Does Virtual Reality Enhance the Management of Stress When Paired With Exercise? An Exploratory Study

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The purpose of the present study was to assess the psychological benefits of virtual reality paired with aerobic exercise in a laboratory setting. In this study, 154 introductory psychology students were randomly assigned to 1 of 4 20-min conditions (a) walking outside around campus, (b) walking on a laboratory treadmill combined with virtual reality to experience both virtual and actual exercise, (c) walking on the laboratory treadmill without virtual reality, and (d) experiencing a virtual walk with virtual reality without actual exercise. Our results suggest that virtual reality may enhance some of the psychological benefits of exercise when paired with actual exercise under certain conditions.

KEY WORDS: exercise; stress; virtual reality

Previous research has demonstrated that exercise enhances both physical and mental health. These health benefits associated with exercise include preventing some forms of cancer, cardiovascular disease, osteoporosis, hypertension, lipid abnormalities, diabetes mellitus, obesity, and cerebrovascular disease, as well as anxiety and depressive illnesses (e.g.,

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Cohen & Baum, 2001; Plante, 1996; Schaie, Leventhal, & Willis, 2002). For example, longitudinal walking programs have demonstrated positive gains in aerobic fitness and lower blood pressure, improvements in lipid profile, increases in bone density, and enhanced mood states (Shepard, 1997).

Not only does regular exercise result in many health benefits, but studies have demonstrated that exercise enhances psychological well-being. However, while researchers are still unsure of exactly how and why exercise plays an important role in enhancing psychological functioning, there is substantial evidence supporting the use of physical exercise for improving mood and well-being (e.g., Plante, Coscarelli, & Ford, 2001; Winett & Carpinelli, 2000). Similar to the research on the physical benefits of exercise, psychological benefits can be achieved through 10 to 15 min of daily physical exercise (e.g., Hansen, Stevens, & Coast, 2001; Nabetani & Tokunaga, 2001). In fact, exercise at any intensity has been shown to improve psychological well-being (Berger & Owen, 1998).

Research has also demonstrated that exercise can improve many psychiatric problems such as lowering depression, anxiety, and stress (Nabetani & Tokunaga, 2001; Spano, 1999; Whiteley & Winett, 2000). For example, in one study examining sedentary ethnic minority women, exercise-related improvements were shown to decrease depressive mood and increase vigor after 5 months from the initial 7-week exercise program (Lee et al., 2001). Cross-sectional and longitudinal research has consistently indicated that aerobic exercise has antidepressant and anxiolytic effects. The anxiolytic effects derived from exercise buffer stress and improve both physical and mental health (Salmon, 2001). Exercise provides clinicians with another treatment option to help improve psychological functioning (Bartholomew, 1999; Salmon, 2001).

Although exercise may clearly have many mental and physical health benefits, Americans are generally inactive, which results in a higher incidence of illnesses such as obesity, diabetes, and heart disease (Whiteley & Winett, 2000). Two thirds of American adults do not get the recommended amount of exercise, and one fourth does not exercise at all (Taylor, 2003). Americans should partake in moderate exercise for 30 min a day everyday of the week (Center for the Advancement of Health, 2000). Factors that inhibit physical activity must be investigated to improve the lives of Americans and reduce the costs of preventable health problems. Environmental factors can play an important role in hindering the desire and ability to exercise. Weather, light, and traffic can all affect the exercise experience. Those reporting cost, weather, and personal barriers to physical activity are less likely to exercise, thus increasing their sedentary behavior (Salmon, Owen, Crawford, Bauman, & Sallis, 2003). Additionally, studies have shown seasonal variation affects both outdoor and indoor activities, with considerably less activity during weather months (Uitenbroek, 1993). Developing creative interventions, such as using virtual reality technology with exercise, that reduce the negative effects of weather and uncomfortable seasons on physical activity might be one way to solve some of the motivational barriers to exercise activity.

It has been observed that individuals who exercise in an enriched environment with a variety of positive visual and auditory stimulation report greater improvement in self-efficacy and mood (McAuley, Talbot, & Martinez, 1999; Plante et al., 2001; Turner, Rejeski, & Brawley, 1997). This suggests that exercise-related self-efficacy and mood can be manipulated, and that these changes are related to the affective social and environmental experience associated with exercise. This may have important implications in terms of enhancing exercise adherence and enjoyment (McAuley et al., 1999). In one study that examined the psychological outcomes of participants exercising in three diverse environmental conditions—in which two conditions were hygienically and aesthetically unsatisfactory environments and one was defined as hygienically and aesthetically pleasing—results demonstrated that exercising in operationally defined excellent conditions reduced state anxiety and negative affect (Jaervekuelg, Neissaar, & Viru, 2001). Another study reported that patterns of endocrine and associated emotional change through exercise differed when environmental setting and attention focus were altered, supporting the notion that setting, attention, and cognitive appraisal may alter the emotional experience associated with physical exercise (Harte & Eifert, 1995).

Biological explanations alone cannot fully explain the relation between physical exercise and emotional health and well-being. The correlation between the two may be due to the use of exercise as a form of meditation, distraction, or biofeedback; a psychological buffer from stress or as a method to obtain social support; and an increased sense of mastery, control, and self-efficacy (Plante, 1999; Spano, 1999). Several theories also propose that a person's perception of exercise and fitness acts as a therapeutic or positive suggestion/belief that results in more positive psychological outcomes. Thus, because individuals perceive fitness or exercise as valuable for health and wellness, the psychological outcome of the exercise experience is enhanced (Folkins & Sime, 1981; Plante, 1999; Plante, Coscarelli, Caputo, & Oppezzo, 2000).

If environment greatly affects participation in physical activity and psychological outcomes such as mood, would a manipulated environment be more agreeable and successful in leading people to experience some of the psychological benefits of exercise? Virtual reality is one technique to control environmental effects. By analyzing a variety of fields that incorporate virtual reality, simulated environments have been shown to improve therapy sessions (Annesi, 2001; Maltby, Kirsch, Mayers, & Allen, 2002). Today, virtual reality environments have been incorporated into a variety of clinical and everyday settings to improve mental health and to enhance well-being. For example, by simulating specific environments and images, therapists can use virtual exposure as an adjunct to cognitive–behavioral therapy with their patients to cope better with phobias (Botella, Villa, Banos, Perpina, & Garcia-Palacios, 1999; Maltby et al., 2002; Wiederhold, Gevirtz, & Wiederhold, 1998; Weiderhold & Wiederhold, 2000).

Exercise is just one of many areas in which virtual simulation may improve mental and perhaps physical health. Though the technology is still new, virtual reality in conjunction with exercise allows users to become immersed in an environment that simulates familiar or novel visual/auditory stimuli (Botella, Perpina, Banos, & Garcia-Palacios, 1998). When combining virtual reality with exercise machines (e.g., a treadmill or exercise bike), enhancement of the psychological benefits of exercise may result. A virtual walk coupled with actual exercise indoors can potentially allow people to experience similar mood benefits achieved with outdoor exercise by enhancing the exercise experience. In addition to mood benefits, people may be more likely to continue to exercise if it is combined with virtual reality (Nigg, 2003; Plante, Aldridge, Bogdan, & Hanelin, 2003). For example, one experiment demonstrated that adherence to exercise and attendance in a fitness center was significantly higher in a paired virtual reality condition than in exercise conditions without virtual reality (Annesi & Mazas, 1997). Thus, these additional psychological benefits from virtual reality may increase the likelihood of achieving outdoor mood benefits, maintaining an exercise program, and participating in a more enjoyable overall exercise experience.

The purpose of this experiment was to examine the effect of virtual reality exercise on mood. Our hypothesis was that virtual exercise would (a) enhance the psychological well-being of participants, (b) produce positive mood benefits similar to actual exercise, and (c) enhance the actual exercise experience. These mood benefits were accessed by the Activation–Deactivation Adjective Check List (AD-ACL; Thayer, 1967, 1978, 1986). The AD-ACL is a reliable and valid self-report checklist designed to measure momentary mood states during and after exercise measuring energy, calmness, tension, and tiredness.

METHOD

Participants

A sample of 154 introductory psychology students (52 men and 102 women) participated in this study. Participants were informed that the experiment required light to moderate exercise. All participants attended an orientation session prior to participating in the experiment and were given credit for their participation after the experiment was completed. They were asked to refrain from exercise on the day of the experiment to ensure that the results obtained were due to laboratory and experimental conditions, rather than recreational or field-based exercise. Those who reported to have engaged in some form of strenuous exercise on the day of the study were excluded from data analyses.

Measures

AD-ACL

The AD-ACL (Thayer, 1960, 1978, 1986) is a brief and frequently used self-report checklist designed to measure momentary mood states including, energy, calmness, tension, and tiredness. Sample items include the following adjectives: *placid, sleepy, fearful, quiet,* and *vigorous.* Each adjective is scored on a 4-point scale reflecting the degree to which the respondent agrees that the adjective reflects his or her current mood state. Thayer (1978, 1986) reported that the AD-ACL has adequate reliability and has been validated in a number of psychopsysiological and biopsychological investigations involving exercise. In the present study scores ranged from 5 to 20, with means for the four mood states ranging from 8.02 to 12.35.

Marlowe-Crowne Social Desirability Scale (MC-SDS)

The MC-SDS was 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 or false item endorsed in the direction of social desirability or defensiveness. The MC-SDS has been found to maintain adequate internal consistency (Kuder Richardson-21 = .75) and construct validity (Crowne & Marlowe, 1960; Strahan & Gerbasi, 1972). In this study scores ranged from 2 to 27, with a mean of 14.63.

Procedure

Participants volunteered for this experiment to fulfill requirements for their general psychology undergraduate classes. Each participant attended a 30-min orientation meeting in which he or she completed a consent form and several questionnaires, and where each received information about the study. At the end of the orientation session, participants also signed up for a day and time to participate in the laboratory session. The research assistants informed the participants of the meeting place and proper exercise attire to wear, and requested that participants refrain from exercise on the day of their participation. The day prior to the experiment, the researcher contacted the participants reminding them of the research appointment, again what to wear, and to avoid exercise on the day of the experiment.

Once in the laboratory, the research assistant measured and recorded the participant's height and weight. A body mass index (BMI) was obtained from these measurements. Participants were then asked to complete the AD-ACL Short Form questionnaire that measured energy, tiredness, calmness, and tension.

Participants were then randomly assigned to one of four conditions. The first condition included a 20-min brisk outdoor walk. The weather conditions were fairly constant, and no participant was made to walk in rainy weather or at night. In this condition, participants were given a map of the predetermined route around campus and asked to complete the walk in about 20 min. To achieve this goal, participants needed to walk about 3 miles per hour (mph). After the walking session concluded, participants again completed the AD-ACL Short Form.

Condition 2 combined virtual reality with walking on the laboratory treadmill (Quniton Q50 Series 90). The virtual helmet (V8 Head Mount Display;Virtual Research Systems, Aptos, California) was used in this experiment and completely encompassed the participants' visual and audio fields, only allowing participants to see and hear what was going on in the virtual video. The helmet is somewhat like a football helmet. However, the participant can only see what is electronically posted onto a small computer screen in the helmet. The video was designed to follow the same route around campus that walkers in Condition 1 completed. The video was also recorded by research assistants on a sunny day. Therefore, the participants experienced a virtual walk around campus via the helmet almost as if they were watching a VCR or television screen that encompassed their entire visual field.

Participants who were randomly selected to participate in Condition 2 experienced the same assessment process as those in Condition 1. The researcher helped the participants put on the virtual helmet and adjusted it for comfort while standing on the unmoving treadmill. Then, after participants were told to hold onto the treadmill safety bar, the research assistant started the treadmill and the participants commenced walking. The virtual reality video was then turned on, and the participants went on a virtual walk around campus. The participants walked under these circumstances for 20 min at a fast walking pace adjusted for height differences. The speeds ranged between 2.7 and 3.5 mph: 2.7 mph for the shorter participants and up to 3.5 mph for the taller participants, thus enabling each participant to experience similar physical exertion. After the exercise session was completed, the participants completed the AD-ACL Short Form.

Condition 3, the control condition, consisted of walking on the treadmill without any virtual reality technology. No visual stimulus was presented before the walk to the participants who were randomly selected for this condition. The treadmill used was the same throughout each condition, and the measuring and recording procedures completed by the researchers were the same as well. Speed was again adjusted to height, and participants walked for 20 min on the treadmill. After the conclusion of the exercise session, the participants completed the AD-ACL Short Form.

The last condition, Condition 4, was the virtual-reality-alone condition. The same video and virtual reality helmet used in Condition 2 were used in this condition. The participants completed the AD-ACL Short Form, and the standard measurements for each condition were recorded by the researcher. The participants then sat down in a chair in the laboratory, and the experimenter helped the participants put on and adjust the virtual helmet for comfort. All participants sat in the same chair in the same place in the laboratory. The experimenter then started the virtual reality video, and participants experienced a virtual walk for 20 min. After the session ended, participants completed the AD-ACL Short Form.

RESULTS

Data from 154 (102 women and 52 men) participants were included in analyses. Means and standard deviations for age, BMI, enjoyment of the experiment, and social desirability are provided in Table 1 by experimental conditional and sex; means and standard deviations for energy, tiredness, tension, and calmness (pre- and postexperimental conditions) are provided in Table 2.

Baseline Differences

A series of 2 (sex) × 4 (experimental condition) between-subject analyses of variance were used to examine potential preexperimental condition baseline differences in mood, BMI, and social desirability to ensure that there were no significant differences across groups prior to the implemen-

Table 1. Means and Standard Deviations for Body Mass Index (BMI), Enjoyment, and Social Desirability by Condition and Sex

Condition	Women		Men	
	M	*SD*	*M*	*SD*
Outside				
BMI	21.09	2.66	24.58	3.71
Enjoyment	7.38	1.79	7.27	1.27
Social desirability	14.40	5.84	14.59	6.58
Laboratory with virtual reality				
BMI	23.54	3.34	24.13	2.27
Enjoyment	5.67	2.37	5.69	1.80
Social desirability	14.40	5.20	15.12	2.99
Laboratory				
BMI	22.42	3.14	25.25	2.35
Enjoyment	6.00	1.96	6.23	2.09
Social desirability	15.02	6.03	13.50	6.53
Virtual reality video				
BMI	23.61	4.83	23.46	3.39
Enjoyment	6.07	2.30	5.73	2.46
Social desirability	15.90	4.68	12.85	4.58

tation of the experimental conditions. No baseline differences in tension, calmness, or tiredness were found between groups (all *p*s > .05). A baseline difference in energy emerged for men, $F(3, 46) = 3.50$, $p < .03$. Tukey post hoc analyses revealed that men exercising in the laboratory started with significantly higher energy scores than those who were watching the video. No significant differences existed regarding social desirability.

Mood Directly Following Exercise

Within-Subject Analyses

Paired-sample *t* tests (baseline mood–mood following exercise) were used to assess changes in mood following exercise for both sexes within each experimental condition. After exercising outside, men significantly decreased in tiredness, $t(10) = 2.38$, $p < .05$, and nearly significantly decreased in tension, $t(10) = 2.02$, $p < .10$. After exercising outside, women gained significantly more energy, $t(24) = –6.76$, $p < .01$, while also experiencing less tiredness, $t(24) = 5.60$, $p < .01$, and less calmness, $t(24) = 2.69$, $p < .05$. Women exercising in the laboratory with virtual reality experienced significantly less tiredness, $t(24) = 3.21$, $p < .01$. Women exercising in the laboratory experienced significantly less tiredness, $t(24) = 2.91$, $p < .01$, and tension, $t(24) = 3.65$, $p < .05$. Women watching the video lost energy, $t(24) = 2.50$, $p < .05$.

Table 2. Means and Standard Deviations for Energy, Tiredness, Tension, and Calmness by Condition and Sex

	Women		Men	
Condition	*M*	*SD*	*M*	*SD*
Outside				
Energy 1[a]	11.24	3.60	10.91	3.27
Energy 2	15.50[b]	2.83	12.90	3.20
Tiredness 1	12.88	4.26	11.18	4.96
Tiredness 2	8.62[b]	3.05	8.55[b]	4.57
Tension 1	9.32	3.40	8.82	2.27
Tension 2	8.85	3.08	7.27	2.15
Calmness 1	10.84	3.33	12.09	1.45
Calmness 2	8.65[b]	2.74	10.27	4.08
Laboratory with virtual reality				
Energy 1	12.13	3.40	12.77	3.27
Energy 2	13.21	3.74	12.08	4.05
Tiredness 1	12.33	3.32	10.38	3.91
Tiredness 2	10.38[b]	3.37	11.23	3.85
Tension 1	8.67	2.53	9.38	2.06
Tension 2	9.42	2.99	8.31	2.39
Calmness 1	10.79	2.69	11.23	1.92
Calmness 2	9.63	2.70	10.07	3.38
Laboratory				
Energy 1	11.12	3.00	13.54	3.23
Energy 2	11.92	3.20	14.00	2.12
Tiredness 1	13.52	3.63	10.23	3.90
Tiredness 2	11.48[b]	3.93	8.92	3.04
Tension 1	8.68	2.79	8.15	2.58
Tension 2	7.36[b]	2.74	7.12	1.80
Calmness 1	11.16	2.81	10.77	2.39
Calmness 2	10.32	2.48	10.50	2.60
Virtual reality video				
Energy 1	10.96	2.94	9.77	3.39
Energy 2	9.15[b]	4.04	8.60	2.87
Tiredness 1	13.17	4.18	12.54	4.50
Tiredness 2	13.93	4.08	14.40	3.33
Tension 1	7.93	2.33	8.08	2.43
Tension 2	7.63	2.87	7.20	2.62
Calmness 1	12.43	3.50	12.15	2.70
Calmness 2	13.69	3.79	12.87	3.40

[a] The 1 reflects scores at baseline and 2 reflects scores immediately following the experimental condition. [b] Number reflects significant difference in mood from baseline condition using within-subject paired sample *t* tests.

Between-Subjects Analyses

A series of 2 (sex) × 4 (experimental condition) analyses of covariance were conducted on mood levels directly following exercise. Baseline mood scores and social desirability were used as covariates in all analyses. Whenever significant effects were found, they were followed by Tukey post hoc analyses to detect when the significant differences occurred.

Energy. Following the experimental conditions for men, a significant main effect for energy occurred with men, $F(3, 50) = 7.86$, $p < .01$. Participants in all three exercise conditions (outside, in the laboratory, and in the laboratory with virtual reality) experienced greater energy than in the virtual-reality–alone condition (all ps $< .05$). A significant main effect for energy also occurred for women, $F(3, 99) = 16.13$, $p < .01$. Women in all three exercise conditions had greater energy than those in the virtual-reality-alone condition directly following experimental conditions (all ps $<$ .05). Furthermore, women exercising outside experienced greater energy following exercise than those who exercised in the laboratory ($p < .01$).

Tiredness. A significant main effect for tiredness following exercise emerged for men, $F(3, 50) = 5.93$, $p < .01$. Men exercising outside or in the laboratory experienced significantly less tiredness than men watching the virtual reality video. A significant main effect for tiredness occurred among women as well, $F(3, 99) = 5.95$, $p < .01$. Women exercising outside experienced less tiredness following exercise than those who exercised in the laboratory ($p < .05$). Women exercising outside and men exercising in the laboratory with virtual reality experienced less tiredness following experimental conditions than did men who watched the virtual reality video ($p <$ .05).

Tension. No significant results for tension emerged among men. For women, a significant main effect for tension occurred, $F(3, 99) = 3.21$, $p <$ .05. Women exercising in the laboratory with virtual reality experienced more tension than did those who exercised in the laboratory only ($p < .10$).

Calmness. No significant results for calmness were found for men. The women, however, experienced a main effect related to calmness, $F(3, 99) = 14.19$, $p < .01$. Following the virtual-reality-alone condition, women experienced more calmness watching the virtual video than in all three exercise conditions ($p < .05$).

DISCUSSION

The main purpose of this experiment was to examine whether virtual reality exercise enhances or simulates the psychological benefits of aerobic exercise. It was predicted that virtual reality paired with actual exercise would positively affect the psychological and stress-managing benefits of exercise. Virtual reality alone (without actual exercise) was investigated to determine if it would elicit similar benefits to that of actual exercise. Our results suggest some support for our hypotheses as virtual reality enhances psychological benefits when paired with actual exercise in certain conditions.

Our results for both sexes suggest that increased energy levels are more likely to occur with actual exercise than with virtual reality exercise. Our data suggest that actual physical exertion from exercise results in increases in perceived energy levels even after 20 min of exercise. This supports the notion that exercise, even for only brief intervals, produces increased vigor and positive mood benefits immediately after an exercise session (Hansen et al., 2001; Plante, 1999). Although, our results did not indicate that virtual reality alone increased energy, when combining virtual reality with exercise the energy levels of the male participants did increase as well. However, we cannot claim that the virtual reality experience is what caused the increase in energy levels and that this effect was not from the exercise alone. Overall, the experimental results provide some evidence for virtual reality benefits that can be applied to the exercise experience. However, the virtual reality paired with actual laboratory exercise condition did not result in the most significant and positive changes in mood relative to the other conditions.

Our findings demonstrate that women generally gained greater mood benefits from outdoor exercise than from any of the indoor or virtual reality exercise conditions in this experiment. This may suggest that women's moods are more affected by their surrounding environment than are men's. Because the outdoor walk was scenic, the environment may have positively enhanced the psychological mood benefits of exercise in the female sample compared with the male sample. The only positive benefit derived from the virtual-reality-alone condition was an increase in calmness for the women.

Additionally, our results suggest that women participating in outside exercise and exercise paired with virtual reality in the laboratory showed no significant differences in their energy levels. The results demonstrated that for these two conditions, the women gained equivalent increased levels of energy. The implications for these findings suggest that women can alternately use virtual reality paired with indoor exercise to gain equivalent increased energy levels if outdoor exercise is unavailable or undesirable. This supports similar findings by Annesi and Mazas (1997), which demonstrate that adherence and attendance to an exercise regimen was significantly higher in the virtual reality exercise condition than in the exercise alone condition. This finding suggests virtual reality may enhance the exercise experience under some conditions.

Contrary to our findings among women, only two of the men's psychological mood scores were found to be significant. Following exercise outside, our results indicate that tiredness in men was significantly decreased after the exercise session. This may suggest that the actual physical exertion occurring in exercise decreases tiredness in men. Additionally, men experienced a significant main effect for energy in all three exercise conditions, with or without virtual reality. These findings show that exercise itself may create these effects, while the virtual reality video or outdoor stimuli might have enhanced the individual effects of exercise.

Furthermore, men exercising in the laboratory were observed to experience a decrease in tension following the exercise session, although the results were not significant. An alternate implication from the results that approach statistical significance might indicate that men were not experiencing an appropriate level of engagement, duration, intensity, or enjoyment. Additionally, the virtual stimulus they encountered in this experiment may not have provided enough novel stimuli. From a technological standpoint, energy levels may have also been unaffected by the virtual reality equipment because of an inadequately simulated exercise experience.

Results must be viewed with caution because of the small sample size used in this experiment. Most notably, the male population could be increased in future studies. Additionally, the homogeneous population of healthy undergraduate students attending school in California may have also affected the outcome of this study. Experiments comprising clinical populations (e.g., depressed, anxious, and disabled) should also be explored for possible benefits from virtual reality exercise. Future studies should also investigate the duration of psychological benefits occurring in all conditions. Furthermore, increasing the duration and intensities of the exercise and virtual reality conditions could lead to more pronounced psychological reactions. However, previous research with college students has found that regardless of exercise intensity, participants tend to feel better after exercising (Berger & Owen, 1998).

Regarding technological considerations, the virtual reality experience should present a more realistic environment with increased ergonomic and tracking features. Finally, perceptions have been shown to influence health and health behaviors, thus virtual reality may be useful in enhancing health through altering one's perception and resulting behavior (Loomis, Blascovich, & Beall, 1999; North, North, & Coble, 1998). Therefore, virtual reality could possibly enhance the psychological benefits of exercise. Our results offer some support for this theory, but future research will hopefully help researchers better understand the potential benefits of virtually assisted exercise.

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