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Might virtual reality promote the mood benefits of exercise?

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Abstract

This study sought to investigate if virtual reality technology enhances the psychological benefits of aerobic exercise in a laboratory setting. In this study, 88 university faculty and staff (44 females, 44 males) were randomly assigned to one of three 30-min conditions including: (1) bicycling at a moderate intensity (60–70% maximum heart rate) on a stationary bicycle, (2) playing a virtual reality computer bicycle game, or (3) an interactive virtual reality bicycle experience on a computer while exercising on a stationary bike at moderate intensity (60–70% maximum heart rate). The Activation-Deactivation Adjective Check List (AD-ACL) was administered immediately before and after the laboratory session. Results suggest that virtual reality enhances some of the mood benefits when paired with exercise. Virtual reality when paired with exercise enhances enjoyment, energy, and reduces tiredness. Virtual reality without exercise was discovered to increase participants' tension, tiredness, and lower their energy level. Results suggest that the combination of virtual reality and exercise might improve some of the beneficial psychological effects of exercise compared with virtual reality or exercise alone.

Keywords: Virtual reality; Exercise; Mood

1. Introduction

Previous research has indicated that physical exercise enhances health including lowering the risks of developing certain types of cancer, cardiovascular disease, and other serious illnesses (Blair, Kohl, Paffenbarger, Clark, Cooper, & Gibbons, 1989; Brill, Kohl, & Blair, 1992; Gauvin & Spence, 1995; Kampert, Blair, Barlow, & Kohl, 1996; Plante, 1996). Research also demonstrates that exercise is associated with

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many psychological benefits including lowering depression, anxiety, and stress (Byrne & Byrne, 1993; Gauvin & Spence, 1995; Plante & Rodin, 1990; Thirlaway & Benton, 1992). Through repeated demonstrations, it has been noted that acute exercise has an anxiolytic effect on individuals (e.g. McAuley, Mihalko, & Bane, 1996). In their review of the literature, Landers and Petruzzello (1994) reported that the anti-anxiety effects of exercise begin almost immediately after acute exercise and last for a minimum of 2 h, regardless of exercise intensity or duration. As a result of recognizing that exercise plays an important role in both physical and psychological health, researchers have investigated the factors that may contribute to people engaging in and enjoying physical exercise (Smith, Handley, & Eldredge, 1998). Presently, a growing body of evidence promotes the use of physical exercise to improve both physical and psychological health and well being (Blair & Connelly, 1996; Winett & Carpinelli, 2000).

There are many theories attempting to understand the mechanisms regarding the benefits of exercise, yet there are many questions that still remain regarding how and why exercise enhances psychological functioning. Biological explanations suggest that exercise increases body temperature, adrenal and steroid activity, and stimulates the release of specific neurotransmitters such as endorphins (Hughes, 1984; Morgan, 1985, 1997; Ransford, 1982). Psychological approaches propose that exercise serves as a beneficial distraction (Long, 1983), meditation (Buffone, 1980; McAuley & Rudolph, 1995), biofeedback (Schwartz, Davidson, & Coleman, 1978), or a psychological buffer (Kobasa, Maddi, & Puccetti, 1982; McAuley & Rudolph, 1995), and can result in an increased sense of self-efficacy, mastery, and control (Bandura, 1977; Marcus, Selby, Niaura, & Rossi, 1992). Studies have shown that when manipulating the social environment of an exercise session, individuals in the socially enriched condition reported greater increases in self-efficacy and mood (McAuley, Talbot, & Martinez, 1999; Plante, Coscarelli, & Ford, 2001; Turner, Rejeski, & Brawley, 1997). Another theory suggests that a person's perception of fitness acts as a therapeutic or positive suggestion/perception that results in more positive psychological outcomes. Because we perceive fitness or exercise as beneficial for health and wellness, the psychological outcome of our exercise experience is thus enhanced (Folkins & Sime, 1981; Plante, 1999; Plante, Coscarelli, Caputo, & Oppezzo, 2000).

Human perceptions and beliefs have proven powerful in affecting both physical and psychological health and well being. Several investigations have demonstrated that health is enhanced through positive beliefs about health and benefits about fitness (Idler & Angel, 1990; Idler & Kasl, 1991; Shephard & Bouchard, 1994). Results of these and other investigations have proved so compelling that measuring perception and belief, for example, must be assessed and potentially controlled for by including placebo conditions in medical and psychiatric research protocols. With the knowledge that perception can positively affect health and well being, additional means of altering perception are being investigated to determine if altering perception can enhance positive health outcomes. Technology, such as virtual reality, currently offers one of the more promising avenues of exploration in this area.

Virtual reality is considered technology's answer to an alternate state of consciousness, and has proven useful in enhancing psychological health by altering perception and their resulting behaviors (Blascovich, 2001, 2002; Loomis, Blascovich, & Beall, 1999). The uses of virtual reality have broadened the scope of psychological treatment, such as in the treatment of phobias (e.g. acrophobia, agoraphobia, and social phobias; North, North, & Coble, 1998; Rothbaum et al., 1995; Wiederhold, 1999). The effects of virtual reality have also been examined using disabled persons who may be unable to participate in many exercises because of reduced mobility. For example, researchers used a virtual reality technique called augmented reality as a treatment for akinesia or freezing gait in Parkinson's disease (Weghorst, Prothero, Furness, Anson, & Riess, 1995). In this study virtual objects were projected into the patients' physical world to give them the impression that they were walking over or through these virtual objects (Andreae, 1996). Virtual reality provides a safe way for disabled persons to participate in tasks that would once have been hazardous or impossible to complete. Furthermore, virtual reality can provide corrective experiences that can alter attitudes and anxieties, yielding new insights into disease mechanisms and providing ingenious tools to perhaps re-enable disabled persons (Andreae, 1996).

Virtual reality is a technology newly adapted to interact with exercise. The reason for using virtual reality paired with exercise assumes that the user becomes immersed in an environment that portrays and simulates beneficial, familiar or novel visual/auditory stimuli (Smith et al., 1998). Combining virtual reality with usual exercise machines, such as the stationary exercise bike used in this experiment, may serve to enhance the psychological benefits of exercise. The additional psychological benefits may increase the chances of long-term maintenance of an exercise program, provide a sense of challenge and regulated competition, and generally result in a more enjoyable exercise experience (Smith et al., 1998).

The rapidly expanding field of virtual reality presents an alternative means of achieving improved psychological well being. In a previous study conducted by Plante et al. (in preparation), college students involved in a virtual reality paired with exercise experiment reported a positive impact on energy and tiredness tension. Results indicated that virtual reality may enhance the energy and tiredness levels of females even hours after participation in the exercise and virtual reality experience (Plante et al., in preparation). Thus, virtual reality appears to enhance the psychological reducing benefits of exercise for females more so than males, since females experienced more lasting psychological rewards when virtual reality was added to the exercise experience.

Since perception plays such an important role in affecting our physical and mental health, it may be assumed that virtual reality can be a successful means for altering these perceptions. As a result, virtual reality might have an important influence on the psychological effects of health behaviors such as exercise. Just as virtual exposure therapies aid in the treatment of phobias, perhaps virtual exercise might produce enhanced benefits to exercise regarding psychological health outcomes such as mood. The purpose of the present study is to investigate the effect of virtual reality exercise on the psychological aspects of mood such as tension, calmness, energy, and tiredness on a more heterogeneous population than college students. We expected that the effects of the virtual exercise experience would positively affect the psychological benefits of exercise. The study sought to expand upon previous research in this area to help us better understand the influence of both actual and virtual exercise on psychological functioning.

2. Materials and method

2.1. Participants

A sample of 44 male and 44 female university employees ranging in ages from 20 to 67 ($M=38.10$, S.D. = 12.31) participated in the study. Participants were obtained through solicitation via e-mail throughout the University. Each participant received a stipend of $40.00 for their efforts.

All participants were asked to abstain from exercise on the day of their participation in the study to assure that the results obtained were due to laboratory-based exercise, rather than field-based exercise.

2.2. Design

All research participants were randomly assigned to one of three 30-min conditions including: (1) bicycling at a moderate intensity (60–70% maximum heart rate) on a stationary bicycle, (2) playing a virtual reality computer bicycle game without actual exercise, or (3) an interactive virtual reality bicycle experience on a computer while exercising on a stationary bike at moderate intensity (60–70% maximum heart rate). Condition 3 combined the first two experimental conditions. A mood measure (the Activation-Deactivation Adjective Check List described later) was administered immediately before and after the laboratory session. A series of analysis of variance and analysis of covariance procedures were conducted to examine the research results.

2.3. Measures

2.3.1. Activation-Deactivation Adjective Check List (AD-ACL; Thayer, 1967, 1978, 1986)

The AD-ACL is a brief and frequently used self-report checklist designed to measure momentary mood states including, energy, calmness, tension, and tiredness. Sample items include placid, sleepy, fearful, quiet, and vigorous. Each adjective is scores on a four-point scale reflecting the degree to which the respondent agrees that the adjective reflects their current mood state. Thayer (1978, 1986) reports that the AD-ACL has adequate reliability and validity and has been validated and used in a number of psychophysiological and biopsychological investigations involving exercise. In the present study scores ranged from 2 to 21 with means for the four mood states ranging from 8.51 to 14.45 (S.D.s ranged from 3.17 to 4.44).

2.3.2. Marlowe Crowne Social Desirability Scale (MC-SDS; Crowne & Marlowe, 1960)

This scale is designed to measure social desirability or defensiveness and consists of 33 true–false statements (Crowne & Marlowe, 1960). Sample items include, “I like to gossip at times" and "I always try to practice what I preach." Items are scored using one point for each true of false item endorsed in the direction of social desirability or defensiveness. The Marlowe Crowne SDS has been found to maintain adequate internal consistency (KR-21 = 0.75) and construct validity (Crowne & Marlowe, 1960; Strahan & Gerbasi, 1972). In this study scores ranged from 4 to 28 with a mean of 15.36 (S.D. = 4.80).

2.3.3. Perceived Exertion Scale (PES; Borg, 1982, 1985)

The PES Scale was used to evaluate the participant's perceived level of exertion ranging from 6 constituting minimal exertion to 20 describing maximal exertion (e.g. 7 = very, very light; 15 = hard; 19 = very, very hard). General ratings of perceived exertion (RPE) were assessed using Borg's (1985) PES, which is frequently used in exercise research and has adequate reliability and validity (Borg, 1985). Test–retest reliabilities of this scale have been measured at 0.80 and higher, and it has been repeatedly demonstrated that this scale is valid for assessing perceived work intensity and exertion (Borg, 1985). The perceived exertion chart was placed directly in front of the participants in the exercise conditions, and they were asked to rate their exertion according to this scale. Scores in this study were recorded every 5 min and ranged from 6 to 19 with means at the different time periods ranging from 10.48 to 14.60 (S.D.s ranging from 1.71 to 2.98).

The last measure that was used in this experiment was a 10-point Likert scale, measuring the enjoyment each participant experienced during their laboratory session. The value of 1 indicated no enjoyment and a value of 10 indicated a high rate of enjoyment for the session.

2.4. Procedure

Participants volunteering in response to a campus-wide e-mail were recruited for the experiment. Participants were mailed a consent form, information about the study, and several questionnaires to complete. Two undergraduate female research assistants were used, each running half of the subjects. The research assistant then contacted the participants to schedule an appointment for the laboratory session. After a time was scheduled, the research assistant informed the participant of the place to meet, the proper exercise attire to wear, and reminded the participant to bring their previously completed forms to the session. On the day prior to the experiment, the researcher again contacted the participant reminding him/her of the appointment. Participants were also reminded to refrain from exercise on the day of the experiment.

Once in the laboratory the research assistant obtained the consent and other forms, and answered any questions. Next the participant was asked to complete the AD-ACL Short Form questionnaire. The participant's height and weight were then measured and recorded. Body Mass Index (BMI) was obtained from these measurements.

The participant was then randomly assigned to one of three conditions. The first condition was a biking condition. The participant was positioned on a Monark 818 Ergomedic stationary bike. Attached to the participant's earlobe was the sensor of a

Cat Eye Model PL-6000 heartbeat counter, used to measure the heart rate of the participant during the exercise session. As the participant commenced peddling on the bike, the start time was recorded. Each participant in this condition exercised on the bike for 30 min. Every 5 min following the commencement time, speed was measured and recorded in revolutions per minute or RPM's, heart rate was recorded, and the participant was asked how they evaluated their perceived exertion on the Borg scale ranging from 6 to 20. During all of the exercise sessions the participant was asked to keep their heart rate between 60 and 70% of the target heat rate for their age. If they deviated from this range, they were asked to either increase or decrease their pace in order to meet the 60–70% target heart rate criteria. There were a total of six recordings during each session, and in all three conditions, each recording was measured 5 min apart from commencement time. After the session was completed, the participant again completed the AD-ACL Short Form. The purpose of condition one was for baseline comparison examining the mood effects of moderate exercise administered without any virtual reality technology.

Participants who were randomly selected to participate in condition two, the virtual reality only condition, experienced the same assessment as participants in condition one. In condition two, participants played a virtual reality biking video game (Trek Extreme Mountain Biking, Head Games Publishing Company, 1999) on the computer using a 21-inch monitor. After filling out the first AD-ACL questionnaire and being measured for height and weight, the heart monitor was attached and the participant was asked to launch the game. Participants were then instructed to go to the main menu, choose practice, and then click on Single-Track racing. Each participant virtually raced against four other bikers and participants were given their choice of five tracks to race on. They also controlled which bike they used in the game, (eight choices possible), as well as which person would represent them. There was a choice from six male and six female bikers. Participants were instructed to hold the mouse button down to power the speed of the bike and shown how to steer using the computer mouse. Time was recorded at the point where the participant commenced controlling the biker in the video game. The research assistants then recorded in condition two, the heart rate of the participant every 5 min during the session. Following the 30-min session the participant was given the AD-ACL to complete again. The purpose of condition two was for another baseline comparison examining the mood effects of exercise virtual reality technology administered without any actual physical exercise.

The last condition, condition three, included the combination of the biking exercise with a virtual reality bike race shown on the same computer, and placed in front of the participant. The same bike used throughout the experiment was connected to the computer and participants who experienced this condition would participate virtually in a race with other bikers on the computer, by peddling on the real bike. This computer program from Ultra Coach VR Lite (Cycle FX, Model ITS-1, 2000), commenced when the participant began peddling on the bike, and time was recorded. Each participant was given the same visual image of a biker, who represented them on the computer. Again, every 5 min from the start time, the participant's heart rate, RPM's, and exertion level was measured and recorded by the researcher.

Also, the participant was instructed to exercise between 60 and 70% of their maximum heart rate. After the conclusion of the 30-min session the participant was asked to complete the AD-ACL Short Form. The purpose of condition three was to evaluate the mood impact of both moderate physical exercise accompanied by a virtual exercise experience and thus blended both conditions one and two mentioned earlier.

3. Results

3.1. Descriptive summary and baseline measures

Eighty-eight participants were included in the data analysis (44 males, 44 females). Means and standard deviations for age, heart rate, relaxation, RPM's, enjoyment of the experiment, self-reported exertion and social desirability by are provided in Table 1 by experimental condition and gender. Table 2 contains AD-ACL mood scores (i.e. energy, tired, tension, calmness) assessed before and after exercise participation by gender and experimental condition. A 2 (gender) by 3 (experimental condition) ANOVA was used to examine potential pre-experimental condition baseline differences in mood to insure that the groups were not significantly different regarding mood prior to the implementation of the experimental conditions. No baseline differences in energy, tension, calmness or tiredness were found between the four experimental groups or between the two genders (all P's > 0.05).

3.2. BMI, enjoyment, and social desirability results

A series of 2 (gender) by 3 (experimental condition) factorial ANOVA's were conducted with BMI, enjoyment, and social desirability as the dependent variables. There were no significant main effects or interactions for BMI (all P's > 0.05). A significant experimental condition main effect surfaced for enjoyment [$F(2, 86) = 5.87$, $P < 0.01$]. Tukey HSD post-hoc analysis found that participants reported enjoying the virtual reality and exercise combination the most relative to the other two experimental conditions. A significant main effect for gender was found for social desirability such that females reported being more defensive than males [$F(1, 86) = 6.41$, $P < 0.05$].

3.3. AD-ACL mood results

A series of 2 (gender) by 3 (experimental condition) between-subjects ANCOVA's were conducted on the AD-ACL mood sub-scales using social desirability as a covariate. The pre-experimental exercise or virtual reality baseline measurement (Time 1) for each AD-ACL mood score was also used as a covariate for each analysis. Following these analyses, the 2×3 ANCOVA analyses were conducted once more with enjoyment of the laboratory experience added as a third covariate. This allowed us to determine if enjoyment of the experience impacted the mood outcomes.

Table 1
Means and standard deviations for age, social desirability, heart rate, relaxation, enjoyment of the experiment, and self reported exertion[a]

	Male			Female		
	E	VR	E+VR	E	VR	E+VR
N	14	14	15	14	14	15
Age						
M	39.38	37.36	41.87	38.57	36.43	35.73
SD	13.3	13.28	13.39	12.95	11.14	12.14
Social desirability						
M	13.21	15.89	16.13	17.64	18.57	18.67
SD	5.27	6.01	5.84	4.8	7.08	6.03
Heart rate (bpm)						
M	130.2	65.31	138.11	129.76	71.74	130.38
SD	18.06	13.03	22.29	17.9	10.57	23.87
Exertion						
M	12.79		13.76	12.99		13.28
SD	2.27		2.33	2.38		2.02
Enjoyment						
M	6.67	6.14	7.87	6.79	5.27	7.67
SD	2.13	2.6	1.55	2.33	3.13	1.8
Relaxation						
M	3.4	4.64	3.27	2.71	5.57	3
SD	1.23	1.69	1.79	1.59	2.1	1.41

[a] E = exercise alone; VR = virtual reality alone; E + VR = exercise with virtual reality.

3.3.1. Energy results

While examining the post experimental (Time 2) AD-ACL energy scores, the between subjects ANCOVA revealed significant condition main effects and approached significance regarding gender main effects. Energy scores measured immediately following the experimental condition differed based on the exercise/virtual reality group assignment [$F(2, 86) = 4.21$, $P < 0.05$]. The subjects from the two exercise groups (exercise alone and exercise with virtual reality) experienced more energy immediately after exercise than participants of the condition containing virtual reality without exercise. Gender main effects approached significance [$F(1, 86) = 3.93$, $P = 0.051$] such that females tended to experience more energy in general across all three conditions following the experimental tasks.

3.3.2. Tired results

A between-subjects ANCOVA conducted on the time 2 AD-ACL tired scores revealed a significant condition main effect. The participants in the exercise and

Table 2
AD-ACL mood scores assessed before the experimental condition (time 1) and directly after the experimental condition (time 2)[a]

	Male			Female		
	E	VR	E+VR	E	VR	E+VR
Time 1						
N	14	14	15	14	14	15
Energy						
M	13.39	14.92	15.21	14.15	13.84	13.6
SD	4.22	2.29	3.58	3	4.14	4.27
Tiredness						
M	8.68	8.31	8.86	9.77	9.23	9.27
SD	3.58	2.78	4.61	4.4	3.54	3.24
Calmness						
M	10.96	10	11.36	10.15	12.69	11.2
SD	3.32	3.39	3.52	3.26	3.01	3
Tension						
M	9.07	8.77	8.82	7.46	6.54	8.67
SD	3.01	2.35	1.88	2.67	1.45	3.5
Time 2						
N	14	14	15	14	14	15
Energy						
M	14.71	14.15	16.46	17.31	15.38	17.26
SD	3.6	4.06	2.1	4.95	3.45	3.97
Tiredness						
M	8.89	9.23	7.71	8.38	8.69	6.6
SD	2.72	6.17	1.98	3.12	3.45	2.16
Calmness						
M	9.75	9.38	9.57	9.62	8	10.17
SD	3.87	4.21	2.31	2.9	3.11	3.16
Tension						
M	9.75	10.65	8.89	7.85	11.62	9.1
SD	2.56	3.82	1.86	1.82	3.71	2.21

[a] E = exercise alone; VR = virtual reality alone; E + VR = exercise with virtual reality.

virtual reality condition experienced the lowest level of tiredness relative to the other two experimental conditions [$F(2, 86) = 3.92$, $P < 0.05$]. However, these significant effects did not retain their significance when enjoyment levels were controlled for in a subsequent analysis (all P's > 0.05).

3.3.3. Tension results

A between-subjects ANCOVA conducted on the time 2 AD-ACL tension scores found a significant experimental condition main effect and a borderline significant interaction effect. The virtual reality condition alone (without exercise) resulted in more tension than either the exercise or exercise/virtual reality conditions [$F(2, 86) = 7.31$, $P < 0.05$]. Furthermore, a borderline significant interaction effect emerged [$F(2, 86) = 2.90$, $P = 0.06$] where females experienced more tension in the virtual reality alone condition. No significant main effects or interactions emerged for AD-ACL calm scores using ANCOVA for Time 2 (all P's > 0.05).

3.4. Relaxation results

A between-subjects ANCOVA for self reported relaxation scores revealed a significant condition main effect [$F(2, 85) = 16.24$, $P < 0.01$] and interaction effect [$F(2, 85) = 3.44$, $P < 0.05$]. Tukey HSD post-hoc analysis revealed that participants reported being more relaxed after the two exercise conditions relative to the virtual reality alone condition and these effects were more prominent among females (all P's < 0.05).

3.5. Perceived exertion results

A between-subjects ANCOVA on self reported exertion approached significance [$F(1, 55) = 2.90$, $P = 0.095$] where participants in the virtual reality and exercise condition tended to report higher levels of exertion than did participants in the exercise alone condition. However, when enjoyment was covaried out of this analysis the effect was lost ($P > 0.05$). There was a significant correlation between enjoyment level and the level of exertion displayed at measurement time 5 (25 min into the workout) and 6 (30 min into the workout), [$r = 0.30$, $P < 0.05$, $r = 0.41$, $P < 0.05$].

3.6. Actual exertion results

A between-subjects ANCOVA was conducted for revolutions per minute (RPM) during the two exercise conditions which found a significant condition effect [$F(1, 55) = 14.64$, $P < 0.01$]. Participants in the virtual reality and exercise condition performed more RPM's than did participants in the exercise alone condition. When enjoyment was co-varied out this effect remained [$F(1, 54) = 10.56$, $P < 0.01$].

4. Discussion

The purpose of the present study was to examine whether virtual reality exercise enhances the psychological benefits of aerobic exercise. It was predicted that the virtual exercise experience would positively effect the psychological benefits of exercise. Our results suggest some support for our hypothesis as virtual reality generally enhances the psychological benefits when paired with actual exercise.

Participants in either exercise condition (with or without virtual reality) experienced more energy and relaxation as well as less tension immediately after exercising relative to the virtual reality without exercise group. This generally supports the notion that exercise (with or without virtual reality) improves mood immediately following an exercise experience (e.g. Gauvin & Spence, 1995; Plante & Rodin, 1990). Exercise with virtual reality resulted in the least tiredness and the most relaxation, exertion, and RPM's relative to the other groups. The virtual reality alone condition resulted in the highest level of tension relative to the two exercise groups. Virtual reality without exercise also resulted in higher tiredness scores and lower energy scores relative to the two exercise groups. Thus, exercise in general resulted in increased psychological benefits as many previous studies have demonstrated (e.g. Byrne & Byrne, 1993; Gauvin & Spence, 1995; Plante & Rodin, 1990; Thirlaway & Benton, 1992). These benefits became more pronounced when virtual reality was added to the exercise experience which supports the findings that surfaced in an earlier study by Plante et al. (in preparation) using college student research participants. Furthermore, the virtual reality exercise condition resulted in more exertion (as measured by RPM's on the bike and not perceived exertion) and was found to be the most enjoyable and some of the significant benefits gained from virtual reality exercise (i.e. tiredness and self-reported exertion) were lost when enjoyment level was controlled for in the data analysis. This suggests that enjoyment level plays an important role in the mood benefits of exercise. Overall, virtual reality provides additional psychological benefits of exercise but some of this value added appears to be due to the enhanced enjoyment of the experience.

The psychological effects of exercise appear to be more prominent among females which was also found by Plante et al (in preparation). Females experienced more energy across all three experimental conditions in the current study. Females were more tense than males during the virtual reality alone condition and they also experienced more relaxation following both exercise conditions.

There are several possible explanations for these gender differences. Females may have experienced greater psychological benefits in the virtual reality condition due to the novelty of the virtual reality stimuli. Males, in general, tend to play more video games and therefore expose themselves more to virtually enhanced computer experiences (e.g. Cowan et al., 2000; McClure & Mears, 1984). The graphics and sophistication of the virtual reality used in this study may not have been advanced or compelling enough to capture the attention or interest of the males and thus may have resulted in a smaller mood effect relative to females. Females were perhaps more attentive and therefore more influenced by the virtual reality software because they may have had less exposure to similar stimuli. However, this is speculative since previous experience with computer games and virtual reality was not assessed in this study.

In general, females admit to vulnerability more than men do (Goldsmith & Flynn, 2000). This may be another possible explanation (other than habituation to virtual reality and computer games) for why females experienced more tension during the virtual reality alone condition compared to men. However, our results statistically controlled for social desirability to combat self-presentation bias.

Results suggest that exercise in general provides psychological benefits and that virtual reality included in an exercise experience may further enhance at least some of these mood benefits of exercise. Our results also indicate that the enjoyment of the exercise experience may play an important role in the benefits attained from the exercise experience. Although speculative, exercise paired with virtual reality may also lead to enhanced motivation and drive to maintain an exercise program. Aside from the potential psychological benefits, virtual reality exercise may enhance the compliance to an exercise program.

Although our results are encouraging they must be viewed cautiously. The sample size of the current study was modest ($N=88$) but was more heterogeneous than a sample of college students used in previous research (Plante et al., in preparation). The study was conducted in a research lab resulting in limited generalizability. Encouraging results supporting our hypothesis were found on several but not all of the dependent measures. Another limitation of the study was that it examined the immediate effects of exercise. Therefore, we cannot conclude that the psychological benefits obtained from the experimental group are long lasting. However, previous research has demonstrated that the mood effects of exercise (regardless of the length and intensity) last for at least 2 h (Landers & Petruzzello, 1994). Furthermore, the virtual reality experience used in this study may not have been compelling enough and may have resulted in a lack of attention particularly for males who tend to be more familiar with computer games. Finally, a number of analyses were conducted given the sample size and thus the possibility of Type I error should be considered. This is especially true given the fact that some of our results approached but did not reach statistical significance at the 0.05 level.

Future studies should incorporate a larger and more diverse sample. Future research should evaluate the long-term psychological effects of exercise and virtual reality exercise. It may also be useful to examine how clinical populations (e.g. depressed, anxious, disabled) respond to virtual reality exercise as well. It may also be helpful to use more advanced virtual reality equipment, such as total head immersion. However, to our knowledge, this technology has yet to be developed and made available. It may be beneficial to also include a questionnaire regarding the participant's familiarity with computer games. This could allow for familiarity to be controlled for to determine if benefits still remain.

Future research in this area is important to better understand the factors that contribute to the psychological benefits of exercise. Furthermore, if virtual reality exercise truly improves the psychological benefits of exercise, then it may be possible to use this technology to help people maximize the psychological benefits of exercise. Virtual reality exercise may also prove to assist those who are injured, disabled or those in harsh weather conditions to benefit from exercise. Although speculative, people who are incapable of physical exercise may be able to reap the psychological benefits of exercise through a virtual exercise experience without physically exercising.

Perceptions can influence health and health behaviors (Idler & Angel, 1990; Idler & Kasl, 1991; Plante, 1999; Shephard & Bouchard, 1994). Virtual reality has proven useful in enhancing health through the alteration of one's perception and resulting behavior (Loomis et al., 1999; North et al., 1998); therefore virtual reality may very well enhance the psychological benefits of exercise. Our results provide some support for this theory but also generate more questions than answers. Future research will hopefully help us to better understand the potential benefits of virtually assisted exercise.

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