THE EFFECTS OF AN INTERACTIVE EXERGAME ON A ROWING MACHINE

by

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ON A ROWING MACHINE

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ABSTRACT

In the United States, physical activity levels are extremely low. With inactivity being linked with negative health outcomes, research has started to investigate different interventions as a way of enticing adults to increase their activity levels. Some of these interventions include music, virtual reality, and interactive exergames. Exergames combine a video game with an exercise machine in hopes of making exercise more enjoyable. The purpose of this study was to examine how exergames affect exercisers' ratings of perceived exertion (RPE), enjoyment, attentional focus, heart rate (HR), and performance outcomes during a rowing exercise task. A total of 26 participants completed a 20-minute rowing task in two conditions (i.e., Row Breaker exergame and Control) on a rowing machine at a preferred exercise intensity. Measurements for RPE, attentional focus, feelings, and HR were collected during the rowing task. Perceived enjoyment and session RPE scales were administered post-exercise. Results found no significant difference between groups for HR and RPE, however, there was a significant difference found across time for both variables ($p < 0.001$) indicating that HR and RPE increased as time progressed. No significant differences were found for attentional focus. Significant differences were found for feelings across time and between groups ($p < 0.05$) revealing that feelings decreased across time but remained higher overall during the exergame. For performance measures, the exergame condition exhibited significantly higher strokes per minute compared to the control condition ($p < 0.01$), due to the exergame's design. No significant difference was found between session RPE scores. A significant difference was found between groups in their perceived enjoyment scores ($p < 0.001$). This study reveals that exergames have the potential to increase exercise enjoyment. This research benefits healthcare providers aiming to recommend exercise to patients, as well as individuals who find it challenging to enjoy exercise.

Chapter I: Introduction

The human body is made to move and withstand daily exercise, but how many people are exercising? In the United States, inactivity levels are at an all-time high. In 2020, only 24.2% of adults over the age of eighteen met the Physical Activity Guidelines for Americans (PAGA) (Centers for Disease and Prevention, 2022). The World Health Organization (2022) recommends 150 to 300 minutes a week of moderate-intensity aerobic physical activity. Over three-fourths of the American population is not reaping the health benefits of exercise and falling short of these recommendations. As individuals live sedentary lifestyles, they put themselves at risk for negative health concerns such as obesity, diabetes, hypertension, and cardiovascular disease (Campbell et al., 2011).

People can achieve adequate levels of exercise through a multitude of activities and in many different environments. Centers for Disease and Prevention (2003) reported that physical exercise has many positive impacts on an individual's physical and psychological health. In the United States, 21% of adults experience the negative impacts of mental health and 34% of adults are obese. These incidences are often correlated to a lack of physical activity within those individual's lifestyles (Park et al., 2020; Mitchell et al., 2011). Additionally, research has further indicated that exercising in an enhanced environment, such as with music or within a simulation, can produce benefits for exercisers (Ballmann, 2021; Mitchell et al, 2011). A technological advancement that has shown probable influence in exercise-related fields is low immersion, interactive exercise games. Exergames, the combination of exercise and video gameplay, have been seen to transform an environment for individuals to allow them to engage in a variety of different activities from a singular location (Benzing & Schmidt, 2018).

With these new exercise technologies, research has suggested that exercise can contribute to improvements in an individual's health and well-being (Neumann & Moffitt, 2018). Although physical activity is effective in improving mental well-being and obesity across populations, individuals continue to struggle with the motivation to exercise regularly. However, the growing phenomenon of exercise games or exergames can become a vital tool in increasing motivation for adults' willingness to exercise (Lotan, 2010). Exergames provide a measurable and controllable environment to stimulate and distract a person's mind from the difficulty of a physical task (Abernathy et al., 2017).

With new advancements, researchers are determined to find different ways to make exercise more enjoyable. By increasing enjoyment, new interventions may increase participation in and adherence to the recommended guidelines for physical activity through the implications of exercise on affective variables. Affective variables refer to the individual differences in responses to attitudes, emotions, motivation, and personalities. Individuals who perceive exercise to be enjoyable are more likely to elicit positive affective responses and adherence compared to those who don't enjoy exercise (Raedeke, 2007). Therefore, affective responses are essential to consider when investigating exercise effects.

Along with analyzing affective responses, researchers further analyze the individual's responses by investigating their ratings of perceived exertion (RPE). Commonly analyzed in exercise-related research is Borg's RPE scale. During exercise, perceived exertion ratings are used as a marker for exercise intensity and the disturbance that the task has on the body's homeostasis (Eston, 2012). This 15-point scale ranges from 6 (no exertion at all) to 20 (maximal exertion) and is found to correlate with heart rates ranging from 60 to 200 beats per minute, respectively (Stewart et al., 2022). The increase in HR is seen to be correlated with RPE in an increasingly linear fashion with time and effort (Braun-Trocchio et al., 2022).

While the relationship between HR and RPE is clear during exercise, little is known about how exercise interventions can be used to delay attentional shifts. When exercising in an interactive environment, attention shifts away from internal stimuli towards the external sensory stimuli of the exergame (Neumann & Moffitt, 2018). Dissociation represents a focus on the distractions coming from environmental stimuli (Stewart et al., 2022). Association reflects an internal focus on the bodily sensations that may appear during exercise, including pain, shortness of breath, or fatigue (Stewart et al., 2022). Dissociating attention will allow the individual to focus on the task at hand rather than the inner workings of their body. RPE during an exergaming task may be affected by dissociative or associative attentional focus. Tenenbaum's effort-related model proposes that as physical workload increases, the attentional focus shifts towards associative thought (Tenenbaum & Connolly, 2008). The unanswered question is whether exergames delay the shift of attentional focus towards associative thought by creating a distraction that will lower RPE.

Affective responses also include the individual's feelings. Hardy and Rejeski (1989) developed the Feeling Scale (FS) to measure affect in terms of pleasure. Rose and Parfitt (2008) showed that FS responses will vary between exercise intensities, shifting toward feelings of displeasure during high intensities and long duration. Furthermore, they asked participants to remain feeling positive during their exercise task, giving them the autonomy to remain feeling "good," potentially increasing enjoyment and adherence to a program.

Keeping affective responses at the forefront of exercise, researchers continue to find how these implicate exerciser's performance. In rowing studies, performance measures analyzed focus on power output, distance rowed, and strokes per minute. Researchers have previously found that virtual reality (VR) rowing, with the presence of others in the room, has caused rowing distance and power output performance to increase (Murry et al., 2016). However, Farrow et al. (2018) found that virtual exergames increased the participants' enjoyment while creating no significant difference in terms of mean power output during high-intensity interval training. Contradictions in literature leave the overall effect of exergames still in question for the average exerciser's performance.

Currently, comparisons between different VR exercise games throughout a workout have little research, leaving no clear conclusion on the exercise benefits. Despite the knowledge that exergames can increase enjoyment, studies have yet to examine how exergames impact an individual’s HR, physical exertion, attention, feelings, performance outcomes, and enjoyment. Exploring the effect of exergames will improve the understanding of technology’s impact on the exercise experience.

The current study investigated the effects of exergames on the individual’s affective responses and performance outcomes during a rowing task with individuals performing at an enjoyable intensity. The first hypothesis was that participants would experience lower perceived exertion with a higher HR during the exergame than compared to the control. The second hypothesis was that participants would experience more dissociative attentional focus during the exergame compared to the control. The third hypothesis was that participants would have higher performance variables (e.g., distance rowed, watts, strokes per minute) during the exergame than compared to control. The fourth and final hypothesis posited that participants in the exergame condition would experience greater enjoyment compared to those in the control group.

Chapter II: Literature Review

A review of published literature related to the use of exergames during exercise to improve physiological and psychological aspects will be introduced. Exergames have demonstrated a positive effect on the responses elicited and performance outcomes that occur during exercise (Bronner et al., 2016; Garn et al., 2015; Glen et al., 2017; Legrand et al., 2011; Mackintosh et al., 2016; Monedero et al., 2015; Russel & Newton, 2008; Stain et al., 2018; Warburton et al., 2007). While most research has focused on exergames utilizing a cycle ergometer and standing range video games, understanding how exergames affect exercise during a rowing task is vital for the progression of research. An analysis of previously published literature developed a complete understanding of how exergame interventions affect exercisers during an exercise bout. The topics addressed are: (1) theories that address how exercise interventions are perceived and interpreted and (2) physiological and psychological effects elicited by exergames during exercise.

Physical Activity

In the United States, physical inactivity levels are at an all-time high. In 2020, the Center for Disease and Prevention reported only 24.7% of adults over the age of 18 are meeting the Physical Activity Guidelines for Americans (PAGA). The PAGA recommends at least 150 minutes of moderate-intensity physical activity per week, 75 minutes of vigorous-intensity physical activity per week, or a combination of the two (Tucker et al., 2011). The new guidelines allow individuals to structure their physical activity around their lifestyles. The development of the PAGA was based on evidence that there are health benefits associated with physical activity (Tucker et al., 2011).

Physical activity has been found to have beneficial effects on noncommunicable diseases (Reiner et al., 2013). Noncommunicable diseases are diseases with a slow progression and long duration, including obesity, cardiovascular heart diseases, and type 2 diabetes, three of which are the most severe in the world (Reiner et al., 2013). Furthermore, the World Health Organization recognizes physical inactivity as the fourth highest risk factor for global mortality (World Health Organization, 2022). Physical inactivity and unhealthy eating habits are two of the major causes of weight gain, being overweight, and obesity. Obesity is a major underlying cause of cardiovascular heart disease and type 2 diabetes (Reiner et al., 2013). Exercise is one of the only manipulatable variables in the precursor to diseases that needs to be of importance to every individual.

Barriers to Physical Activity

To understand the reason behind physical inactivity, it is important to analyze the barriers that people face when it comes to exercise. Identifying these barriers helps design effective public health interventions aimed at reducing inactivity (Bauman et al., 2012). From an ecological perspective, a comprehensive framework has been created to integrate determinants explaining physical inactivity. Ecological models are effective due to their interrelation between individuals, their social and physical environments, and policy factors. Individual determinants include psychological factors, such as cognition, beliefs, and motivation, and biological factors, such as genetics and evolutionary physiology. Environmental determinants include the social interactions on a personal, local, and global level and the built and natural environments in their community. Policy factors are related to transportation systems, health sectors, economic development, and urbanization, to name a few (Bauman et al., 2012). In simpler terms, individual factors are internal barriers, and environmental and policy factors are external barriers

(Herazo-Beltrán et al., 2017). These barriers, however, do not act in isolation. It is the interaction of perceived barriers that work to hinder or enable healthy behaviors (Herazo-Beltrán et al., 2017).

Since physical activity is done for many reasons and is influenced by interrelated determinants, it is important to understand the specific barriers that decrease physical activity. Arango et al. (2011) determined the relevant barriers to physical activity were lack of time and motivation. Another study also identified lack of motivation and time as barriers, as well as lack of resources, social support, information, and fear of injury (Herazo-Beltrán et al., 2017). These barriers are influenced by the individual's perceptions. Active individuals perceive fewer barriers to physical activity, including time, while inactive people perceive more barriers due to differing usage of time (Herazo-Beltrán et al., 2017) (Brinthaupt et al., 2010).

While these barriers continue to persist throughout the world, it is important to note the unknown and everlasting effects of the COVID-19 pandemic on physical activity levels. The pandemic restricted physical activity in people of all ages with indoor and outdoor sports and facilities being shut down (Shahidi et al., 2020). Online communication for work, leisure, shopping, and school had become the daily routine for people worldwide. Some individuals maintained continuous exercise habits, however, others declined in their mobility and physical conditioning due to increased social isolation and sedentary behaviors (Hoffman et al., 2021). Current research is still needed to expand on the effects of the COVID-19 pandemic on physical health and activity.

Physical Activity Interventions

While it has been identified that individuals need to exercise more, little has been effective in increasing the rate of exercise in Americans. Several interventions have been placed as hypothetical incentives to increase physical activity rates. Tuso (2015) examined a five-step strategy to increase the physical activity of Americans.

First, individuals need to measure physical activity as a vital sign. This could mean implementing a process during physician visits that includes indicating how many minutes per week that individual is exercising (Tuso, 2015). Just like taking blood pressure, patients would be held accountable for identifying how many minutes they choose to be active and report it to a health professional who can inform them of the positive implications associated with physical activity.

Second, people need to be encouraged to be physically active based on the Physical Activity Guidelines. Since it has been identified how influential physical activity is on our health, this can be a motivator for individuals (Tuso, 2015). Choosing a behavioral intervention can be encouraging and motivational to an individual who has chosen a lifestyle of sedentary activities without being aware of the consequences of their actions.

The third strategy to increase physical activity is to create healthy environments that make it easier to be physically active in our everyday lives (Tuso, 2015). A barrier to exercise can be the lack of a safe environment to exercise in or the means of getting there. By promoting simple interventions, such as walking instead of driving, the hope is to increase the activity during everyday activities.

A fourth intervention would be continuous monitoring of disease incidences in active individuals compared to those physically inactive (Tuso, 2015). Since the physical activity guidelines have not effectively created an incentive to get people to exercise, it is important to educate individuals about the risks associated with sedentary activities. Furthermore, it is important to link physical inactivity with the associated diseases. By doing so, the hope is to increase physical activity rates and potentially decrease future healthcare costs.

Finally, physicians and patients need to continue spreading positive practices (Tuso, 2015). By identifying and advertising the most effective activities, individuals have a clearly developed guide on how to find their preferred exercise method. It is important, as a community, to spread the health benefits associated with exercise and create a positive environment where people feel motivated and included to increase their activity levels and overcome barriers.

While these interventions are important to increase the motivational aspect of physical activity, specific interventions in the exercise setting have also been identified. These interventions include listening to music, using virtual reality, and exergames.

Music listening interventions have been shown to improve exercise performance and promote secondary health benefits related to physical activity (Clark et al., 2024). A systematic review concluded that listening to music while walking has the potential to improve exercise capacity, specifically in adults who have cardiac and pulmonary disease. While it is still uncertain if music alone can support an increase in physical activity, it is important to understand the potential influence music can have during exercise bouts on increasing individuals' capacity to exercise as well as the potential to shift their focus away from the task at hand.

With the rise of technology, researchers have shifted to analyzing its effects on physical activity. VR creates an immersive video game environment that has shifted in prevalence into the exercise genre. Farrow et al. (2017) conducted a study investigating VR’s effect on performance in high-intensity interval training (HIIT). This study concluded that an acute bout of HIIT was more enjoyable for participants when immersed in a VR platform. Furthermore, the VR environment allowed participants to increase their exercise intensity without compromising their enjoyment during the exercise session.

Technology has also been able to transform the average exercise machine or gaming console into a full-body interactive game through exergames. Exergames combine physical activity with VR to distract from pain or create enjoyment (Martín-Martínez et al., 2019). Exergames have also demonstrated improvements in cognitive-motor abilities and enhanced balance in older adults (Chen et al., 2021). It is important to analyze different types of exergames with as many people as possible to truly understand the implications it has for exercise.

While these interventions are effective for individuals, it is inconclusive as to which of these interventions is the most beneficial in increasing a population's physical activity. Interventions need to be further analyzed to add to the literature on effective methods to increase enjoyment, motivation, and intensity during exercise.

Affective Responses to Exercise

Since the late 1960s, the controversy on how exercise makes people feel has persisted. It was originally believed that exercise may increase the risk of anxiety attacks among individuals with a history of anxiety (Pitts, 1971). However, this theory was quickly debunked and overtaken by a theory that has continued unquestioned. Morgan et al. (1970) believed that individuals 'felt better' following exercise, even if psychological changes were not observed. While it is still believed that exercise makes one 'feel good', evidence has been found associating exercise with negative experiences in adults who are sedentary, overweight, or suffering from disease (Ekkekakis & Brand, 2019). Rather than focusing on discrete emotional states, such as anxiety and depression, Ekkekakis and Brand (2019) proposed a solution to encompass all varieties of affect. Given its dynamic nature, affect should be repeatedly measured before, during, and after the exercise bout, as well as examining the affective changes during different exercise intensities.

Researchers have been able to elicit a dose-response pattern through the Dual-Mode Theory that has linked exercise intensity to affective responses during moderate, heavy, and severe metabolic domains (Ekkekakis et al., 2011). The dual-mode theory links affective responses to metabolic domains, acknowledges the negative effects of exercise, and includes interindividual variability (Ekkekakis & Brand, 2019). The moderate domain includes intensities below and up to ventilatory threshold with the ability for the individual to remain in a steady state for an extended period. Here, individuals associate exercise with increases in pleasure and perceived energy. The heavy domain includes intensities ranging from ventilatory threshold to respiratory compensation threshold in which a generalized stress response is triggered. Findings revealed that affective responses began to increase in ambivalence showing that some experienced pleasurable results whereas others reported displeasure. The severe intensity includes exercise intensities beyond respiratory compensation threshold until peak oxygen consumption. Individuals during severe intensity exercise will begin to experience a drastic decline in affective pleasure responses due to physiological disturbances. Thus, the Dual-Mode theory conceptualized exercise intensity with affective responses into three domains: moderate intensity with an increase in pleasure, ambiguity in pleasure during heavy intensity, and decline in pleasure with heavy exercise intensity.

Furthermore, research has shown a decrease in oxygenated blood to the dorsolateral prefrontal cortex, a brain region associated with negative affective responses. During exercise, as the intensity approaches maximal exertion, the body shifts oxygenated blood away from this region (Rooks et al., 2010). Cognitive methods used to regulate affective responses, such as music, videos, cognitive reappraisal, motivational imagery, and efficacy-focused self-talk, may diminish in effectiveness as the exercise intensity enters the severe range (Ekkekakis & Brand 2019). This research shows the plausibility that affective responses can account for variance in physical activity behavior.

While still being studied, it has been shown that affective responses are significantly associated with physical activity (Ekkekakis & Dafermos, 2012). Researchers have started to analyze interventions that facilitate positive affective experiences during exercise prescription. Being told to exercise at an intensity that "feels good" or being able to self-regulate their intensity resulted in enhanced affective responses as well as participation in physical activity (Baldwin et al., 2016; Ekkekakis & Brand, 2019; Williams et al., 2016). While researchers are now able to manipulate the motivational force in exercise, a new challenge appears from the associative memories made from exercise and whether affective experiences are included in that process (Ekkekakis & Brand, 2019). While most individuals are aware of the health benefits of exercise and would consider themselves capable of exercising, they may be hindered by previous negative experiences and the pleasantry of sedentary activities (Ekkekakis & Brand, 2019). This leaves a gap in knowledge for researchers to dive into. The hope is to find effective strategies to facilitate more motivational aspects of exercise that will limit the effect of restricting factors. These motivational factors may become strong enough to elicit an increase in physical activity levels due to diminished negative evaluations of exercise.

This discovery led to further analysis of dual-process models that explain the existence of two closely integrated processes. The first process is associated with automatic processes that rely on past affective experiences to generate an emotional response (Ekkekakis & Brand, 2019). The more negative experiences one has with a situation, the more likely they are going to associate that behavior with negative emotions, even if they are just thinking about the activity and not performing it. The second process comes from a multivariable conscious awareness of behavioral action plans. This means individuals have the ability to appraise and estimate the future outcomes associated with different decisions. Intrinsic associations of pleasant or unpleasant experiences will lead individuals to either approach or avoid those situations, respectively. The goal of exercise interventions is to create positive affective experiences associated with exercise so that when self-control depletes during stress, the individual views exercise to be pleasurable and continues being physically active.

Theories

Dual-Mode Theory

To understand the specifics associated with affective responses, the Dual-Mode Theory (Ekkekakis, 2009) for exercise explains how these responses are elicited during an exercise bout. This theory states that cognitive processes will affect physiological and psychological changes during exercise. The Dual-Mode Theory was developed to satisfy five relevant gaps in exercise-affective-related ideas.

The first gap the Dual-Mode Theory was developed to bridge was between “mind-focused” and “body-focused” approaches to explain the exercise-affective relationship. Researchers previously saw no sign of convergence between the two camps of ideas and determined if a new theory were developed it must include both knowledge bases in its perspective. Ekkekakis hypothesized that affective responses to exercise were the product of cognitive processes related to goal setting, self-efficacy, and physiological interoceptive cues within the central nervous system and peripheral pathways.

The second gap this theoretical framework would acknowledge was found in cognitive appraisals (Ekkakakis, 2009). Affective responses during exercise fell on a continuum. At one end of the continuum lies the complex responses that are appraisal-based and culturally framed. The other end of the spectrum is related to basic responses associated with naturally unpleasant or pleasant forms of exercise. An unpleasant exercise would be related to exercising outside on a hot day while performing a high-intensity exercise. Pleasant exercise would be related to walking for some minutes at your own pace on a moderate temperature day. Exercisers would use their prior schemas to analyze their abilities in the context of the affective responses that would produce feelings related to negative or positive appraisals of the situation (Ekkekakis, 2009).

The third gap was related to the dose-response patterns elicited by exercise related to affective responses. The Dual-Mode Theory worked to recognize that the amount and intensity of exercise are directly related to how the individual emotionally responds (Ekkekakis, 2009). The closest thing prior to the Dual-Mode Theory was related to the exercise-affect inverted-U that demonstrated intensities “too-low” or “too-high” would create ineffective affective responses. Intensities in the “mid-range” elicited the best affective results. However, this didn’t account for the interindividual variability of affective responses to exercise.

Fourthly, as previously mentioned, the Dual-Mode Theory explains the interindividual variability of identical stimuli. The Dual-Mode Theory worked to answer the question of what exercisers will experience based on their psychological patterns and affective responses to exercise intensity (Ekkekakis, 2009). As exercise increases in intensity, affective responses become dependent on their psychological coping resources during the bout.

The fifth gap in the literature that the Dual-Mode Theory worked to fill was the incorporation of a scheme for physiological responses to exercise that is related to the individual's dose-response pattern (Ekkekakis, 2009). This led to the development of an exercise classification system including three domains: moderate, heavy, and severe. These domains were related to the individual's lactate threshold and maximal oxygen uptake. The heavy and severe domains involved considerable amounts of lactate production and the ability to continue becoming nearly impossible. The moderate domain was related to exercise where lactate buildup did not occur, and steady-state metabolism was maintained.

In sum, the Dual-Mode Theory establishes that affective responses to exercise are influenced by cognitive factors and interoceptive cues. The balance between these two factors is related to shifts in exercise intensity. Cognitive factors remain dominant at low exercise intensities and shift interoceptively as the intensity increases beyond the individual's ability to maintain a physiological steady state (Ekkekakis, 2009).

Dual Process Theory

While the Dual-Mode Theory is used to explain the affective responses to exercise, the Dual Process Theory is used to explain how people process information and make decisions. The Dual Process Theory explains that moral judgments are the result of two competing processes (Kvaran et al., 2013). The first process, System 1, is known as the fast, affect-driven process. The second process, System 2, refers to more of the slow, reason-based processing. When a moral dilemma arises, both systems are provoked, and responses are received from the competing systems.

According to System 1, these processes are related to the automatic, non-reflective affective association that one establishes from past experiences (Kvaran et al., 2013). Once a situation and process in the mind has been learned, the individual will repetitively sustain those beliefs without much thought. In an exercise setting, an individual may have learned that feelings of exhaustion or embarrassment after exercise attempts are normal. Therefore, every time the individual exercises or thinks about exercising, they will automatically associate that activity with those emotions.

System 2 is related to the more rational and deliberative reflective process (Kvaran et al., 2013). This slower reflective system requires the individual to be aware of the entire situation. While the individual may not like exercising, they know that there are health benefits to physical activity. This system would reveal the individual's contemplation about the health benefits of exercise, regardless of their likes or dislikes toward the activity.

Previous research has found more findings that relate human reactions to a situation based on System 1. It has been revealed that when System 1 has an aversive response, it will overwhelm the individual's ability to create a utilitarian reason through System 2 (Kvaran et al., 2013). However, research has also found that damage to the ventromedial prefrontal cortex (VMPFC) was associated with decreased emotional processing (Greene, 2007). When individuals had damage to this region, they relied on the utilitarian judgments from System 2, due to the decrease in conflict between the two processes (Greene, 2007). It has also been revealed that when individuals are primed to think in an analytical manner, they make more utilitarian judgments toward the situation than those who are not primed. This reveals that when individuals are asked to think rationally, they can decrease the rapid emotional response created by System 1 and rationalize the situation for their benefit (Kvaran et al., 2013).

Cognitive Appraisal Theory

To understand how one can turn an emotional response into a rational choice, it is important to acknowledge the individual's interpretation of the situation. The Cognitive Appraisal Theory is grounded in the idea that an individual's interpretation of a situation is the main factor in perceiving if their surroundings are stressful or not (Litwic-Kaminska, 2020). Lazarus (1991) established a defining method for this process. The process begins with a stimulus from the environment. According to Lazarus, the appraisal process begins when this stimulus triggers the individual to place their intrapersonal filter on the situation. The intrapersonal filter consists of their needs, goals, attitudes, and beliefs that are at the foundation of their identity. Following the intrapersonal filter comes the emotional response to the situation. After emotion and intrapersonal factors are added to the situation, the appraisal outcome is determined. This reveals how the individual perceived and reacted to the situation both emotionally and physically. If perceived positively, the individual will have a positive emotional reaction and will be more likely to return to that environment. Conversely, if perceived negatively, this individual will elicit a negative response and avoid the situation.

Perceived Exertion

Delving deeper into perception, perceived exertion is a personal reflection of how hard you feel like your body is working (CDC, 2022). Through this perception, the individual is evaluating physical sensations that are experienced during physical activity. Gunnar Borg developed the Borg RPE scale to rate exertion, breathlessness, and fatigue based on how hard the activity is by looking at the individual’s heart rate and respiratory rate (CDC, 2022). The original scale ranged from 6 to 20 with a high correlation to one’s HR by multiplying each subjective number given by 10. This scale has been validated and found reliable in its criterion validity and rating of exertion (Chen et al., 2002; Lamb et al., 1999; Skinner et al., 1973).

Furthermore, Borg’s RPE scale is related to psychophysics. Psychophysics studies the relationship between perceptual and physical intensities (Borg, 1990). When using a scale for subjective aspects such as psychophysical responses, it reveals the important relationship between sensory organs and the conscious perception of disturbances in the environment. RPE is important in terms of psychophysiological measures because it integrates information from the mind with cues from systems in the body, such as the musculoskeletal system, cardiovascular and respiratory systems, and the central nervous system. This scale was designed to grow linearly with exercise intensity and HR or work and is popular for the evaluation and monitoring of exercise intensities from the individual's total perception of physical exertion during the activity.

Effort Perception and Attentional Focus

While the RPE scale provides an identifying number for the individual's total perceived exertion, Tenenbaum's effort-related model describes how psychological processes guide the perception of effort and exertion during physical activity. From a social-cognitive theoretical perspective, Tenenbaum hypothesized three factors that are external to the perceived effort through one common mediator (Tenenbaum & Hutchinson, 2007).

The first category of the effort-related model is of physical load and duration of the work (Tenenbaum & Hutchinson, 2007). This includes what the exercise task consists of as well as how long the individual is participating in that task. The second category is the environmental conditions. This can be related to the time of the task, the temperature of the physical activity setting, and anything specific to the exercise task's context. The third category is the task's characteristics. These are the unique specifications of the task. While these three categories are what make up the external factors, the mediator in this model is related to the set of internal factors unique to the individual. These factors include motivation, familiarity with the task, commitment, determination, competence, self-efficacy, and readiness to invest effort.

While this model summarizes the psychological factors that mediate one's effort perception, there is an important limit on how these factors are related to exercise intensity. Under submaximal conditions, psychological factors are the most influential (Tenenbaum & Hutchinson, 2007). This allows the individual to cognitively mediate the exercise task through their psychological evaluations. However, the limit occurs when the exercise intensities go beyond their submaximal levels. At high intensities, the physical stress of the task itself overwhelms the sensory cues and decreases the individual's ability to mediate the task through psychological factors. This model elicits the oversimplification of a single-item measure, such as measuring RPE in isolation.

Furthermore, the psychological component of attentional focus is important when analyzing exercise. Attention is represented by a continuum with association and dissociation at opposing ends (Braun-Trocchio et al., 2022). To associate means the individual is attending to their breathing or how their muscles feel during the exercise task (Tenenbaum, 2001). Dissociation is when the individual is cued into the scenery of the environment, the music they are listening to, or perhaps the game they are playing. When an individual is focused on associative strategies, they are allowing themselves to adjust the effort put into the task based on the physiological changes they are experiencing. However, when utilizing dissociative strategies, the individual isn't focused on their perception of exertion or fatigue since they are attributing their attention to an external cue.

During physical activity, individuals shift their attention based on the physical workload they are enduring (Tenenbaum, 2001). Specifically, as intensity and workload increase, individuals are seen to shift their attentional focus from dissociative to associative. When this occurs, one may perceive an increase in their level of exertion due to the shift towards bodily associative factors (Tenenbaum, 2005). With the use of exercise interventions, individuals may experience more dissociative attention as they focus on the intervention rather than the physical task and exertion needed to complete the exercise bout. The hope is that by doing so, individuals perceive exercise to be more enjoyable. Since their attention isn't on the physical load of the exercise, but rather the intervention that distracts them, they begin to view exercise as a pleasant experience and will want to continue being physically active.

Effect of Exergames During Exercise

It is important to understand how exergames psychologically and physiologically affect exercise to understand how exergames influence exercise performance. Studies have shown that exergames have psychological effects consisting of affective responses, attentional focus, enjoyment, motivation, and dissociation. Physiological effects of exergames during exercise include HR, physical exertion, power output, energy expenditure, and VO_2.

Physiological and Psychological Effects of Exergames During Exercise

Over the years, studies have begun to analyze the effects that exergames have on the psychological and physiological aspects of exercise. Bronner et al., (2016) assessed physical exertion, upper and lower extremity movement, game proficiency, motor learning, and player engagement through an interactive dance game, Dance Central. Fourteen healthy participants, seven women and seven men, were recruited from a local university, with minimal to no experience playing Dance Central. Using a skill-based protocol, participants trained until they attained a skill level for post-testing. The participants' data was collected on their initial testing and post-training scores. Three different dances were measured during their initial training on the easy level. During post-training testing, the dances consisted of the same game songs on the same levels, with the addition of new game songs at moderate difficulty. The results indicated that, with training, player's physical exertion and game proficiency increased. However, contrary to their hypothesis, limb movements and engagement post-training did not change. This study showed that with exergames, along with training, physical exertion and proficiency in the task can be increased.

While the previous study revealed an exergame's effect on physical exertion and task proficiency, Mackintosh et al., (2016) investigated the effect of acute exergaming on the physiological and psychosocial responses of young adults in a single- and dual-player game. Thirty-six participants were each asked to complete two 30-minute exergame sessions. Energy expenditure, positive and negative affect, subjective vitality, and intrinsic motivation were assessed directly following each gaming bout. Results revealed that there were no significant differences in energy expenditure or psychosocial outcomes between the two conditions. In this study, males expended more energy than females overall, however, females reported greater vitality and effort. In addition, males reported greater negative affect and pressure. A large conclusion from this study was the revelation of a linear mixed effect that showed how energy expenditure was a significant predictor of interest, enjoyment, effort, and importance with no gender or game difference.

While the previous study revealed exergames having an association with energy expenditure, Garn et al., (2015) examined the possible physical and motivational benefits of Nintendo Wii Fit exergames in college-aged students. In this study, a repeated measures design was used on 30 college-age students to investigate the effects of exergames on physical activity, enjoyment, and future intentions of physical activity. To compare with the Wii Fit Basic Run exergame condition, the participants also participated in a generic physical activity. Results revealed that the Wii Fit Basic Run produced moderate to vigorous activity levels consistently.

Furthermore, this study demonstrated that future intentions were higher for the exergaming setting compared with generic exercise. Obese individuals reported that they enjoyed exergaming more than generic physical activity, revealing motivation benefits towards physical activity.

Adding to the literature with a focus on exergames effects of obese individuals, Staiano et al., (2018) investigated the effects of a home-based exergame intervention among children with overweight and obesity. A total of 46 children were randomized into an exergaming or control condition for 24 weeks. The exergame condition utilized GameSquad on a Kinect and Xbox 360 console that encouraged the participants to meet a goal of 60 minutes per day of moderate to vigorous physical activity. The researchers were investigating the primary outcome of body mass index (BMI) z-scores and secondary outcomes of fat mass on a DEXA scan and cardiometabolic health metrics. Following the intervention, the children's acceptability and enjoyment ratings were high. The exergaming condition elicited high adherence and improvement in the children with overweight and obese BMI z-scores and cardiometabolic health. Furthermore, the children's self-efficacy towards physical activity improved significantly with the usage of the exergame.

To focus literature more on adult populations, Glen et al., (2017) investigated the effects of exergaming modes on the individuals' HR, work rate, perceived exertion, and affective valence. Twenty participants completed one 45-minute workout session on a cycle ergometer with fifteen minutes in each of the three randomized settings: control, track, and game. The control mode consisted of a blank screen, while the track mode had the participants following a woodland trail, and the game mode involved collecting points from chasing dragons. The results revealed a higher work rate in the track and game modes compared to the control, and more positive affect, dissociation, and enjoyment in the game mode compared to the track mode and control. Participants also exercised at a higher intensity during the exergaming modes compared to the control, revealed in the increase in HR and RPE.

Another study analyzed the effectiveness of interactive video games during stationary cycling on health-related physical fitness and exercise adherence (Warburton et al., 2007). The study included fourteen college-age males who were randomly assigned to a 6-week program utilizing the interactive video game or the control conditions. In the interactive video game condition, participants were allowed to select a video game from the GameBike system connected to a Sony PlayStation 2. Both conditions were instructed to cycle for the duration and intensity that they desired. Individuals in the interactive video game setting were seen to have higher attendance at their training sessions and a significant increase in their submaximal VO2. This study revealed that interactive video games do have significant improvement in health status markers and should be further investigated as this was one of the first of its kind.

Expanding on the previous study, Monedero et al. (2015) conducted a study comparing the physiological responses of exercise with enjoyment levels during an interactive cycling video game and a conventional stationary cycling bout. A total of 34 participants were analyzed over four visits. The first visit measured the individual's maximal test on a cycle ergometer. The second day included a 30-minute familiarization session with the GameBike and the video game. The final two visits were where the individual participated in the control and interactive game conditions, determined randomly. The main findings of the study revealed higher rates of energy expenditure, an increase in enjoyment, with a decrease in negative affective states in the interactive cycling game compared to the conventional cycling. Furthermore, it was discovered that individuals during the video game setting were exercising at higher percentages of their VO_2 with similar perceived effort to conditions without the exergame. This study determined that the cycling video game is a valid alternative for individuals to achieve physical activity recommendations and furthered the data supporting the research conducted by Warburton et al. (2007).

On a larger scale, researchers examined the influence of a regular exercise environment, an imposed interactive VR environment, and a self-chose interactive environment on affective responses during and following exercise (Legrand et al., 2011). Legrand et al. (2011) recruited one hundred thirty-one volunteers to be randomly assigned to one of the three continuous exercise conditions, where the participants continuously ran or cycled for 10 minutes. Pleasure was assessed at 3-minute intervals, as well as before and after. Results revealed a significant improvement in mood state post-exercise in all experimental conditions with the interactive VR environment creating a positive but similar affective benefit. However, researchers found higher ratings of in-task pleasure during the interactive condition compared to the control. While affective mood states remained consistent, the interactive exergame elicited higher enjoyment of the task, proving that interventions can elicit positive emotional responses to exercise.

Similarly, Russell and Newton (2008) examined the short-term psychological effects of interactive video game technology. A sample of 168 university students completed one of three 30-minute conditions. The conditions included a regular bicycle ergometer, a video game interactive bicycle ergometer, and a 30-minute video game-only control condition, without exercise. The results revealed marginal support for interactive video game-based exercise providing more beneficial mood changes and no support for the interactive condition creating an enhanced concentration. This study found that exercise in general increased mood benefits, however, interactive video game exercise may increase interest in exercise. Having individuals desire to be physically active through these interventions can lead to boosts in physical health and mood. This study attributed differences in the mood benefits from video game-based exercise to gender, hypothesizing that since more females fell into those conditions, gender may be a limiting factor and should be further investigated.

Conclusion

To date, few studies have specifically investigated exergaming on a rowing machine. Research on exergames has included a cycle ergometer, running, or other video game modalities, but studies have yet to be inclusive of rowing. Furthermore, research needs to continue to investigate exergames effects due to differences in outcomes, different populations analyzed, and limitations that should be further examined. However, it has been found that exergames have the potential to make exercisers perceive less physical exertion with an increase in HR, while also enjoying the task more compared to a control condition (Garn et al., 2015; Glen et al., 2017; Legrand et al., 2011; Monedero et al., 2015, Russell & Newton, 2008; Staiano et al., 2018). In order to address the lack of research on a rowing machine, the present study looked to further confirm exergame’s effects including another exercise machine.

Chapter III: Method

Participants

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.

Instrumentation

Informed Consent

An informed consent document was administered by the researcher to define the study's parameters for the participant. This document informed participants of their protected identity and ability to terminate the study at their discretion. Their signature determined their agreement to participate.

Physical Activity Readiness Questionnaire (PAR-Q)

The PAR-Q screens for the individuals' personal health history in reference to cardiovascular conditions and other diseases that could pose as risk factors during moderate physical activity (Warburton et al., 2011). The participants were able to complete the study if they answered “No” to all questions.

Demographic Questionnaire

This questionnaire contains demographic information, including the participant's age, gender, and frequency and intensity of regular physical activity. The demographics questionnaire is used to provide a general understanding of the participant's personal history.

Task-Specific Motivation Scale

This questionnaire assesses task-specific self-efficacy, perceived ability, and motivation (Hutchinson & Tenenbaum, 2007). Participants were asked to rate their self-efficacy, perceived ability, and motivation on a Likert-type scale ranging from 0 to 10, very low to very high respectively.

Task Commitment Check

This scale asks participants to report their commitment and effort investment on a 5-point scale from 1 (Completely Uncommitted) to 5 (Very Highly Committed). This questionnaire is given at the end of the task to assess commitment to performance, tolerance to physical discomfort, and effort put into the task.

Physical Activity Enjoyment Scale (PACES)

This scale is a reliable assessment administered post-exercise to measure the participant's exercise enjoyment (Murrock et al., 2016). PACES reliability was supported by an internal consistency alpha score of 0.95. PACES uses an 18-question 7-point Likert scale, ranging from 1 (I enjoyed it) to 7 (I hated it), to assess the participant's enjoyment after exercise and specifically the completion of the session.

Rating of Perceived Exertion (RPE)

The RPE scale is a 15-point category-ratio scale that ranges from 6 (no exertion) to 20 (maximal exertion), measuring the individual's perceived exertion during the exercise task

(Borg, 1982). The Borg Rating Scale for Perceived Exertion has a test-retest reliability score of $r > 0.83$.

Attention Scale

To measure attention allocation during the task, a 10-point scale ranging from 0 (external thoughts, daydreaming, environment) to 10 (internal thoughts, how the body feels, breathing) was used (Tammen, 1996). Participants were asked to rate their attentional focus before, during, and after the physical activity.

Feelings Scale (FS)

The FS was used to assess the participant's emotional perception during the motor task. It is an 11-point scale ranging from –5 (very bad) to +5 (very good). This scale has been validated for measuring affective responses during exercise (Hardy & Rejeski, 1989). Participants were asked to assess their feelings towards physical activity and adjust their rowing to maintain a +3 good feeling.

Session Ratings of Perceived Exertion (sRPE)

The session ratings of perceived exertion (sRPE) scale was used to assess the participant's overall feelings of exertion throughout the entirety of the exercise bout. This scale has a range from 0 (no exertion) to 10 (maximal exertion).

Apparatus

Heart Rate (HR)

HR was monitored throughout the physical task using the Polar H10 HR sensory with a Pro Strap. Beats per minute were collected via the Polar HR app on an iPad.

Exercise Rower

An Avrion Tough Series rower was utilized for all exercise tasks. The Aviron Tough Series rower is a full-body exercise machine with a magnetic resistance system and a 22-inch high-definition touchscreen with dual air. The resistance level was controlled at 1, on a scale ranging from 1 (no resistance) to 16 (max resistance). The “Row Breaker” game was utilized in the ‘Easy’ setting. This game was inspired by the old-school Brick Breaker game and is designed to sync with the individual’s rowing rhythm.

Physical Task

Rowing is a full-body aerobic exercise that engages various muscles, including the latissimus dorsi, deltoids, triceps, biceps, pectorals, abdominals, quadriceps, glutes, hamstrings, and calves. To row, the participants strapped their feet into the footrests and adjusted the width and tightness of the straps. They pushed against the footrests with the soles of their feet and fully extended their legs. Finally, the participant pulled on the oar bar until it reached their body below chest level.

Procedure

Before the study began, Institutional Review Board (IRB) approval was confirmed. In order to complete the rowing tasks, participants were asked to review and sign the digital informed consent form. Next, they completed the PAR-Q to determine eligibility. Upon finding readiness, the demographics questionnaire and IPQ were administered. Participants’ height and weight were collected. They were then fitted with a HR monitor and resting HR was collected. After collecting resting HR, the participant was familiarized with the scales to be administered during the rowing task using a standardized script. These scales included the RPE scale, Attention Scale, and FS.

Utilizing a within-subjects design, each participant completed two randomly assigned exercise intervention conditions: (1) Control and (2) Row Breaker Exergame. Both conditions took place 24 to 72 hours apart. Participants completed the conditions during the same time of day. The control condition involved using the metric screen during the rowing task. The Brick Breaker condition involves using an interactive game based on the individual's performance. Each exercise session took approximately 30 minutes.

To familiarize the participants with the task, each participant watched a standardized introduction video on the Aviron rower. Next, the Task-Specific Motivation Scale was administered. After completion, 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 rower was set to the metrics screen for the warmup and the exercise bout began (0-5 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 being restarted or the Row Breaker game being selected. 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 on the metrics screen (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 (η_p^2). The significance level was set to $p < 0.05$.

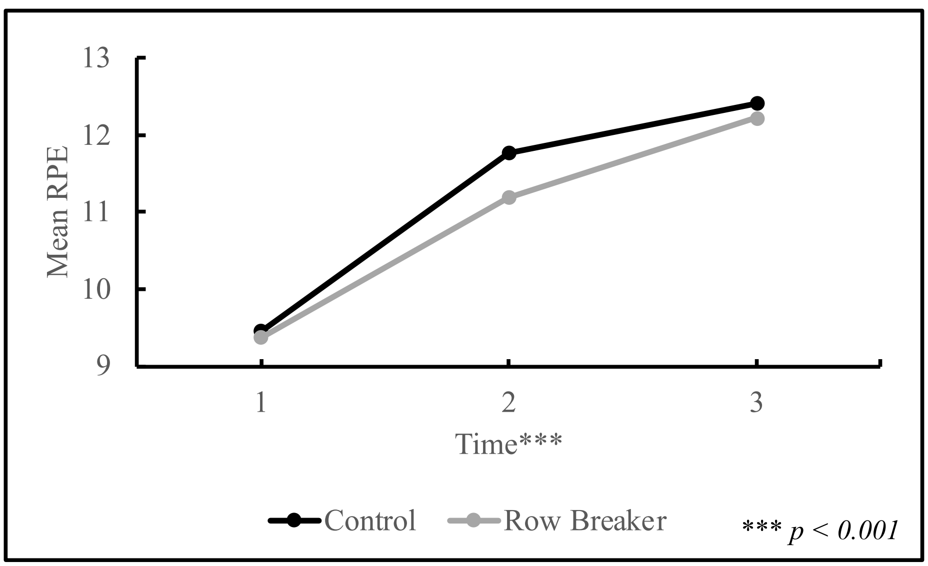
Chapter IV: Results

Ratings 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) = 0.95, p = 0.34, $\eta_p^2 = 0.04$ (see Figure 1). RPE did not vary between conditions. A significant difference was found on time, F (2, 50) = 66.88, $p < 0.001$, $\eta_p^2 = 0.73$. Pairwise comparisons indicated significantly higher RPE scores across all time points ($p < 0.01$). As time progressed, RPE increased in all conditions. A non-significant condition x time interaction was found, F (2, 50) = 0.63, p = 0.53, $\eta_p^2 = 0.03$.

Figure 1

Mean RPE between conditions across time

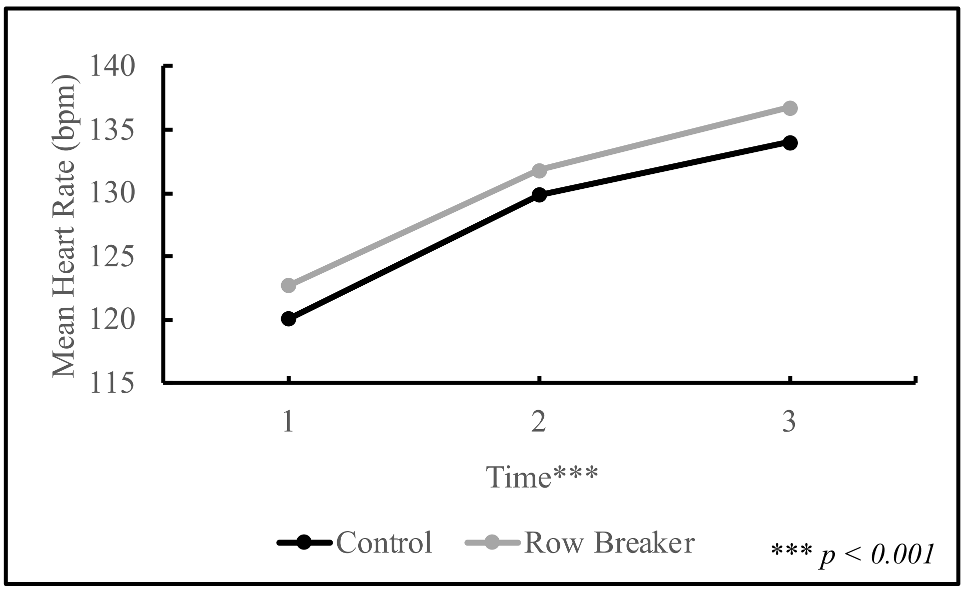


Heart Rate

A within-subject two-way RM ANOVA examined the differences in HR between the conditions across time. No significant differences were reported between conditions, F (1, 25) = 0.74, p = 0.40, $\eta_p^2 = 0.03$ (see Figure 2). HR did not vary between conditions. A significant difference was found on time, F (1.32, 33.10) = 16.94, $p < 0.001$, $\eta_p^2 = 0.40$. Pairwise comparisons indicated significantly higher HR scores across all time points ($p < 0.05$). As time progressed, HR increased in all conditions. A non-significant condition x time interaction was found, F (2, 50) = 0.04, $p = 0.96$, $\eta_p^2 = 0.002$.

Figure 2

Mean HR between conditions across time

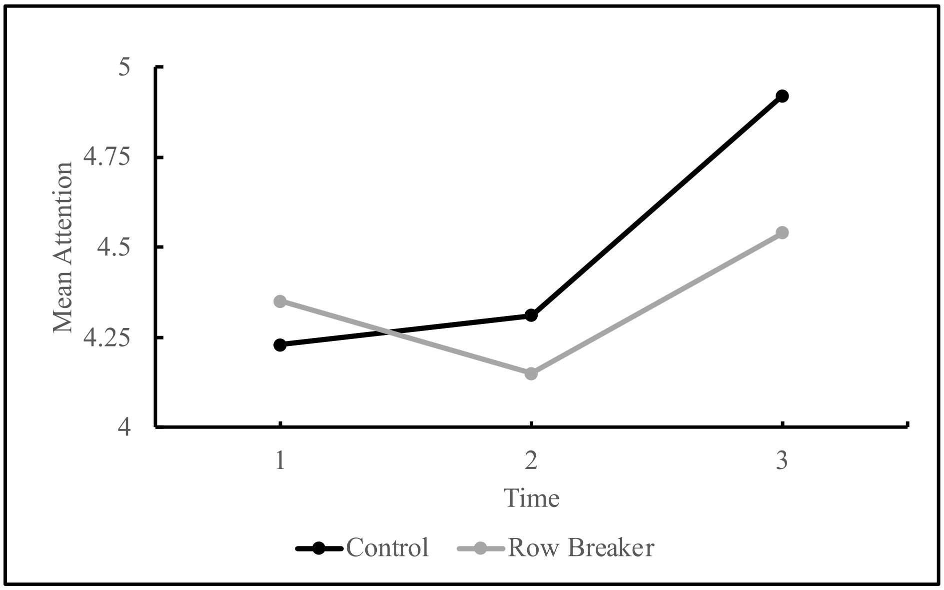


Attention

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) = 0.07, $p = 0.79$, $\eta_p^2 = 0.003$ (see Figure 3). Attention did not vary between conditions. A significant difference was not found on time, F (1.63, 40.84) = 2.06, $p < 0.15$, $\eta_p^2 = 0.08$. A non-significant condition x time interaction was found, F (1.49, 37.29) = 0.45, $p = 0.59$, $\eta_p^2 = 0.02$.

Figure 3

Mean attention between conditions across time

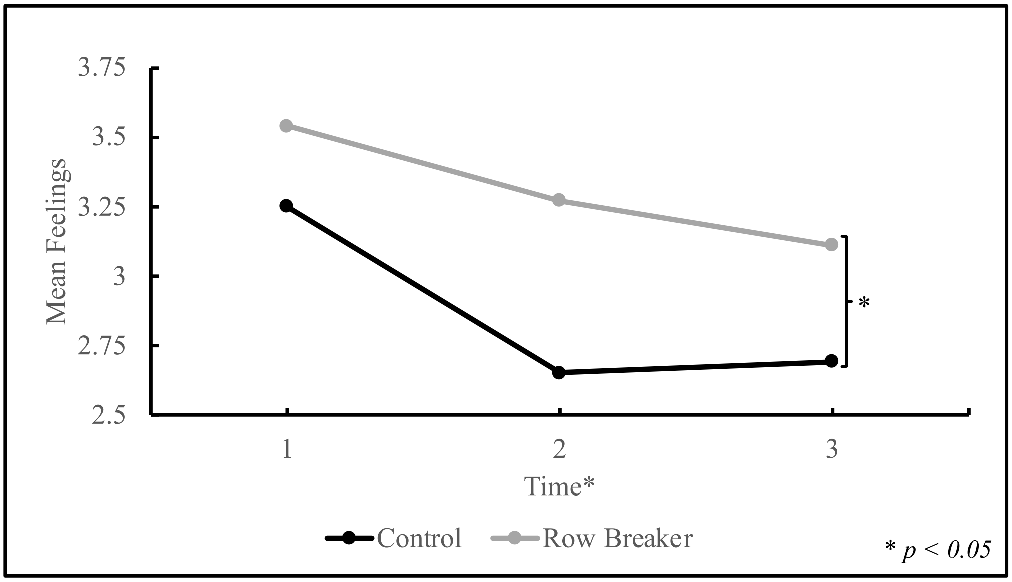


Feelings

A within-subject two-way RM ANOVA examined the differences in FS between the Conditions across time. A significant difference was reported between conditions, F (1, 25) = 5.44, p = 0.03, η_p^2 = 0.18 (see Figure 4). Pairwise comparison indicated significantly higher feelings *(p = 0.03).* The Row Breaker condition has higher feeling scores across time compared to the control condition. A significant difference was found on time, F (2, 50) = 5.45, p < 0.007, η_p^2 = 0.18. Pairwise comparisons indicated a significant difference between time point 1 and time point 2 (p = 0.026). A non-significant condition x time interaction was found, F (2, 50) = 0.99, p = 0.38, η_p^2 = 0.04.

Figure 4

Mean feelings between conditions across time

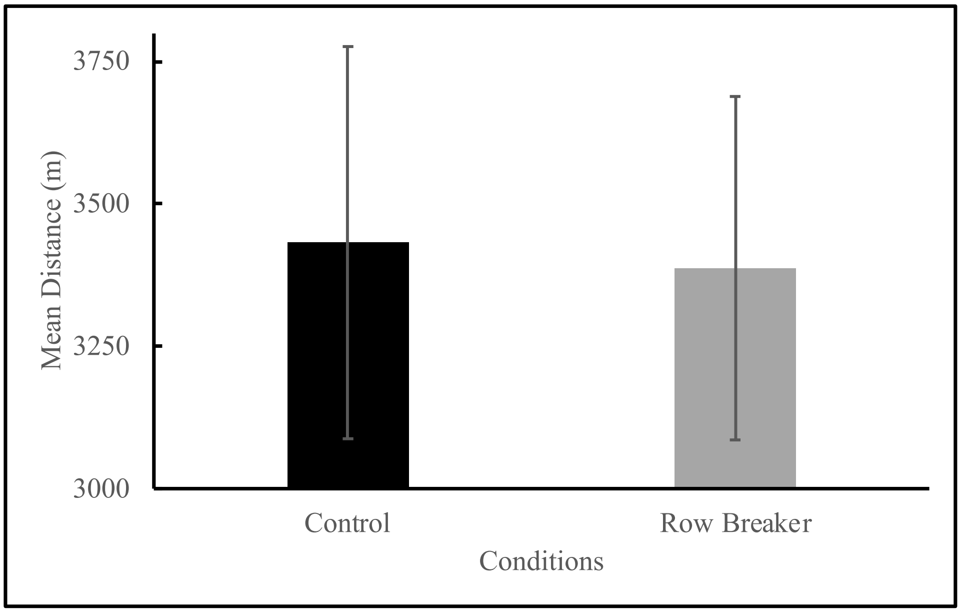


Distance Rowed

A paired t-test was computed to determine the difference in distance rowed between the control condition and the Row Breaker condition. A non-significant difference was found between the conditions, t (25) = 1.27, p = 0.22 (see Figure 5).

Figure 5

Mean distance rowed between conditions

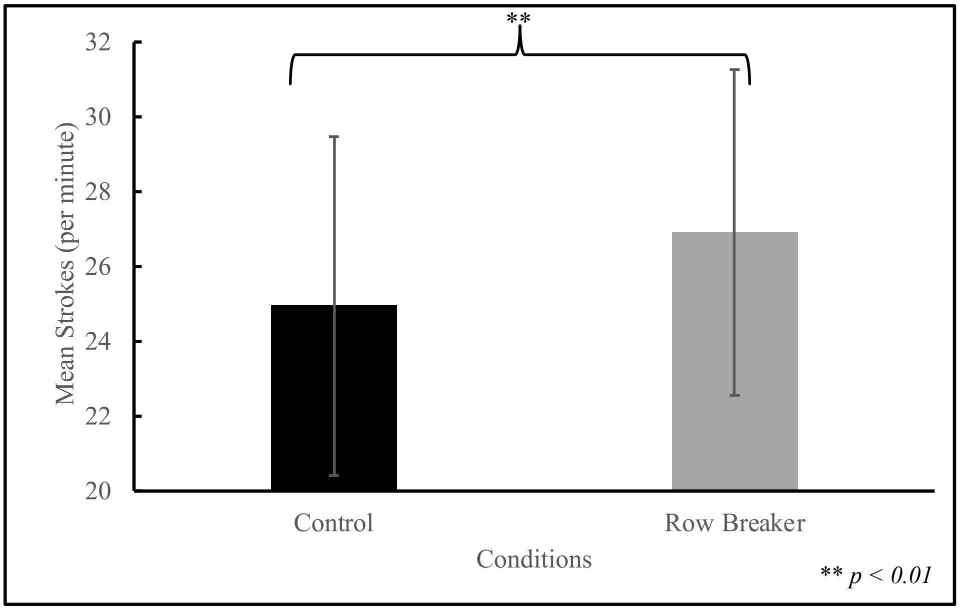


Strokes Per Minutes

A paired t-test was computed to determine the difference in strokes per minute between the control condition and the Row Breaker condition. A significant difference was found between the conditions, t (25) = -3.15, p = 0.004. Participants showed higher strokes per minute in the Row Breaker condition compared to the control group (see Figure 6).

Figure 6

Mean strokes per minute between conditions

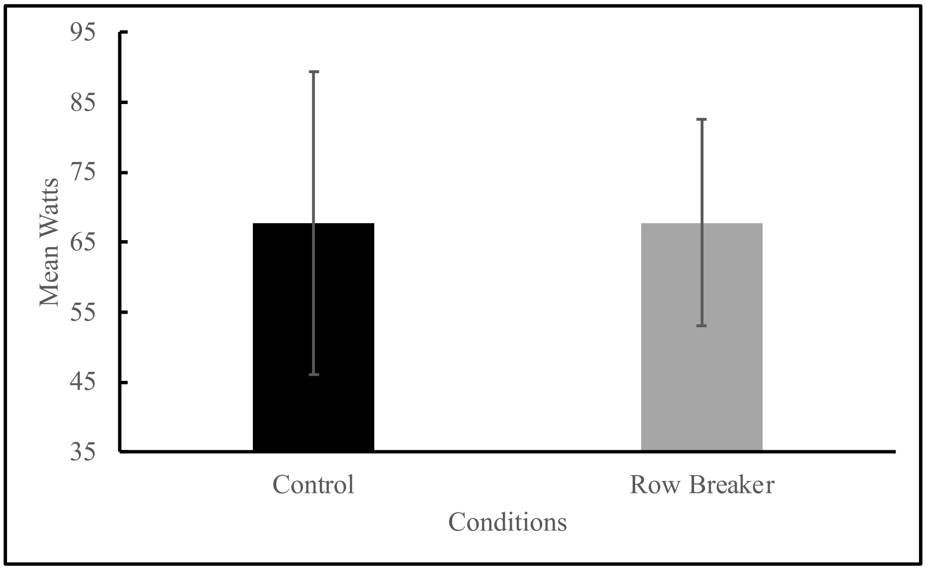


Watts

A paired t-test was computed to determine the difference in watts between the control condition and the Row Breaker condition. A non-significant difference was found between the conditions, t (25) = -0.04, p = 0.97 (see Figure 7).

Figure 7

Mean watts between conditions

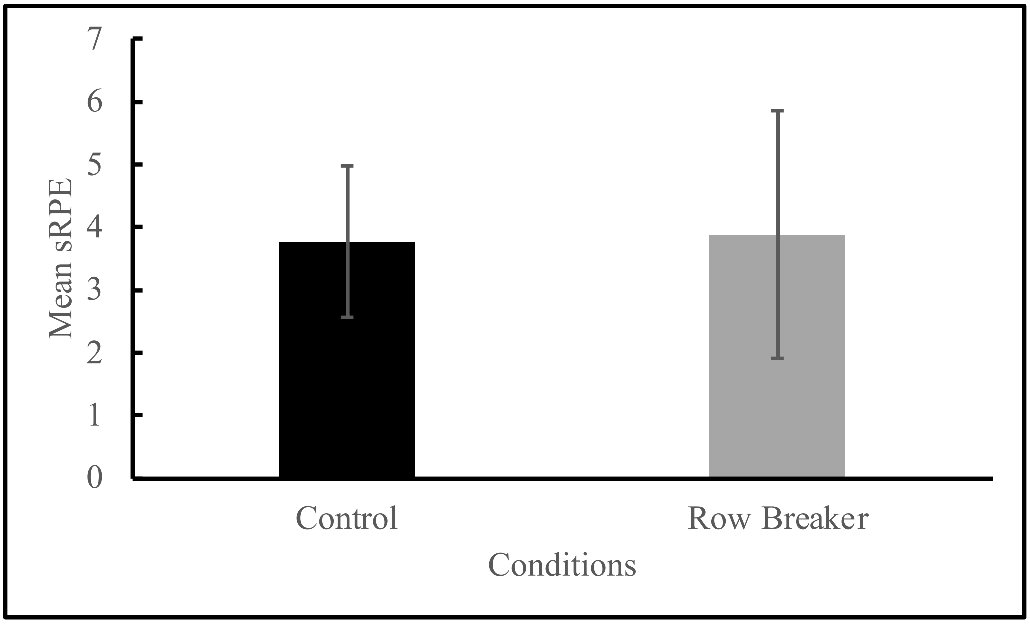


Session Ratings of Perceived Exertion

A paired t-test was computed to determine the difference in sRPE between the control condition and the Row Breaker condition. A non-significant difference was found between the conditions, t (25) = -0.32, p = 0.76 (see Figure 8).

Figure 8

sRPE between conditions

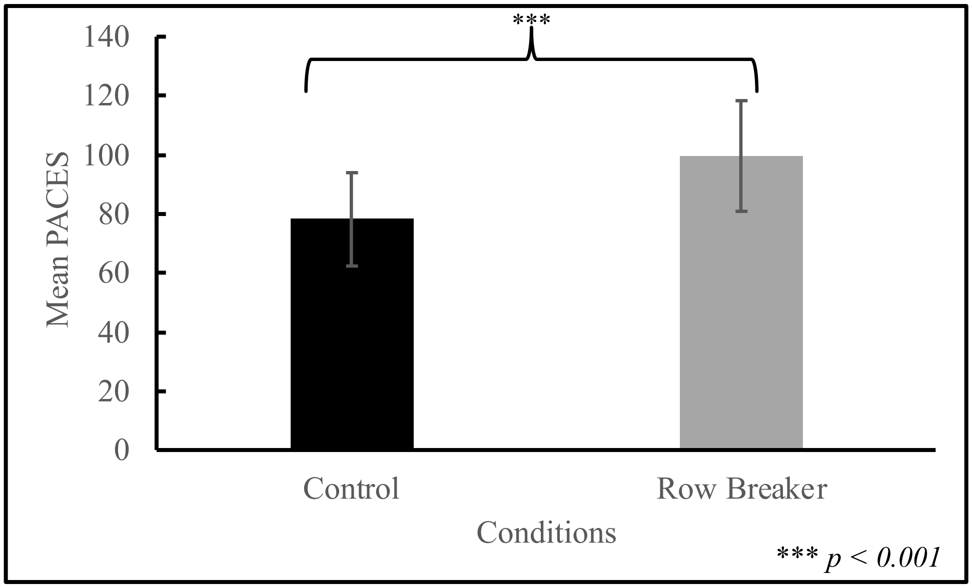


Enjoyment

A paired t-test was computed to determine the difference in enjoyment between the control condition and the Row Breaker condition. A significant difference was found between the conditions, t (25) = -5.67, $p < 0.001$. Participants showed higher enjoyment scores in the Row Breaker condition compared to the control (see Figure 9).

Figure 9

Enjoyment between conditions



Chapter V: Discussion

The purpose of this study was to investigate the effects of exergames on affective responses and performance outcomes during a rowing task with individuals performing at an enjoyable intensity level. The results indicated that HR and RPE increased across time for both conditions, with the exergame condition eliciting higher overall feelings, enjoyment, and strokes per minute compared to the control. However, no differences were found between groups in terms of HR, RPE, attention, distance rowed, and watts.

Consistent with previous literature, it is seen in this study that the participants' HR and RPE increased significantly across time in both conditions (Braun-Trocchio et al., 2022). This finding is of significance as the exercise bout revealed consistent findings with what is known about the correlation between HR, RPE, and exercise intensity. As exercise intensity increases, HR will increase to match the body's need for oxygen, which can lead the individual to perceive the exercise as getting harder. While there was a significant difference across time, there was no significance found between groups. This contradicts previous research with exergames, as it has been shown that participants were exercising at a higher intensity in exergames compared to a control (Glen et al., 2017; Monedero et al., 2015). The present study showed that the exergame was similar in exercise intensity compared to the control and did not decrease the participant's perceived exertion.

Despite instructing participants to row at a "+3 good feeling" throughout the exercise bout, significant differences were revealed both across time as well as between groups. This result is consistent with the literature as it is known that feelings fluctuate based on exercise intensity (Rose & Parfitt, 2008). As intensities increase and duration continues, feelings will shift negatively towards displeasure in the activity. Similar to Rose and Parfitt (2008), the participants were asked to row at a consistent good feeling, meaning that they might have needed to adjust their rowing speed to ensure that it still felt good. This was in the hope of giving the participants more autonomy over their exercise bout and increasing their enjoyment. While the participants' feelings shifted negatively overall, the exergame was found to have higher feelings throughout the task. This is consistent with results found previously with in-task pleasure during the interactive condition being higher compared to the control (Legrand et al., 2011). Regardless of instruction, the fluctuation in feelings is still relevant as it revealed the exergame elicited a higher overall good feeling compared to the control to suggest that this intervention can make exercise feel more pleasant.

The exergame also revealed significantly higher strokes per minute compared to the control. This finding is interesting since there was no significant difference found between distance rowed and watts. Since minimal research has been conducted on exergames through a rowing machine, it is unclear if this finding would be consistent. However, based on researcher observations, it is possible to attribute the higher strokes per minute to the game's design. As the participants played the game, a key feature was the increase in strokes per minute to catch the ball in order to continue playing. If the participants did not change their rowing speed, the game was designed so that they would lose a 'life' if they were unable to catch the ball.

The largest finding in this study was found with the significant difference between conditions on the PACES scale. It was shown that the exergame condition revealed a higher overall score compared to the control, meaning that the participants were found to enjoy exercising more during the exergame. This is consistent with previous research that has shown exergames to increase an individual's enjoyment of the exercise task (Glen et al., 2017; Monedero et al., 2015; Garn et al., 2015; Legrand et al., 2011).

Furthermore, this finding contradicts a previous study that attributed a decrease in mood benefits from video game-based exercise to gender (Russell & Newton, 2008). This past study found that exercise in general increased mood, with no significant difference between the control and the exergame. Russell and Newton (2008) attributed the lack of difference to more females being in the exergame condition, saying that gender may be a limiting factor. However, the present study, being comprised mainly of females, revealed that the exergame did elicit higher overall enjoyment in the task despite them playing a video game.

Limitations and Future Research

This study did come with limitations. An important limitation of this study was the sample population. The study had a skew in participants towards the female demographic. Individuals were mostly of college age with little diversity in race and ethnicity. This limits the results to not be generalized towards all individuals, including other genders, races, ages, and educational backgrounds. Due to the limitation in population, it is unclear whether the exergame intervention would be influenced by the individual's background, gender, or age, as there is an entire segment of the world's demographic underrepresented. Future research should focus on finding equal representation of both genders, all ethnicities, and all ages.

A second limitation came along with the one-time intervention. Participants were asked to come in twice in one week to complete one rowing bout in each intervention. Future research should investigate comparing the individual’s motivation and adherence to a training program over a longitudinal study. Exercisers need to understand the long-term implications of such interventions. Exergame interventions may continue to influence the individual to enjoy exercise or cause them to revert to their sedentary lives.

Another limitation was the exercise method. This study only looked at the interactive games on an Aviron Tough Series Rower. While this is a full-body exercise, not every individual enjoys rowing, which can influence their attention, enjoyment, and perceived exertion while participating in the study. For generalizability, future research should analyze other exercise methods including walking, running, and biking.

Additionally, the "Row Breaker" exergame would stop if the participant lost their 'lives' in the game. This game on the Aviron rower was limited to only 10 lives, and not contingent on a set exercise time. Depending on how fast and hard the participant rowed, they may have lost all their lives before the 20-minute intervention was done. This would cause the screen to load their metrics, removing them from the interactive experience. It is unclear what effect this had on the participant's attention during the rowing task while the game was being restarted. It is important that future research be conducted to analyze a full 20-minute rowing task, without the risk of individual exercise variability being able to manipulate the exergame.

Finally, it is important to note that all the measures recorded in this study, minus HR, were self-reported. It is unclear whether the participants were entirely truthful in their responses or if they fully understood the scales being asked. While they were instructed to answer based on what they were feeling at that moment, skews may exist based on the self-reported measure and risk of dishonest responses. Future research should investigate a more objective approach to these responses to ensure accurate results are obtained.

Conclusion

In conclusion, the aim of this study was to examine the effects of an exergame on affective and performance variables during a rowing task. Results indicated that the exergame condition had significantly higher feeling scores during the rowing task compared to the control.

However, no significant differences were found between conditions for HR, RPE, and attentional focus. Thus, the use of an exergame during a rowing task may not be an adequate solution for all exercisers to reduce RPE with an increase in dissociative states when exercising at a preferred intensity. Instead, exergames should be utilized to increase the overall feelings during the exercise task and enjoyment post-exercise. Healthcare providers can use this information to help increase the enjoyment of patients who are struggling to stay active. Exercisers can also use this information as an additional intervention to make physical activity more enjoyable for themselves. Future research should expand upon the influence of exergames on RPE, HR, and attentional focus, as well as examine other exercise methods and exergames. Although this study was not without limitations, it adds to the research on exergames and provides future research with a protocol for examining exergames' effects during a rowing task.

References

Abernathy, M., Shaw, L. A., Lutteroth, C., Buckley, J., Corballis, P. M., & Wünsche, B. C. (2017). Enjoyment, immersion, and attentional focus in a virtual reality exergame with differing visual environments. In ICAT-EGVE (pp. 117-124).

Arango, E. F., Patiño, F. A., Quintero, M. A., & Arenas, M. M. (2011). Levels of physical activity, barriers, and stage of change in an urban population from a municipality in Colombia. *Colombia Medica*, 42(3), 352–361. https://doi.org/10.25100/cm.v42i3.882

Aviron Active. (n.d.). Workouts. Retrieved from https://www.avironactive.com/workouts/

Baldwin, A. S., Kangas, J. L., Denman, D. C., Smits, J. A., Yamada, T., & Otto, M. W. (2016). Cardiorespiratory fitness moderates the effect of an affect-guided physical activity prescription: A pilot randomized controlled trial. *Cognitive Behaviour Therapy*, *45*(6), 445–457. https://doi.org/10.1080/16506073.2016.1194454

Ballmann, C. G. (2021). The influence of music preference on exercise responses and performance: A review. *Journal of Functional Morphology and Kinesiology*, *6*(2), 33. https://doi.org/10.3390/jfmk6020033

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J., & Martin, B. W. (2012). Correlates of physical activity: Why are some people physically active and others not? *The Lancet*, *380*(9838), 258–271. https://doi.org/10.1016/s0140-6736(12)60735-1

Benzing, V., & Schmidt, M. (2018). Exergaming for children and adolescents: Strengths, weaknesses, opportunities and threats. *Journal of Clinical Medicine*, *7*(11), 422. https://doi.org/10.3390/jcm7110422

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise, 14*(5), 377-381. https://doi.org/10.1249/00005768-198205000-00012

Borg, G. (1990). Psychophysical scaling with applications in physical work and the perception of exertion. *Scandinavian Journal of Work, Environment & Health*, *16*, 55–58. http://www.jstor.org/stable/40965845

Braun-Trocchio, R., Renteria, J., Warfield, E., Harrison, K., & Williams, A. (2022). The effects of face coverings on perceived exertion and attention allocation during a stepping task. *International Journal of Environmental Research and Public Health*, *19*(11), 6892. https://doi.org/10.3390/ijerph19116892

Braun-Trocchio, R., Williams, A., Harrison, K., Warfield, E., & Renteria, J. (2022). The effects of heart rate monitoring on ratings of perceived exertion and attention allocation in individuals of varying fitness levels. *Frontiers in Sports and Active Living, 3*, 798941. https://doi.org/10.3389/fspor.2021.798941

Brinthaupt, T. M., Kang, M., & Anshel, M. H. (2010). A delivery model for overcoming psycho-behavioral barriers to exercise. *Psychology of Sport and Exercise*, *11*(4), 259–266. https://doi.org/10.1016/j.psychsport.2010.03.003

Bronner, S., Pinsker, R., Naik, R., & Noah, J. A. (2016). Physiological and psychophysiological responses to an exer-game training protocol. *Journal of Science and Medicine in Sport*, *19*(3), 267–271. https://doi.org/10.1016/j.jsams.2015.03.003

Campbell, H. M., Khan, N., Cone, C., & Raisch, D. W. (2011). Relationship between diet, exercise habits, and health status among patients with diabetes. *Research in Social and Administrative Pharmacy*, *7*(2), 151–161. https://doi.org/10.1016/j.sapharm.2010.03.002

Centers for Disease Control and Prevention. (2022, June 3). Perceived exertion (Borg rating of perceived exertion scale). Centers for Disease Control and Prevention. https://www.cdc.gov/physicalactivity/basics/measuring/exertion.htm#:~:text=The%20Borg%20Rating%20of%20Perceived,like%20your%20body%20is%20working

Chen, M. J., Fan, X., & Moe, S. T. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: A meta-analysis. *Journal of Sports Sciences*, *20*(11), 873–899. https://doi.org/10.1080/026404102320761787

Chen, Y., Zhang, Y., Guo, Z., Bao, D., & Zhou, J. (2021). Comparison between the effects of exergame intervention and traditional physical training on improving balance and fall prevention in healthy older adults: A systematic review and meta-analysis. *Journal of NeuroEngineering and Rehabilitation*, *18*(1). https://doi.org/10.1186/s12984-021-00917-0

Clark, I. N., Taylor, N. F., & Peiris, C. L. (2024). Music listening interventions for physical activity: A systematic review and meta-analysis of randomised controlled trials. *Disability and Rehabilitation*, *46*(1), 13–20. https://doi.org/10.1080/09638288.2022.2155715

Ekkekakis, P. (2009). The dual-mode theory of affective responses to exercise in metatheoretical context: I. Initial Impetus, basic postulates, and philosophical framework. *International Review of Sport and Exercise Psychology*, *2*(1), 73–94. https://doi.org/10.1080/17509840802705920

Ekkekakis, P., & Brand, R. (2019). Affective responses to and automatic affective valuations of physical activity: Fifty years of progress on the seminal question in exercise psychology. *Psychology of Sport and Exercise*, *42*, 130–137. https://doi.org/10.1016/j.psychsport.2018.12.018

Ekkekakis, P., & Dafermos, M. (2012). Exercise is a many-splendored thing, but for some it does not feel so splendid: Staging a resurgence of hedonistic ideas in the quest to understand exercise behavior. *Oxford Handbooks Online*. https://doi.org/10.1093/oxfordhb/9780195394313.013.0016

Ekkekakis, P., Parfitt, G., & Petruzzello, S. J. (2011). The pleasure and displeasure people feel when they exercise at different intensities. *Sports Medicine*, *41*(8), 641–671. https://doi.org/10.2165/11590680-000000000-00000

Eston, R. (2012). Use of ratings of perceived exertion in sports. *International Journal of Sports Physiology and Performance*, *7*(2), 175–182. https://doi.org/10.1123/ijspp.7.2.175

Farrow, M., Lutteroth, C., Rouse, P. C., & Bilzon, J. L. (2018). Virtual-reality exergaming improves performance during high-intensity interval training. *European Journal of Sport Science*, *19*(6), 719–727. https://doi.org/10.1080/17461391.2018.1542459

Garn, A. C., Baker, B. L., Beasley, E. K., & Solmon, M. A. (2012). What are the benefits of a commercial exergaming platform for college students? Examining physical activity, enjoyment, and future intentions. *Journal of Physical Activity and Health*, *9*(2), 311–318. https://doi.org/10.1123/jpah.9.2.311

Glen, K., Eston, R., Loetscher, T., & Parfitt, G. (2017). Exergaming: Feels good despite working harder. *PLOS ONE*, *12*(10). https://doi.org/10.1371/journal.pone.0186526

Greene, J. D. (2007). Why are VMPFC patients more utilitarian? A dual-process theory of moral judgment explains. *Trends in Cognitive Sciences*, *11*(8), 322–323. https://doi.org/10.1016/j.tics.2007.06.004

Hardy, C. J., & Rejeski, W. J. (1989). Not what, but how one feels: The measurement of affect during exercise. *Journal of Sport and Exercise Psychology*, *11*(3), 304–317. https://doi.org/10.1123/jsep.11.3.304

Herazo-Beltrán, Y., Pinillos, Y., Vidarte, J., Crissien, E., Suarez, D., & García, R. (2017). Predictors of perceived barriers to physical activity in the general adult population: A cross-sectional study. *Brazilian Journal of Physical Therapy*, *21*(1), 44–50. https://doi.org/10.1016/j.bjpt.2016.04.003

Hoffman, G. J., Malani, P. N., Solway, E., Kirch, M., Singer, D. C., & Kullgren, J. T. (2021). Changes in activity levels, physical functioning, and fall risk during the COVID-19 pandemic. *Journal of the American Geriatrics Society*, *70*(1), 49–59. https://doi.org/10.1111/jgs.17477

Hutchinson, J. C., & Tenenbaum, G. (2007). Attention focus during physical effort: The mediating role of task intensity. *Psychology of Sport and Exercise, 8*(1), 233-245. https://doi.org/10.1016/j.psychsport.2006.03.006

Kvaran, T., Nichols, S., & Sanfey, A. (2013). The effect of analytic and experiential modes of thought on moral judgment. *Progress in Brain Research, 202*, 187–196. https://doi.org/10.1016/b978-0-444-62604-2.00011-3

Lamb, K. L., Eston, R. G., & Corns, D. (1999). Reliability of ratings of perceived exertion during progressive treadmill exercise. *British Journal of Sports Medicine*, *33*(5), 336–339. https://doi.org/10.1136/bjsm.33.5.336

Lazarus, R. S. (1991). Cognition and motivation in emotion. *American Psychologist*, *46*(4), 352–367. https://doi.org/10.1037//0003-066x.46.4.352

Legrand, F. D., Joly, P. M., Bertucci, W. M., Soudain-Pineau, M. A., & Marcel, J. (2011).

Interactive-Virtual Reality (IVR) exercise: An examination of in-task and pre-to-post exercise affective changes. *Journal of Applied Sport Psychology*, *23*(1), 65–75. https://doi.org/10.1080/10413200.2010.523754

Litwic-Kaminska, K. (2020). Types of cognitive appraisal and undertaken coping strategies during sport competitions. *International Journal of Environmental Research and Public Health*, *17*(18), 6522. https://doi.org/10.3390/ijerph17186522

Lotan, M., Yalon-Chamovitz, S., & Weiss, P. L. (2010). Virtual reality as means to improve physical fitness of individuals at a severe level of intellectual and developmental disability. *Research in developmental disabilities, 31*(4), 869–874. https://doi.org/10.1016/j.ridd.2010.01.010

Mackintosh, K. A., Standage, M., Staiano, A. E., Lester, L., & McNarry, M. A. (2016). Investigating the physiological and psychosocial responses of single- and dual-player exergaming in young adults. *Games for Health Journal*, *5*(6), 375–381. https://doi.org/10.1089/g4h.2016.0015

Martín-Martínez, J. P., Villafaina, S., Collado-Mateo, D., Pérez-Gómez, J., & Gusi, N. (2019). Effects of 24-week exergame intervention on physical function under single- and dual-task conditions in fibromyalgia: A randomized controlled trial. *Scandinavian Journal of Medicine & Science in Sports*, *29*(10), 1610–1617. https://doi.org/10.1111/sms.13502

Mitchell, N. S., Catenacci, V. A., Wyatt, H. R., & Hill, J. O. (2011). Obesity: Overview of an epidemic. *Psychiatric Clinics of North America*, *34*(4), 717–732. https://doi.org/10.1016/j.psc.2011.08.005

Monedero, J., Lyons, E. J., & O'Gorman, D. J. (2015). Interactive video game cycling leads to higher energy expenditure and is more enjoyable than conventional exercise in adults. *PLOS ONE*, *10*(3), e0118470. https://doi.org/10.1371/journal.pone.0118470

Morgan, W. P., Roberts, J. A., Brand, F. R., & Feinerman, A. D. (1970). Psychological effect of chronic physical activity. *Medicine & Science in Sports & Exercise*, *2*(4), 331-333. https://doi.org/10.1249/00005768-197000240-00010

Murrock, C. J., Bekhet, A., & Zauszniewski, J. A. (2016). Psychometric evaluation of the physical activity enjoyment scale in adults with functional limitations. *Issues in Mental Health Nursing, 37*(3), 164–171. https://doi.org/10.3109/01612840.2015.1088904.

Neumann, D. L., & Moffitt, R. L. (2018). Affective and attentional states when running in a virtual reality environment. *Sports, 6*(3), 71. https://doi.org/10.3390/sports6030071

Park, J. H., Moon, J. H., Kim, H. J., Kong, M. H., & Oh, Y. H. (2020). Sedentary lifestyle: Overview of updated evidence of potential health risks. *Korean Journal of Family Medicine*, *41*(6), 365–373. https://doi.org/10.4082/kjfm.20.0165

Pitts, F. N. (1971). Biochemical factors in anxiety neurosis. *Behavioral Science*, *16*(1), 82–91. https://doi.org/10.1002/bs.3830160107

Raedeke, T. D. (2007). The relationship between enjoyment and affective responses to exercise. *Journal of Applied Sport Psychology, 19*(1), 105-115. https://doi.org/10.1080/10413200601113638

Reiner, M., Niermann, C., Jekauc, D., & Woll, A. (2013). Long-term health benefits of physical activity – a systematic review of longitudinal studies. *BMC Public Health*, *13*(1), 813. https://doi.org/10.1186/1471-2458-13-813

Rooks, C. R., Thom, N. J., McCully, K. K., & Dishman, R. K. (2010). Effects of incremental exercise on cerebral oxygenation measured by near-infrared spectroscopy: A systematic review. *Progress in Neurobiology*, *92*(2), 134–150. https://doi.org/10.1016/j.pneurobio.2010.06.002

Rose, E. A., & Parfitt, G. (2008). Can the feeling scale be used to regulate exercise intensity? *Medicine & Science in Sports & Exercise*, *40*(10), 1852–1860. https://doi.org/10.1249/mss.0b013e31817a8aea

Shahidi, S. H., Stewart Williams, J., & Hassani, F. (2020). Physical activity during COVID-19 quarantine. *Acta Paediatrica*, *109*(10), 2147–2148. https://doi.org/10.1111/apa.15420

Skinner, J. S., Hutsler, E., Bergsteinova, V., & Buskirk, E. R. (1973). The validity and reliability of a rating scale of perceived exertion. *Medicine & Science in Sports & Exercise*, *5*(2). https://doi.org/10.1249/00005768-197300520-00018

Staiano, A. E., Beyl, R. A., Guan, W., Hendrick, C. A., Hsia, D. S., & Newton, R. L. (2018). Home-based exergaming among children with overweight and obesity: A randomized clinical trial. *Pediatric Obesity*, *13*(11), 724–733. https://doi.org/10.1111/ijpo.12438

Stewart, T. H., Villaneuva, K., Hahn, A., Ortiz-Delatorre, J., Wolf, C., Nguyen, R., Bolter, N. D., Kern, M., & Bagley, J. R. (2022). Actual vs. perceived exertion during active virtual reality game exercise. *Frontiers in Rehabilitation Sciences*, *3,* 887740. https://doi.org/10.3389/fresc.2022.887740

Tammen, V. V. (1996). Elite middle- and long-distance runners' associative/dissociative coping. *Journal of Applied Sport Psychology, 8*(1), 1-8. https://doi.org/10.1080/10413209608406304

Tenenbaum, G. (2001). A social-cognitive perspective of perceived exertion and exertion tolerance. In R. N. Singer, H. A. Hausenblas, & C. M. Janelle (Eds.), *Handbook of Sport Psychology* (2nd ed., pp. 810-820). New York, NY: Wiley & Sons.

Tenenbaum, G., (2005). The study of perceived and sustained effort: concepts, research findings, and future directions. In D. Hackfort, J. Duda, & R. Lidor (Eds.), *Handbook of Research on Applied Sport Psychology: International Perspective* (pp. 335-349). Morgantown, WV, USA: Fitness Information Technology.

Tenenbaum, G., & Connolly, C. T. (2008). Attention allocation under varied workload and effort perception in rowers. *Psychology of Sport and Exercise*, *9*(5), 704–717. https://doi.org/10.1016/j.psychsport.2007.09.002

Tenenbaum, G., & Hutchinson, J. C. (2007). A social-cognitive perspective of perceived and sustained effort. In G. Tenenbaum & R. C. Eklund (Eds.), *Handbook of Sport Psychology*, (3rd ed., pp. 560–577). John Wiley & Sons.

Tucker, J. M., Welk, G. J., & Beyler, N. K. (2011). Physical activity in U.S. adults. *American Journal of Preventive Medicine*, *40*(4), 454–461. https://doi.org/10.1016/j.amepre.2010.12.016

Tuso, P. (2015). Strategies to increase physical activity. *The Permanente Journal*, *19*(4), 84–88. https://doi.org/10.7812/tpp/14-242

Russell, W. D., & Newton, M. (2008). Short-term psychological effects of interactive video game technology exercise on mood and attention. *Journal of Educational Technology & Society*, *11*(2), 294–308. http://www.jstor.org/stable/jeductechsoci.11.2.294

Warburton, D. E. R., Bredin, S. S. D., Horita, L. T. L., Zbogar, D., Scott, J. M., Esch, B. T. A., &

Rhodes, R. E. (2007). The health benefits of interactive video game exercise. *Applied Physiology, Nutrition, and Metabolism*, *32*(4), 655–663. https://doi.org/10.1139/h07-038

Warburton, D. E., Bredin S. S., Jamnik, V. K., & Gledhill, N. (2011). Validation of the PAR-Q+ and ePARmed-X+. *The Health & Fitness Journal of Canada, 4*(2), 38-46. https://doi.org/10.14288/hfjc.v4i2.151

Williams, D. M., Dunsiger, S., Emerson, J. A., Gwaltney, C. J., Monti, P. M., & Miranda, R. (2016). Self-paced exercise, affective response, and exercise adherence: A preliminary investigation using ecological momentary assessment. *Journal of Sport and Exercise Psychology*, *38*(3), 282–291. https://doi.org/10.1123/jsep.2015-0232

World Health Organization. (2022). *Indicator metadata registry details*. World Health Organization. https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3416#:~:text=Insufficient%20physical%20activity%20is%20the,attributable%20to%20insufficient%20physical%20activity.