a process where individuals enter into a period of time without considering and often forgetting the specific actions that they are performing. Developed by Csikszentmihalyi in 1990, flow theory was first known as a function of play as it completely engulfs the human mind and takes over both internal and external thoughts and variables. By entering into a "flow state," individuals can find intrinsic motivation to perform a task and push themselves (Kooiman & Sheehan, 2015).

Along with its temporary increase in intrinsic motivation, flow theory can also cause increased motivation to adhere to a program in order to re-enter this state. Its intense gratification that it gives, as well as its ability to completely engulf an individual, allows for temporary dissociation from one's reality. In a study on increasing motivation within disabled women, Weybreight et al. (2010) examined flow theory in the context of exergaming. When these women used these exergames and entered this flow state, they felt a greater motivation to continue with this task and adhere to this program than those who did not have the opportunity to enter the flow state through exergaming (Kooiman & Sheehan, 2015).

Regulatory Focus Theory

Regulatory focus theory, a theory established by Lwin and Malik, examines how individuals use regulatory focus in order to achieve a goal or perform a task. The two aspects of this theory involve the concepts of promotion focus and prevention focus. Promotion focus involves the idea of an individual anticipating and working towards the end of the task or completion of the goal, while prevention focus involves an underlying motivation due to a fear of falling short, which causes the player to work towards this goal to avoid failure or loss. Varying personality types, circumstances, and tasks can facilitate whether promotion focus or prevention focus may be most effective and ultimately most motivating in achieving a task. Competition becomes a factor as well when considering focus on specific stimuli within environments (Kooiman & Sheehan, 2015).

Game Theory Model

The game theory model addresses competition and proposes different ways in which an organism will respond when presented with competition-provoking stimuli. This theory proposes two open strategies that an individual will consider when entering a closed competitive environment. The first of these is that the individual can accept the competition or those that they will be competing against and “passively compete” or defy the competition by actively attempting to beat or wipe out this competition (Colegrave, 1994). These strategies originally applied to intraspecific competition among species throughout animal kingdoms and have begun to seek applicability among the modern world in considering humans competing with one another in closed environments.

Dual Process Model

Dual process models imply that while exercising an individual’s mind incorporates not only controlled processes but automatic processes as well (Cheval & Boisgontier, 2021). Cheval and Boisgontier describe controlled processes as those that “rely on higher brain function.” Controlled processes during exercise incorporate a consciousness or awareness of an individual’s mind. On the contrary, automatic processes are faster processes involving a lack of present awareness that does not require a great amount of brain function. For example, an individual may experience dissociative thinking, daydreaming, or remembering memories while exercising. Incorporating their automatic processes at another time may be much more associative and aware of their exercise movements and breathing during exercise. This model incorporates both dissociation and association through controlled and automatic processes.

Theory-Based Exergame Model

The theory-based exergame model proposes a comprehensive and multidimensional theory that utilizes Bloom's taxonomy of learning (1956) in order to develop a model that examines how an exergame system can affect the system's player. Bloom's taxonomy of learning utilizes three different domains, including the cognitive, the affective, and the motor, in domain order to explain and categorize individualized learning. The theory-based exergame model builds upon this taxonomy and states that the purpose of the exergame system exists to improve physical, motor, cognitive, and psychological skills (Chow & Mann, 2023).

The model first focuses on the improvement of motor function. This focus derives from the importance of control of voluntary movement in order for an individual to achieve success in physical activity. Fine, gross, and perceptual motor skills all work interconnectivity to achieve an individual's coordination and ultimately success in physical exercise (Chow & Mann, 2023).

The second focus of this model is the enhancement of cognitive skills. Cognitive skills include one's ability to process and interpret information as well as perceiving one's environments and surroundings. The model states that these cognitive skills can specifically be divided into four specific areas including memory, executive functions, visual perception, and attention. The incorporation of many and often all of these domains within cognitive function becomes necessary for a player navigating an exergame system (Chow & Mann, 2023).

The final focus of the theory-based exergame model involves an individual's psychological skills. These psychological skills can be broken into four social, emotional interaction domains including emotion, self-efficacy, enjoyment, and social skills. Through interacting with a novel virtual environment, exergames can enhance these four domains involved in an individual's psychosocial skills and development.

Effects of Exergames During Exercise

In examining how exergame systems can impact an individual physically and psychologically, one can better understand how motivation to exercise and exercise achievement can be met through exergaming. Physically, an exergame system can involve physical exertion, heart rate, muscular ability, endurance, and speed. Psychologically, an exergame system can alter association and dissociation, focus, enjoyment, and perceived exertion (Qian et al., 2020).

Physical Effects of Exergames During Exercise

Researchers have conducted multiple studies across the globe considering virtual reality and its effects on exercise. Four particular studies regarding virtual reality and its effects on physical output and fitness can be examined in order to understand virtual reality's relationship with physiological factors.

The first of these studies, conducted by Qian and colleagues (2020) examined the effects of virtual reality on physiological factors in a rehabilitative setting. The study prefaced itself with the knowledge that virtual reality could positively enhance muscle strength and function, balance, and extremity function. The study then examined 246 articles in total before deleting duplicate articles and narrowing down the criteria. The population of the selected studies ranged from children to the elderly and most participants participated in an intervention program that lasted between two weeks to twelve weeks. A variety of tests were included in this study in order to effectively examine different physiological components. For example, the Berg balance scale was used to examine participants' balance as well as the one-legged stand test and the trunk control test. The Wolf motor function test examined muscle strength and mobility of different extremities. The sit to stand test was used as well in order to measure lower extremity function, and electromyography was used as well. Due to the great amount of variation of tests, duration, and participants, the meta-analysis presented multiple conflicting articles and results on specific variables such as balance, however, concluded that virtual reality does continue to hold many positive variables that have and continue to positively impact an individual's physiological ability and fitness (Qian et al., 2020).

The second study that examined physiological components regarding virtual reality and exercise comes from researchers Giakoni-Ramírez and colleagues (2023) who used a meta-analysis approach to examine physical fitness as a result of virtual reality in exercise. In order to meet these researchers' criteria, the reviewed articles must include real human subjects who had used a VR headset before that involved physical activity and were published by December of 2021. These researchers specifically examined immersive virtual reality within physical exercise to interpret results. Ultimately, this study concluded that when using virtual reality at moderate to vigorous intensity levels, participants' heart rates can be increased while continuing to feel less pain than the participants recorded in the absence of virtual reality. The study concluded that through the use of virtual reality, exercisers can physically feel less pain and increase their physical exertion in order to meet medical exercise recommendations for their given population (Giakoni-Ramírez et. al., 2023).

In an additional study conducted by researchers Khundam and Nöel (2021), virtual running techniques were assessed by evaluating an individual's arm swing and squat while using an immersive virtual reality system. Every participant used a virtual running track to run for approximately one to two minutes. While the participants were in the virtual reality simulation, the researchers examined the participants' heart rates in both the arm swing and squat conditions, and the participants were then given time to rest and take three questionnaires examining user enjoyability, system usability, and motion sickness. The arm swing condition involved the participant manipulating their environment by swinging their arms in a posture while holding onto the controller. The squat condition involved the participant manipulating their environment by squatting with their knees bent to a hold and then standing back up to standing posture while holding the controllers. The researchers examined 30 participants who were all given in-depth instructions in order to complete the task within the virtual reality simulation. When comparing the two simulations of arm swing and squat, researchers found that participants preferred the arm swing virtual running over the squat. The participants further replied on their questionnaires that they felt unchallenged by the arm swing condition and did not undergo exertion that they felt they could endure, demonstrating the necessity of individualized virtual reality systems in response to an individual's exercise and fitness ability. The study concluded that the users did feel less physically exerted while using the arm swing virtual reality system than those who did not, however, that they felt bored by this and felt as if they could perform at a higher level had they been adequately challenged (Khundam & Nöel, 2021).

The final study examining the physiological components of humans in response to virtual reality systems examined increasing exercise endurance through the use of virtual reality. Lemmens (2023) had 97 participants between the ages of 17 and 34 participate in a lab environment and who were told that their participation would include vigorous exercise and the use of a VR headset. The participants were asked to perform a baseline assessment of a dead hang that would measure grip and forearm strength, and a core test that would measure abdominal and lower back muscle strength. The participants then rested for five minutes and completed the same tasks in three separate virtual environments (stadium, beach, and city) each with five minutes allowed of rest and the VR headset to be taken off between them. Lemmens found that when comparing the results of the social environment (stadium) and the stressful (city) environment increased persistence and exercise endurance when compared to the calming (beach) condition. This allowed her to further conclude that while calming environments may help in areas such as meditation, they can decrease physical exertion during exercise. However, participants did report that a calming environment provided them with the most joy, and Lemmens hypothesized that researchers and medical professionals should take this into account when attempting to increase exercise adherence through increased enjoyment (Lemmens, 2023).

Psychological Effects of Exergames During Exercise

One of the primary psychological components of exergaming is an individual's enjoyment during the experience. Three particular articles examine enjoyment and pleasure during exercise while using virtual reality and using different variables to assess perceived enjoyment.

The first article conducted by Lyons (2015) examined the process of cultivating an engaging and enjoyable environment through exergaming. Lyons examined three mechanisms including feedback, challenge, and reward in order to evaluate engagement and enjoyment during individual exergame sessions. Lyons defines feedback as a variable given by the exergame that provides in-depth feedback and increases with greater activity. She then defines challenge as a necessary factor of the exergame that include both physical and cognitive obstacles. Next, she defines reward as a complex system that could offer either negative or positive effects and therefore must be carefully interwoven in order to produce an effective impact. Lyons continues through her article with a theoretical review of these three mechanisms, and hypothesizes that through studying these mechanisms more closely, researchers will be able to increase the enjoyment and engagement of an individual using an exergame system (Lyons, 2015).

The second article addresses different interventions that have been used to increase sociability in older adults through virtual reality and exercise. Researchers Freed et al. (2021) conducted a study that evaluated twenty healthy, older adults who were asked to play two different exergame systems, one Kinect Just Dance condition and one Kinect Sports Rivals condition, each for ten minutes. In this study, the participants reported both qualitative and quantitative feedback, and younger and more extroverted participants reported a higher rating of perceived enjoyment. The participants also reported a greater motivation to succeed and do well in their exercise environment but reported lower levels to exercise in these conditions in the future due to a lack of desired exertion or aerobic exercise. These reports led the researchers to conclude that the exergames did provide positive effects of increasing social engagement and decreasing social isolation, but that appropriate measures of aerobic exercise need to be incorporated based on individual capability in order to increase exercise adherence in the future (Freed et al., 2021).

The third article examines the idea of escaping one's reality using exergames in order to increase exercise enjoyment and pleasure within children. Researchers Ho and colleagues (2017) used data collected from surveys given to children living in Singapore in order to analyze children's mood experiences during exercise. The researchers of this study confirmed their initial hypothesis and found there to be a positive relationship between the presence of exergames and mood experience and mood games in children. Additionally, the children reported not only an increase in mood while playing the exergame, but also a greater likelihood to participate in the games in the future (Ho et al., 2017).

Effects of Competition-Based Exergames During Exercise

While virtual reality in the form of exercise has been analyzed and researched, the impact of competition-based exergames on an individual's exercise enjoyment and likelihood to increase exercise adherence continues to lack sufficient research and data. Many articles examine the two separate concepts of competition and exergames but have yet to combine the two into a concrete supported study. One study analyzed earlier on in this literature review, conducted by Qian, Mcdonough, and Gao, briefly addressed the concept of "competitive spirit" in their exercise-based virtual reality sports game. The researchers concluded that many of the participants' competitive spirits motivated them to exert themselves more vigorously and achieve more points in the sports-based game. While this article briefly addressed competition in exergames, it—along with many others—lacks concrete data of the potential to increase exercise enjoyment and adherence through competition-based exergaming (Qian et al., 2020).

Research Questions

- Is there a difference in adult exercisers' perceived exertion, attention, heart rate, and enjoyment while participating in a competition-based exergame from a control condition?
- Is there a difference in adult exercisers' strokes per minute, power output, and distance rowed while participating in a competition-based exergame from a control condition?

Hypotheses

- Adult exercisers would have a lower RPE, dissociative attention, and higher enjoyment in the competition-based exergame compared to the control condition.
- The heart rate of the adult exercisers would be non-significant between the two conditions.
- Adult exercisers would have higher strokes per minute, power output, and distance rowed while participating in a competition-based exergame compared to the control condition.

Definition of Terms

Virtual Reality: type of technological advancement that allows an individual to interact with various computer-simulated environments (Aminabadi, 2022).
Immersive Virtual Reality: Usually achieved through a headset that completely engulfs an individual's visual attention, blocking out physical visual distractions (Omlor et al., 2022).
Non-Immersive Virtual Reality: An observable visual system often displayed through a computer or monitor but does not block out one's surrounding environment (Omlor et al., 2022).
Affective State: A state or construct that combines one's psychological and physiological processes (Cittadini et al., 2023).
Dissociation: the narrowing of the mind away from physical and mental fatigue (Karageorghis & Priest, 2008).
Researcher-Selected Competitive Rowing Game: a standardized competitive rowing game referred to as Grand Prix that includes robots who race the individual rowing.
Exergame: A form of digital game that requires active bodily movements in order to accomplish the tasks of the video game (Benzing & Schmidt, 2018).
Enjoyment of Exercise: positive affective response due to physical activity (Wankle, 1993).

Assumptions

For this study, we can assume that the participants followed the instructions given by the researcher. We will also assume that the participants responded honestly to the written and verbal questionnaires. We will also assume that the rowing system was correctly set up each time.

Delimitations

One delimitation of this study was that it only included adults around a North Texas College Campus. Therefore, while some participants were older, a significant amount of the sample population was from a young adult college-aged population. The study also only included one of many types of exergames with a competitive component and used rowing as the measure of aerobic exercise as opposed to other forms of exercise.

Limitations

One limitation that we as researchers were unable to control was whether an individual had experience using a rowing machine before participating in this study. Participants who did not have prior experience of using a rowing machine may have had to focus more on their physiological movement than participants who were familiar with a rowing machine. Another limitation of this study was how competitive-natured an individual may be. Individuals with a more competitive personality or nature may have been more likely to exert themselves during the competitive exergame than individuals who were less competitive-natured.

Independent and dependent variables

- Independent variable: Exergame Condition (competitive “Grand Prix” rowing game condition and control condition).
- Dependent variable(s): Reported scores of rating of perceived exertion, attention, feeling, heart rate, enjoyment, strokes per minute, power output, and distance rowed.

Significance of study

While the study of the various impacts of gaming and virtual reality has been extensively researched, as well as the extensive lack of exercise across the United States, there is a lack of research regarding the potential impact that the combination of the two could have on increasing a population’s participation in exercise. Specifically, research lacks on increasing the enjoyment of exercise using the enhancement of an exergaming device. Further, this study incorporated a competition-based exergame that allows further analysis of exergaming in the form of competition for an exerciser. In further examining and studying how the different physical and psychological components of exergaming impact an individual’s exercise routine, one can examine an individual’s actual enjoyment of their exercise experience when often correlated with motivation, repetition, and adherence.

Research studies have also discovered that in addition to simply playing exergames while exercising, competition-based exercise can significantly increase one’s exercise performance (Viru et al., 2010). However, research lacks in examining combining these two transformational variables in motivating and ultimately enhancing one’s exercise experience.

CHAPTER III: METHODS

Participants

Participants were recruited from Fall of 2022 until Spring of 2024. A total of 33 participants were recruited for the current study. Due to missing data and failure to complete study requirements, seven participants were dropped. Therefore, 26 participants, between the ages of 18 to 47 (21.5 +/- 5.55), completed the study. Participants were deemed eligible to participate in the study if they could pass a Physical Activity Readiness Questionnaire (PAR-Q). Of the 26 participants that were analyzed, 23 were female and three were male. The average height was 65.23 +/- 2.55 inches. The average weight of the participants was 146.61 +/- 26.47 pounds. Race was distributed with 21 White individuals, 1 African American, 1 American Indian, and 3 Asian. Ethnicity was distributed with 21 non-Hispanic or Latinx and 5 of Hispanic or Latinx descent.

Measures

Informed Consent

Each participant was required to complete an informed consent form that included the outline, directions, and risks of the study. The participants were also informed that they may discontinue and withdraw their participation at any time during their sessions. The participants then acknowledged their consent by signing this document.

Physical Activity Readiness Questionnaire (Par-Q)

The Par-Q was a test administered to the participants in order to assess a physical activity readiness exam. It gives details of a participant's level and ability within physical activity. The participant was verified and permitted to participate in the study if they responded "NO" to every question on the Par-Q assessment. If the participants responded "YES" to any question, they were told that they may not participate in this study.

Demographic Questionnaire

The participants also completed a demographic questionnaire that recorded each individual's race, age, ethnicity, and exercise history.

Task Specific Motivation Scale

This scale was used to measure and assess the participant's motivation, perception of their own ability, and their own self-efficacy. Using the Likert scale, participants recorded their perceived motivation on a scale from 0 (very low) to 10 (very high).

Rating of Perceived Exertion

Borg's Rating of Perceived Exertion scale is a 15-point scale that each participant used to record their perception of exertion during each session. Researchers have used Borg's scale as a psycho-social analytical device that helps interpret an individual's perception of exertion (Scherr et al., 2013). Researchers have further found that Borg's RPE scale has a significant relationship with heart rate. The scale is measured from 6 (no exertion) to 20 (extremely hard maximal exertion).

Attention Scale

Participants' attention was assessed using a 10-point scale starting at a 0, which meant external thoughts, daydreaming, singing songs, environment, and ranging to a 10, which meant internal thoughts, how one's body feels, and breathing. Like the other scales, the attention scale was used as a measure before, during, and after the rowing task.

Feeling Scale

Participants were also assessed on a feeling-based scale that ranged from -5 (very bad) to +5 (very good). Using this scale helped assess each participant's enjoyment of exercise before, during, and after their individual session. Each participant was instructed to attempt rowing a +3 (good) feeling in both the control and experimental condition.

Commitment Check

The participants then completed a commitment check that assessed their individual commitment to completing the research study. The commitment check used a scale ranging from 1 (not committed) to 10 (very committed) that the participants were asked to use to rate their anticipated commitment to the study. The scale then asked the participants three different questions, including a) "How hard did you try while you were completing this task?" (b) "How well do you believe you handled any physical discomfort or pain during the task?" and (c) "How much effort did you invest in the task?" (Braun-Trocchio et al., 2022).

Physical Activity Enjoyment Scale (PACES)

Finally, the participants filled out the Physical Activity Enjoyment Scale (PACES) after each exercise session. This scale included 18 separate questions with a 7-point scale that the participants used to rate their responses to each question. The 7-point scale ranged from 1 ("I enjoyed it") to 7 ("I hated it"). This exercise helped to measure enjoyment after the exercise had been completed as opposed to the feeling scale that assessed feeling and enjoyment while exercising.

Apparatus

Heart Rate

Heart rate was measured through a Polar H10 heart rate monitor attached to a sensor strap that participants wore around beneath their sternum. The participants' heart rate was then monitored using the Polar Heart Rate app on an iPad that synced to the individual device that the participant was wearing. The participants' heart rates were measured before, during, and after their rowing session.

Exercise Rower

The Aviron Tough Series advanced exercise rower was used for participants to complete their exercise rowing sessions. This is a full body rowing machine that includes a high tech 22-inch touch screen that displays participant statistics as well as a variety of game and environment settings.

Exergame Setting

Using a within subjects design, the participants rowed in both the control condition that included only a summary of current exercise statistics displayed on the screen with no external noise and the experimental exergame setting called the "Grand Prix" exergame. The Grand Prix exergame condition included a 20-minute rowing exergame where the participants rowed against other avatars that adapted to each individual's level of rowing. The avatars on the screen appeared to be racing the individual's own avatar on the screen around a racetrack, which introduced the element of competition. The Grand Prix exergame setting is a non-immersive virtual reality exergame that includes an avatar that responds to the participant's effort and expenditure during their exercise session.

Physical Task

The rowing task was implemented as the participants' form of exercise in order to incorporate a full body workout that worked arms, core, legs, and back muscles. The participants began their introduction session with a rowing 101 course that instructed them how to use the machine. The participants rowed by pushing back off of the footplates while holding the rowing handles, leaning back, and finally pulling their arms back to complete one row backwards. The participants then allowed the machine to pull them back forward to the start of the motion and continued this motion throughout the exercise task.

Procedures

Before beginning the study, Institutional Review Board (IRB) was confirmed. After the IRB approved the study, participants were then recruited and scheduled. On their first day, participants filled out and signed an informed consent. After completing this, they then completed the Par-Q questionnaire to be deemed eligible to participate in the study. The participants then completed the final demographics questionnaire before beginning rowing. After this, the participants' height and weight were recorded and they were then read an explanation of each scale including feeling, attention, and RPE.

Next, the participants moved over to the rowing machine where they watched and actively followed along to a Rowing 101 demonstration and instructional video about how to use the rowing machine. Each participant completed both the experimental and control condition based on a pre-selected and randomized participant ID number. Based on the assigned ID number, the participants then completed either the control or the experimental condition. The participants completed both sessions within the same week with no less than 24 hours and no more than 72 hours between sessions.

Participants were asked to exercise at a +3 good feeling corresponding to the FS. Before starting the 5-minute warm-up session, RPE, AS, FS, and HR were collected. The participants warmed-up for 5 minutes. At the end of 5 minutes, RPE, AS, and FS were reported, and HR was recorded. Depending on the session for the day, the 20-minute rowing session involved either the metrics screen or the Grand Prix game. At the halfway point, HR was collected from the iPad, and participants were asked to report RPE, AS, and FS while continuing rowing (5-15 minutes). After the 20-minute rowing task, participants reported RPE, AS, and FS, and HR was recorded (15-25 minutes). Following the 20-minute rowing task, participants completed a 5-minute cool down (25-30 minutes). At the end of the task, all data was recorded. Following each exercise session, participants completed the PACES, sRPE, and task commitment check to assess the participant's enjoyment, overall exertion, and commitment to the exercise task.

Data Analysis

After completion of all 26 participants, data was analyzed using SPSS statistical software Version 29. Descriptive statistics were used to analyze the demographic information. The hypotheses were tested with the data collected between the control and the Row Breaker exergame. A within-subject two-way repeated measures (RM) ANOVA assessed HR, RPE, attention, and feelings. A paired sample t-test was implemented to determine significant differences for strokes per minute, distance rowed, watts, PACES, and sRPE. Greenhouse-Geisser (GG) correction was used to interpret the results where the sphericity assumption was violated. When the F ratio showed to be significant, Bonferroni Post Hoc tests were used to identify significant pairwise comparisons. The effect size was measured by partial eta squared ($\square_p^2$). The significance level was set to $p < 0.05$.

CHAPTER IV: RESULTS

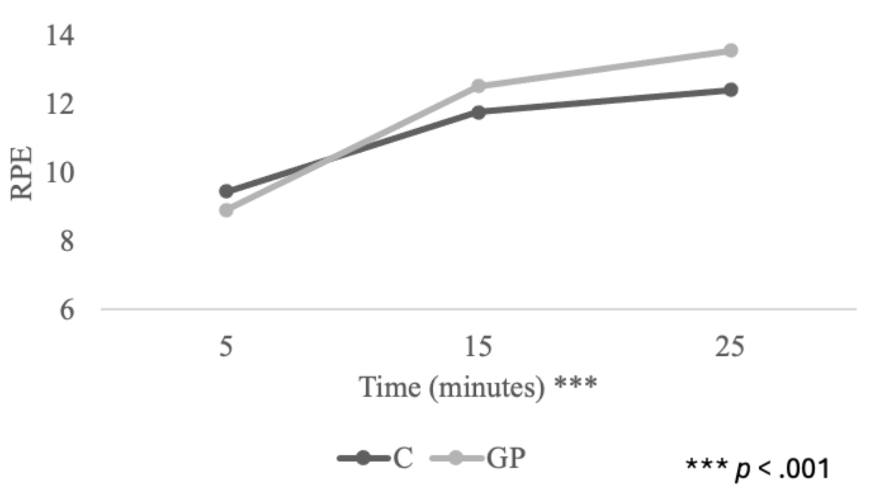
Hypothesis Testing

Rating of Perceived Exertion

A within-subject two-way RM ANOVA examined the differences in RPE between the conditions across time. No significant differences were reported between conditions, $F\,(1, 25) = 2.69$, $p = 0.11$, $\square_p^2 = 0.10$ (see Figure 1). RPE did not vary between conditions. A significant difference was found with time, $F\,(1.58, 39.40) = 100.01$, $p < 0.001$, $\square_p^2 = 0.80$. Pairwise comparisons indicated significantly higher RPE scores across all time points ($p < 0.01$). As time progressed, RPE increased in all conditions. A significant condition x time interaction was found, $F\,(2, 50) = 13.51$, $p < 0.001$, $\square_p^2 = 0.35$.

Figure 1

Mean RPE between conditions across time

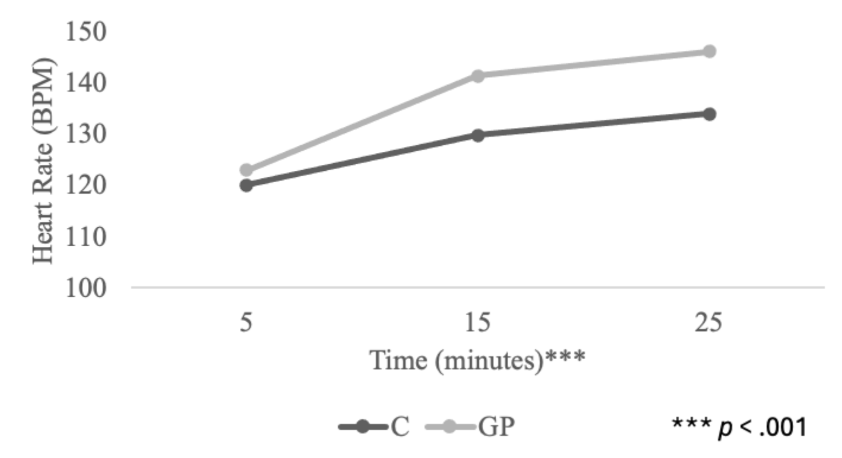


Heart Rate

A within-subject two-way RM ANOVA examined the differences in HR between the conditions across time. Significant differences were reported between conditions, $F\,(1, 25) = 9.56$, $p = 0.005$, $\square_p^2 = 0.28$ (see Figure 2). Heart Rate in the Grand Prix condition was significantly higher than the control condition. A significant difference was found with time, $F\,(1.30, 32.46) = 27.56$, $p < 0.001$, $\square_p^2 = 0.52$. Pairwise comparisons indicated significantly higher heart rate across all time points ($p < 0.05$). As time progressed, heart rate increased in all conditions. A significant condition x time interaction was found, $F\,(2, 50) = 6.44$, $p = 0.003$, $\square_p^2 = 0.21$.

Figure 2

Mean heart rate between conditions across time

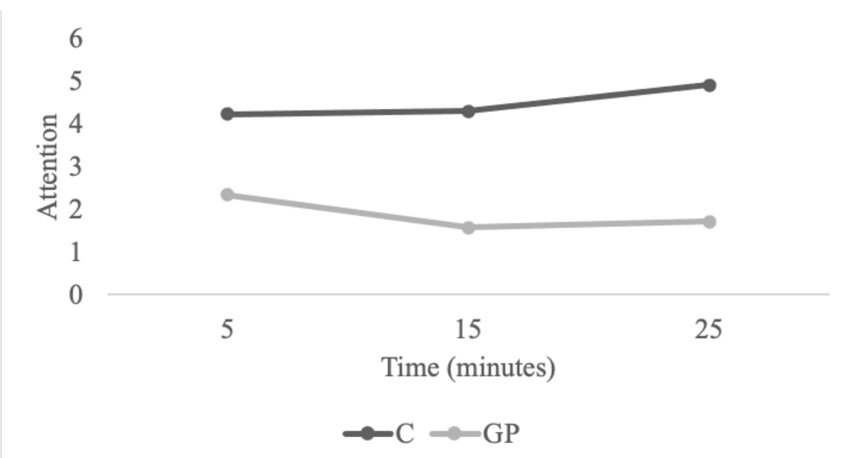


Attention

A within-subject two-way RM ANOVA examined the differences in attention allocation between the conditions across time. No significant differences were reported between conditions, $F\,(1, 25) = 2.61$, $p = .12$, $\square_p^2 = 0.09$ (see Figure 3). There were no significant differences between groups. There were no significant differences found with time, $F\,(1.34, 33.37) = 3.72$, $p = 0.05$, $\square_p^2 = 0.52$. As time progressed, participants became more associative. A nonsignificant condition x time interaction was found, $F\,(1.56, 39.04) = 0.84$, $p = 0.41$, $\square_p^2 = 0.03$.

Figure 3

Mean attention between conditions across time

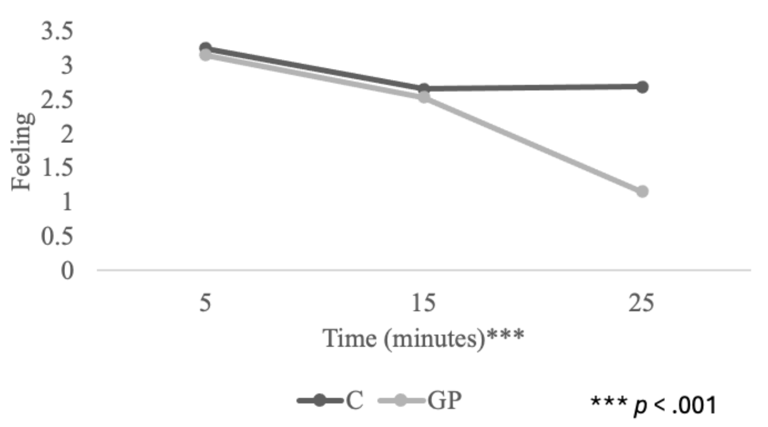


Feeling

A RM ANOVA was computed to test the conditions differences on attention. No significant differences were reported between conditions, F (1, 25) = 2.03, p =.17, $\square_p^2$ = 0.08 (see Figure 4). There were no significant differences between groups. There were no significant differences found with time, F (1.57, 39.13) =8.82, p =0.002, $\square_p^2$ = 0.26. As time progressed, feelings significantly decreased. A nonsignificant condition x time interaction was found, F (2, 50) = 0.69, p =0.51, $\square_p^2$ = 0.03.

Figure 4

Mean feeling between conditions across time

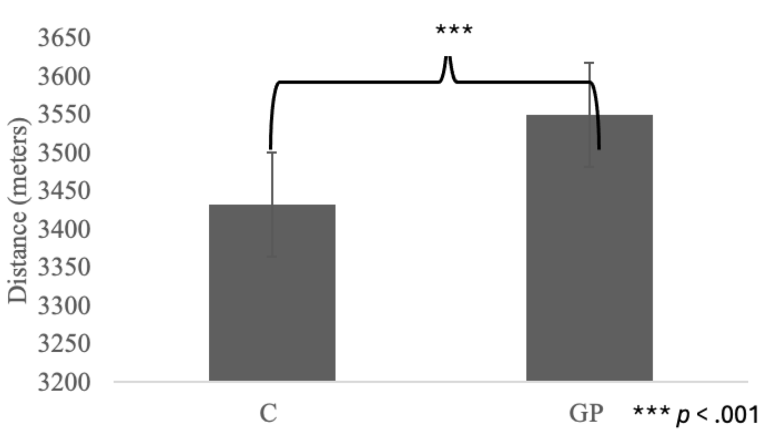


Distance Rowed

A paired t-test was computed to determine the distance rowed between the grand prix in the control condition. A significant condition was found between the conditions, t (25) = -3.41, p = 0.001 (see Figure 5). The Grand Prix condition rowed further than the control condition.

Figure 5

Mean distance rowed between conditions

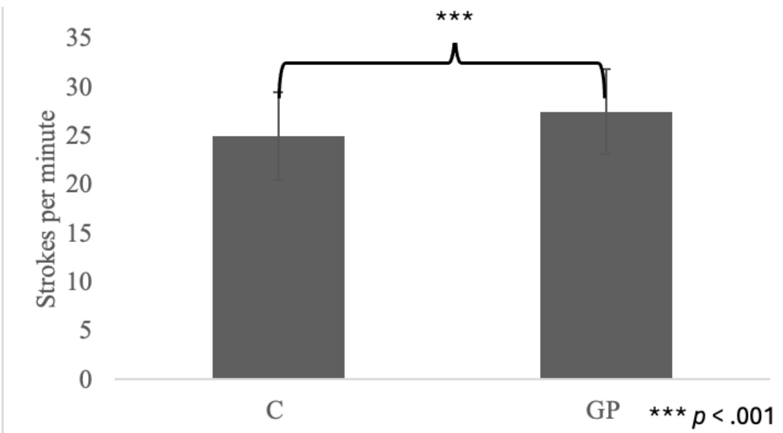


Strokes Per Minute

A paired t-test was computed to determine the strokes per minute rowed between the grand prix in the control condition. A significant condition was found between the conditions, t (25) = -4.52, p <0.001 (see Figure 6). The Grand Prix condition had higher strokes per minute than the control condition.

Figure 6

Mean strokes per minute between conditions

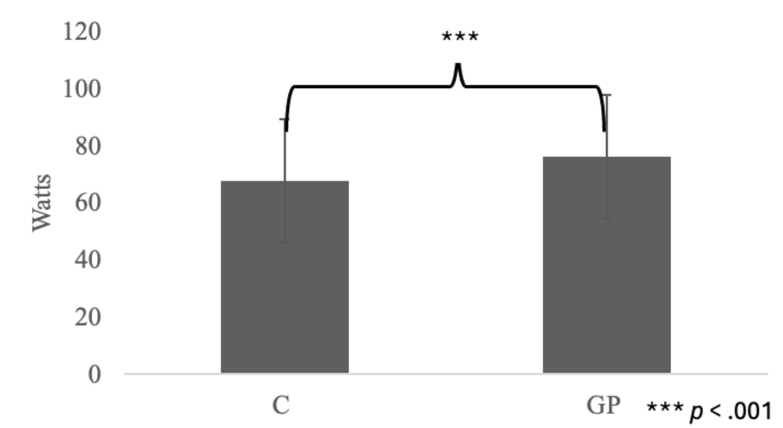


Power Output

A paired t-test was computed to determine the power output while rowing between the grand prix in the control condition. A significant condition was found between the conditions, t (25) = -4.07, p< 0.001 (see Figure 7). The Grand Prix condition had higher power output than the control condition.

Figure 7

Mean watts between conditions

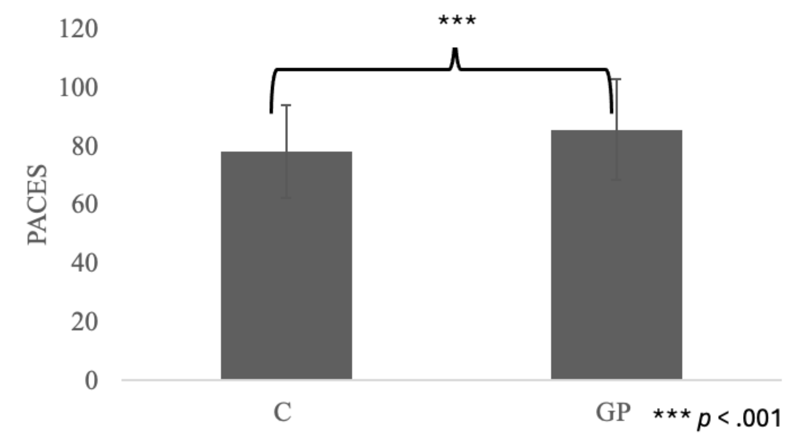


Enjoyment

A paired t-test was computed to determine enjoyment while rowing between the grand prix in the control condition. A significant condition was found between the conditions, *t* (25) = -4.50, *p* =0.001 (see Figure 8). The Grand Prix condition had higher perceived enjoyment than the control condition.

Figure 8

Mean enjoyment between conditions

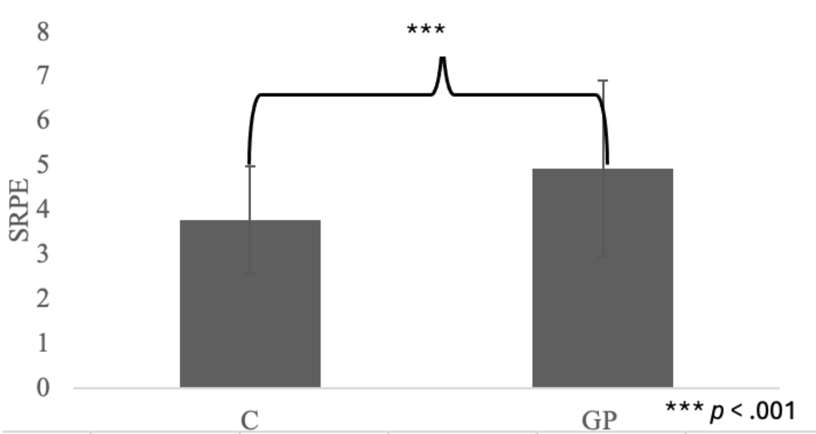


sRPE

A paired t-test was computed to determine sRPE (session rating of perceived exertion) while rowing between the grand prix in the control condition. A significant condition was found between the conditions, *t* (25) = -3.48, *p* = 0.001 (see Figure 9). The Grand Prix condition had higher sRPE than the control condition.

Figure 9

Mean sRPE between conditions



CHAPTER V: DISCUSSION

According to the CDC, only 28% of adult Americans were meeting the physical activity guidelines recommended (Elgaddal et. al., 2022). Further, researchers have found that this problem does not exist simply due to a lack of free time or inability, but rather an additional underlying issue in the lack of enjoyability in exercise experience (Sturm & Cohen, 2019). With this in consideration, the results of this study revealed the potential of competitive exergames in increasing individuals' enjoyment of exercise and performance.

The findings of this experiment revealed heart rate was significantly greater for both groups, showing increased physiological exertion across time for both groups. Researchers explain that individuals have a template RPE within them that allows their exertion to increase but to refrain from reaching an overly intense or dangerous level, which can further be seen in these results (Tucker, 2009). RPE also increased for both groups across time and increased faster for the grand prix condition, which was not expected from the original hypotheses; however, this was revealed through observational research while participants were rowing. Both RPE and heart rate increased with the competition exergame, revealing the drive for individuals when engaged in competition to push themselves and therefore physiologically exert themselves more. According to the CDC, both heart rate and RPE have a significant correlation in response to physical activity and a person's physical heart rate has often been used in order to estimate personal RPE as well (CDC, 2022). Through our observational research we saw that individuals increasingly exerted themselves in the competitive exergame system and were aware of it, as robots continued to pass and challenge them. By feeling challenged and competing with individuals, they pushed themselves more and were more aware of their exertion.

Along with heart rate and RPE, attention became more dissociative in the grand prix condition than in the control condition, although non-significant. This showed that the competitive exergame caused individuals to leave their present reality and dissociate more. Participants' feelings decreased for both groups across time. Again, through our observational research, we could see participants becoming more frustrated while rowing in the competitive exergame, which decreased their reported feeling during the session. Despite being instructed to row at a plus three "good feeling," the participants reported a decreased level of feeling as they competed and felt challenged by the robots attempting to pass them in a rowing race.

Our data further supported the majority of the original hypotheses in that distance rowed, power output, strokes per minute, and enjoyment were all greater in the exergame condition than in the control condition. Overall session enjoyment was greater in the competitive exergame condition than the control condition, which contradicted the lower reported feeling during the rowing task during the sessions. This supports the hypothesis that rowing in a competitive exergame system increases enjoyment of exercise. The final variable, sRPE, was greater in the exergame system which contradicted the original hypothesis; however, it correlates to earlier findings during the session of RPE increasing throughout the session (Lind, 2009). The results of the increased distance rowed, power output, and strokes per minute, as well as the increase in overall enjoyment in the competitive exergame system, immensely supported the claim that competitive exergaming can not only allow an individual to exert themselves more, cover a greater distance with higher power output, and increase strokes per minute but also can increase the overall enjoyment of exercise.

In considering limitations and future research, the population was a key variable to consider in that the primarily female, college-aged, Caucasian population used for the study was not entirely representative. Further, the study was conducted over two sessions on two separate days and therefore could have attained more accuracy if conducted across a more longitudinal design. Also, many participants lacked familiarity with the Aviron rower used and therefore could have altered their usual exercise performance. An additional form of exercise with greater participant familiarity should be considered in evaluating the accuracy of these findings in future research.

Conclusion

These findings suggest that competitive exergaming could be a gateway to a solution for the growing concern with physical inactivity and that by continuing to incorporate this new technology, researchers could make exercise more enjoyable. The results of the competitive exergame system used on the Aviron rower revealed that participants exercising in a competitive exercise system experienced greater power output, a greater distance rowed, greater strokes per minute, higher perception of exertion, and most importantly, greater overall level of enjoyment upon completing the session. These findings can open the gate to future research and many areas of application, including rehab centers, machines in public gyms, and advanced exercise technology. By using a device that could motivate individuals to exercise through the drive to compete and greater enjoyment, technology, like pelotons with a greater variety of games and systems, including competitive exergames, can be manufactured. With these games and systems, gyms, rehab centers, hospitals, and exercise technology companies can continue to create optimal opportunities for exercise and ultimately decrease the deficit in exercise across the United States.

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