Virtual Reality Exercise Effects on College Students with Anxiety and Depression: A Pilot Study

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Abstract

Both within and outside of the classroom, mental health has become a primary concern across college campuses. Using virtual reality (VR) to provide an alternative exercise environment may amplify the beneficial effects of traditional exercise on mental health that have already been established. The purpose of this study is to investigate the physiological and psychological effects of VR exercise on college students with anxiety and/or depression. A sample of fourteen participants (M_{age} =19.86 ± 1.16; 11 females) with symptoms of anxiety and/or depression was recruited from the University of Minnesota Duluth campus. Participants performed two 20-minute sessions of VirZoom immersive VR exercise biking and VirZoom biking without the VR system (traditional condition) on separate days. Participants' heart rate (HR), rate of perceived exertion (RPE), enjoyment, self-efficacy, and mood were measured at various points during each of the two biking sessions. The VR biking sessions resulted in significant improvements in exercise self-efficacy, as well as the mood subscales of anger, confusion, depression, tension, and vigor. The traditional sessions resulted in significant improvements in only three mood subscales (depression, tension and vigor). A paired t-test indicated there were no significant differences in average HR or RPE between the two exercise conditions. College students suffering from symptoms of anxiety and depression can benefit from 20 minutes of exercise biking, regardless of the use of VR. While the physiological response may be comparable between the two exercise conditions, VR exercise may be more effective in enhancing mood and self-efficacy compared to traditional bike exercise. The results of this study may lend themselves to improved long-term exercise adherence in individuals suffering from mental illness and suggest a potential way to improve mood supplemental to traditional therapies.

Review of Literature

Psychological Effects of VR Exercise

Anxiety and depression are chronic conditions that are not measurable following acute bouts of exercise. Because the current study is focused on the immediate effects of VR exercise on individuals with these mental health disorders, it is imperative to assess changes in the acute predictors of anxiety and depression to determine the effects of VR. Directly measuring symptoms of anxiety and depression using standardized assessments, such as the GAD-7 or PHQ-9, would not be appropriate as they generally question the status of individuals over a period of several weeks. Enjoyment, mood, and self-efficacy are primary measures of the current study because they can acutely change with exercise (Abrantes et al., 2017; McAuley et al., 2011; Plante et al., 2003) and can predict mental health status for those with anxiety and depression (Rabani Bavojdan et al., 2011). The enjoyment of the specific activity can also impact the effect it has on mood outcomes following a bout of exercise (Abrantes et al., 2017), which would provide information related to the purpose of the present study in analyzing the psychological effects of VR exercise.

Mood & Enjoyment

Mood and exercise enjoyment are frequently assessed concurrently in studies researching the psychological effects of VR. In general, regardless of the use of VR, exercise has been shown to improve mood (Plante et al., 2003); however, several studies suggest that the addition of VR to exercise may bring additional improvements in mood and enjoyment. In a study analyzing VR exercise compared to traditional exercise, it was found there were significant improvements in mood measures such as calmness and energy following VR exercise (Plante et al., 2003). Additionally, Plante et al. (2003) also found higher enjoyment scores with VR in both males and

females when compared to traditional exercise. A pivotal study from Zeng et al. (2017) - designed similarly to the present study - looked into the use of biking VR-based exercise games in healthy college students and found there were higher enjoyment scores when compared to traditional exercise biking, although these researchers did not investigate its effects on mood. When looking at the rehabilitation setting, the use of VR during physical therapy among older adults was also shown to improve mood and enjoyment during the sessions when compared to a traditional therapy session (Qian et al., 2020). A plausible reason for these improved psychological factors revolves around the idea that the novelty of VR and the hyperarousal state caused by the games may stimulate the reward centers of the brain and increase dopamine production, which is associated with improved mood, motivation, and pleasure (Olguin et al., 2016). Several studies have even cited a possible increase in dopamine during VR exercise as the potential mechanism for reducing symptoms of depression among users (Li et al., 2016; Qian et al., 2020).

There is evidence that not all emotions assessed in various mood questionnaires have improved with the use of VR during exercise, and that there may be differences between the sexes. Plante et al. (2003) found that female participants experienced an increase in tension following the use of VR while biking, but that overall mood improvements were greater in females compared to males. Similarly, Qian et al. (2020) found that young adult males experienced smaller differences in mood and enjoyment between traditional and VR exercise. These variations in mood changes and enjoyment levels between the sexes may be attributed to the differences in familiarity with video games and VR (Qian et al., 2020). While it is not fully understood why females experienced greater tension scores (Plante et al., 2003), males may have less improvement in mood and enjoyment because they are more likely to be experienced with

VR and video games (Qian et al., 2020). Having more experience with the gaming style would not cause the same novelty effect as it would in someone with less experience. Additionally, males may be less likely to be vulnerable when answering questionnaires regarding mood and enjoyment compared to females, which could result in less accurate and smaller differences between the measured psychological effects of VR and traditional exercise. These suggest there are areas that need further research regarding VR exercise effects between males and females. In general, though, VR exercise has been shown to improve mood and increase enjoyment. This can also impact the way users believe in their ability to perform the exercise.

Exercise Self-Efficacy

Exercise self-efficacy relates to a person's belief in their ability to perform an exercise or physical activity task well. Measuring exercise self-efficacy has not been a focus of many research studies involving VR exercise. The study investigating VR exercise biking compared to traditional biking in college students by Zeng et al. (2017) did assess self-efficacy as one of their primary psychological measures. The researchers found that the addition of VR resulted in higher self-efficacy questionnaire scores when compared to traditional biking (Zeng et al., 2017). Exercise self-efficacy is not widely researched in younger populations; it is commonly used as a predictor and indicator of physical activity levels in those over 50 (French et al., 2015). Although, it may still be applicable to note that a decrease in exercise self-efficacy is one of the primary factors that reduces physical activity levels (French et al., 2015). Another area of interest when using VR involves the changes in physiological responses that occur with exercise.

Physiological Effects of VR Exercise

The physiological factors that are most commonly researched with VR exercise include heart rate (HR), blood pressure (BP), and rate of perceived exertion (RPE). RPE is generally

considered a psycho-physiological factor (Scherr et al., 2013); however, because it is involved in determining how intense a participant is exercising (as do HR and BP), it will be characterized as a physiological factor. When comparing the RPE of a VR exercise biking game compared to traditional exercise biking in healthy college students, Zeng et al. (2017) found that the VR condition resulted in a significantly lower RPE than traditional exercise biking, despite participants experiencing similar increases in BP for both conditions. This suggests that the addition of VR may be enough to reduce the perception of unpleasant feelings associated with exercise while allowing users to still receive the benefits of working at higher intensities. When investigating the effects of VR biking on exercise tolerance, Rutkowski et al. (2021) found that HR was lower and exercise duration was longer for those performing a standardized submaximal exercise test using immersive VR compared to traditional exercise biking. This indicates a similar finding to Zeng et al. (2017). VR exercise lowers physiological responses and perceptions when compared to traditional exercise at the same intensity. Rutkowski et al. (2021) concluded that VR may be distracting from the exertion and negative feelings associated with exercise, allowing users to exercise for longer and with lower stimulation of physiological measures such as HR. Because VR has been shown to reduce the unpleasant perceptions associated with exercise, its effect on exercise habits should also be considered.

Effect of VR Exercise on Adherence

Several barriers have been identified as negatively impacting the amount and frequency of exercise among college students, including low self-efficacy and a lack of motivation and enjoyment during exercise (Eichorn et al., 2018). A lack of adherence to an exercise routine can make these barriers even more difficult to overcome (Eichorn et al., 2018). Several researchers (Plante et al., 2003; Zeng et al., 2017) have credited VR as a way to increase motivation, one of

the major barriers to exercise adherence identified by Eichorn et al. (2018). Very few studies have explicitly identified the effectiveness of VR in increasing exercise adherence, with most mentioning VR as a possible way to increase general physical activity levels among various populations (Dębska et al., 2019; Elor & Kurniawan, 2020; Wang et al., 2020; Zeng et al., 2017). This is likely due to the fact that the majority of VR games and systems involve at least some physical action or motion component. Determining adherence rates requires researchers to track exercise habits over a long period, which is likely one of the largest limitations of research related to the effects of VR on exercise adherence. While participants in the present study were not followed over an extended period of time, the measures may still be useful for research related to adherence rates among this particular population.

Introduction

Mental health has been an extensive concern across college campuses, especially coming out of the COVID-19 pandemic. During the 2020-2021 academic year, a survey of 373 campuses across the U.S. found that over 60% of college students met the criteria of at least one mental health problem, including over 100% increases in positive screenings for both anxiety and depression in all sampled students since 2013 (Lipson et al., 2022). Medications and psychotherapies are the most common treatments for anxiety disorders and depression (Health Quality Ontario, 2017); however, there exist many barriers to accessing these treatments, such as high out-of-pocket costs, healthcare deserts, and a lack of available appointments (Coombs et al., 2021). Left untreated, the impact of anxiety and depression can be detrimental to the daily and academic life of college students (Ho et al., 2018).

It is well-established that exercise is an effective behavioral intervention used in reducing the symptoms of both anxiety and depression (Henriksson et al., 2022; Rebar, 2015; Recchia et

al., 2022). There has also been increasing evidence supporting the use of immersive virtual reality (VR) technology for treating symptoms of anxiety and depression, including the addition of VR to psychotherapy and exposure therapy (Baghaei et al., 2021). The combination of VR and exercise is an area of minimal research when it comes to its use as a supplemental treatment for anxiety and depression, particularly among college-aged students experiencing symptoms. The purpose of this study is to determine the acute physiological and psychological effects of immersive VR biking exercises on college students with anxiety and/or depression. The results may lend themselves to support VR exercise as a way to alleviate the symptoms of anxiety and depression, suggesting its use as a supplemental or alternative option to traditional pharmacological and psychotherapy treatments. While not directly measured in this study, the results may also promote VR exercise as a tool for increasing exercise adherence rates among this population in the long term. It is hypothesized that (1) heart rate and RPE will be different between the VR exercise session and traditional exercise session; and (2) VR exercise will result in a significantly greater improvement in psychological variables (mood, enjoyment, self-efficacy) than traditional exercise.

Method

Participants

A sample of fourteen college students ages 18-25 with mild to moderate symptoms of anxiety and/or depression were recruited using flyers across the University of Minnesota Duluth campus. Participants were screened for the severity of their anxiety and depression symptoms using the Generalized Anxiety Disorder-7 (GAD-7) (Spitzer et al., 2007) and Patient Health Questionnaire-9 (PHQ-9) (Kroenke & Spitzer, 2002) questionnaires. Mild-to-moderate PHQ-9

and GAD-7 scores range from five to fourteen. Participants were also asked if they had experience playing VR before.

University Institutional Review Board approval and Participant Consent were obtained prior to data collection. Research was supported through the University of Minnesota's Undergraduate Research Opportunity Program.

Procedure

Subjects completed two 20-minute biking sessions on a VirZoom exercise bike, one with a VR headset and one without, in a randomized order. The VirZoom bike has sensors that allow the gaming console to respond to pedaling speed, as well as buttons to allow users to control different functions and movements within the VR game. The VR headset and camera system track the player's movements to allow them to steer and view 360 degrees in the virtual environment (VirZOOM, 2019).

During the immersive VR condition, participants played the game "Lotus Pond" on VirZoom Arcade for the PlayStation. "Lotus Pond" involves pedaling a kayak through a scenic pond and scoring points by attracting ducks. Participants were instructed to score as many points as they could while keeping a moderate intensity. The traditional session was also performed on the VirZoom bike to ensure resistance was kept the same. Participants were instructed to exercise at a moderate intensity.

Measures

Heart Rate

Heart rate was measured before and during each exercise session using a Polar H10 chest strap (Polar Electro, Kempele, Finland). HR was measured at the beginning of each session and every 4 minutes during exercise.

Rate of Perceived Exertion

Rate of perceived exertion was assessed using the Borg Scale (*6: no exertion* to *20: maximal exertion*) to provide a subjective measure of participants' exercise intensity (Borg, 1998). RPE was assessed at the beginning of each session and every 4 minutes during exercise.

Mood

Participants completed the Brunel Mood Scale before and after each biking session. The Brunel Mood Scale (BRUMS) is a 24-item questionnaire developed by Terry et al. (1999) in order to assess mood states. It has six subscales (i.e. anger, confusion, depression, fatigue, tension, and vigor). Each subscale has four corresponding mood descriptors (Terry et al., 1999). Participants were asked to describe how they were feeling for each mood descriptor at that moment on a 5-point Likert scale (*0: Not at all* to *5: Extremely*). The sum of each subscale was used to calculate a mood score.

Self-Efficacy

Participants completed a three-item questionnaire, developed by Gao et al. (2009), before and after each biking session to assess their exercise self-efficacy on a 5-point Likert scale (*1: strongly disagree* to *5: strongly agree*). Participants were asked to answer the questions: "When (VR or traditional) exercising biking… I have confidence in my ability to do well in this activity; I have confidence in my ability to learn skills well in this activity; and I have confidence in my performance in this activity" (Gao et al., 2009). The average of the three items was calculated for a self-efficacy score.

Enjoyment

Participants completed a five-item questionnaire adapted from Ommundsen et al. (2008) before and after each biking session assessing their enjoyment on a 5-point scale (*1: strongly*

disagree to *5: strongly agree*). Participants were asked to rate their answers to the following items: I have more fun exercise biking than doing other things; exercise biking is the thing I like to do best; I wish I could exercise bike more than I get the chance to; I usually prefer to watch rather than exercise bike; and I really like exercise biking on campus. The average of the five items was used for an enjoyment score.

Results

Participant Characteristics

Fourteen subjects were eligible to participate based on their age and anxiety and/or depression symptom severity. Participant characteristics are outlined in Table 1.

Table 1

Sample Characteristics

Sex	*n*	%	M	SD
Male	3	21		
Female	11	79		
Race-Ethnicity				
White-American	11	79		
Asian-American	1	7		
Hispanic-American	2	14		
VR Experience				
Yes	9	64		
No	5	36		
Age (y)			19.86	1.12
PHQ-9 Score (*n*)			8.73	2.63
GAD-7 Score (*n*)			9.93	3.79

Note. PHQ-9 = Patient Health Questionnaire; GAD-7 = Generalized Anxiety Disorder. PHQ-9 and GAD-7 scores range from 0 to 27 and 0 to 21, respectively. Mild to moderate symptoms are indicated with a score between 5 and 14.

Psychological & Physiological Measures

Paired sample t-tests were performed to compare traditional and virtual reality HR and RPE, as well as pre-exercise and post-exercise questionnaire scores for BRUMS (mood),

exercise self-efficacy, and exercise enjoyment. Results for paired sample t-tests comparing average HR and RPE are outlined in Table 2. There were no significant differences in HR or RPE between the exercise conditions.

Table 2

Paired T-Test Results of Average HR and RPE

	Traditional	Virtual Reality	p-value
HR	141.1 (16.7)	140.75 (14.5)	0.916
RPE	13.2 (0.98)	13.3 (0.96)	0.579

Note. HR = Heart Rate; RPE = Rate of Perceived Exertion. The numbers in parentheses indicate standard deviations. RPE is measured on a scale of 6 to 20.

The traditional exercise condition resulted in a significant decrease in the mood subscales of depression t (1,13) = 2.75, $p < 0.05$) and tension (t (1,13) =4.41, $p < 0.001$), and a significant increase in vigor (t (1,13) = -5.14, $p < 0.001$). The VR exercise condition resulted in significant decreases in anger (t (1,13) =2.80 $p < 0.05$) confusion (t (1,13) =3.02, $p < 0.05$), depression (t (1,13) =4.48, $p < 0.001$) and tension (t (1,13) = 6.05, $p < 0.001$), and a significant increases in vigor (t (1,13) = -5.15, $p < 0.001$). Self-efficacy significantly improved from pre-exercise to post-exercise (t (1,13) = -2.197 $p = 0.04$) during the VR exercise condition. However, there was no significant change in self-efficacy during the traditional exercise condition or enjoyment from pre- to post-exercise for either condition.

Table 3

Means and Standard Deviations of Mood, Self-efficacy and Enjoyment.

		Traditional	p-value	Virtual Reality	p-value
BRUMS					
Anger	Pre	1.29 (0.99)	0.102	1.64 (2.06)	< 0.05*
	Post	0.50 (1.61)		0.43 (0.76)	
Confusion	Pre	1.86 (2.70)	0.063	2.35 (2.95)	< 0.05*
	Post	0.86 (1.46)		0.79 (1.53)	
Depression	Pre	2.14 (2.38)	< 0.05*	2.93 (2.59)	< 0.001*
	Post	1.14 (1.41)		0.86 (1.46)	
Fatigue	Pre	6.2 (3.33)	0.334	6.07 (3.58)	0.634
	Post	7.00 (4.45)		5.57 (3.50)	
Tension	Pre	4.64 (3.52)	< 0.001*	5.43 (3.23)	< 0.001*
	Post	2.00 (2.83)		1.86 (2.28)	
Vigor	Pre	7.21 (2.75)	< 0.001*	7.64 (2.02)	< 0.001*
	Post	11.4 (3..50)		11.43 (2.93)	
Self-Efficacy	Pre	3.45 (0.72)	0.254	3.43 (0.61)	< 0.05*
	Post	3.51 (0.66)		3.71 (0.43)	
Enjoyment	Pre	1.94 (0.46)	0.303	2.01 (0.48)	0.082
	Post	1.80 (0.63)		2.19 (0.45)	

Note.*Indicates a statistically significant difference between pre-exercise to post-exercise score.

Discussion

Findings

The results indicate that although participants were exercising at a similar intensity between the two conditions, VR exercise elicited improvements in exercise self-efficacy and more subscales of mood than traditional exercise biking. These results are in line with previous findings from Zeng et al. (2017), which found an increase in self-efficacy in VR exercise biking with VirZOOM. The significant changes in mood also align with the results of a study from Plante et al. (2003), who found that fatigue and vigor significantly improved from VR exercise more than traditional exercise. A decrease in feelings of depression found in the present study

was also seen in previous studies on the effects of VR alone and its ability to increase dopamine levels (Li et al., 2016; Qian et al., 2020). However, a lack of improvement in exercise enjoyment is conflicting with the results of studies from Qian et al. (2020) and Zeng et al. (2017), who found VR exercise to elicit greater enjoyment scores than traditional exercise. These researchers found enjoyment to be most improved in those who had never experienced VR before, which was only a small portion of the sample in the current study. Another reason for an insignificant increase in enjoyment during the VR condition could stem from a misinterpretation of the questionnaire or a general dislike of exercise, even with the addition of a game.

The VR condition required users to use a more innovative form of exercise technology than a standard stationary bike. Greater improvements in self-efficacy may be the result of participants successfully using this equipment and completing objectives within the game. We speculate that improvement in a greater number of mood subscales during VR bike sessions may be due to the gamification of exercise. Since it is common to feel boredom while an individual engages in aerobic exercise such as cycling, adding ancillary tasks to a form of exercise and immersing users in a natural landscape may have distracted them from the negative feelings often associated with exercise (sweating, fatigue, pain, etc.).

Limitations & Future Directions

Research and results related to VR exercise are difficult to compare as there are a plethora of interfaces, games, and modalities that are considered VR. Research on the topic of VR exercise ranges from Avatar-based balance training to dancing, cycling, and boxing (Qian et al., 2020). Some VR systems employ a gaming component, while others simply simulate an alternative exercise environment. The greatest limitations of this study include the small sample size and the disproportionate number of females. Additionally, not all participants had the same

amount of time between the two bike sessions or performed their sessions at the same time of day.

Potential future research includes examining the effectiveness of VR exercise intervention study by having participants return for additional exercise sessions over the course of several months. This would give a better indication of the effect VR exercise has on symptoms of anxiety and depression, which are chronic and unlikely to change from single bouts of acute exercise. An additional adjustment could involve allowing participants to choose the game of their preference from the VirZOOM Arcade, which could lead to greater changes in exercise enjoyment from the VR condition.

Contextualization of Work

The present study has large implications on both college students and the general population who suffer from anxiety and depression. Seeing that simply changing the exercise environment can elicit greater psychological improvements means individuals can gain more benefits from exercise of similar intensity. VR also provides a change of scenery for those who may not be able to get outdoors, whether that be due to the climate, a disability, or an inaccessible built environment. Those who suffer from mild to moderate anxiety and depression are also going to have a more difficult time going into commercial gyms and spaces where this type of equipment is more readily available. Being able to switch into an immersive environment from the comfort of one's home makes exercise seem like a less daunting task.

We recognize that immersive VR equipment is still too expensive for most, with headsets alone costing over $400 (Statista, 2021). Users would also have to purchase a compatible system, games, and exercise equipment (although some would not require a bike, treadmill, etc.). Non-immersive VR, however, is a lower-cost option and an area of future research regarding the

impact it has on mood, enjoyment, and self-efficacy. Non-immersive VR involves the user having a recorded scene on a display that changes with the way the device is held; however, it is not mounted to the user's head to change with their point of view (Comparcini et al., 2023). This may provide an easier way for individuals to create an alternative exercise environment if they struggle to navigate technology or find immersive VR to be inaccessible.

The use of VR during exercise could also lead to improved adherence to exercise, which is known to be an effective behavioral treatment for individuals with anxiety or depression symptoms (Henriksson et al., 2022; Rebar, 2015; Recchia et al., 2022). With a greater enhancement in self-efficacy and mood, users of a VR exercise system are more likely to consistently partake in exercise. Increasing levels of physical activity can elicit better overall health and quality of life (An et al., 2020), which is advantageous for all - regardless of age or the presence of a mental illness.

Conclusion

College students suffering from mild to moderate symptoms of anxiety and depression can benefit from 20 minutes of exercise biking, despite the use of VR. While the physiological response was comparable between the two exercise conditions, VR exercise was more effective at enhancing mood and self-efficacy compared to traditional exercise. Further research is needed to determine differences in exercise enjoyment between traditional and VR exercise.

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