Virtual Augmented Exercise Gaming for Older Adults

PAUL VAN SCHAIK, Ph.D.,1 JONATHAN BLAKE, M.Sc.,2,3 FRED PERNET, MBA,3 IAIN SPEARS, Ph.D.,4 and CLIVE FENCOTT, Ph.D.2

ABSTRACT

This paper details the design, development, and testing of virtual augmented exercise (VAE) gaming for older adults. Three versions of an underwater VAE environment were tested with a sample of 22 healthy adults aged 50 or over. Participants strongly preferred VAE to traditional physical exercise, and adherence rate was 100%. The findings suggest that VAE with puzzles changes or negates the expected negative associations among exercise outcomes. Fitness level was not associated with performance in the game, irrespective of VAE type, indicating that persons who are less physically fit can expect to perform similarly to those who are more physically fit. In conclusion, the research found some evidence for the benefits of VAE with cognitive exercise (solving simple puzzles and hitting targets based on the answer). This type of exercise appears to be a promising method of exercise for older adults.

INTRODUCTION

THE CURRENT RESEARCH PROJECT investigates the effectiveness of virtual augmented exercise (VAE) as an emerging technology that can help promote physical activity and combine the strengths of indoor and outdoor exercise. By creating a strong sense of agency in a virtual environment (VE) that interacts with exercisers, distraction can be taken to greater levels while retaining the benefits connected with exercising indoors, shifting focus from negative to positive thoughts about exercise. Recent findings on young participants show that virtual reality (VR), when paired with exercise, enhances mood, thus increasing enjoyment and energy.1 However, the tremendous potential of such environments has yet to be explored for older adults.

Although the combination of computer game technology and exercise bicycle exists already (see, e.g., Plante et al.1), to date the combination has primarily been used as a tool that gives game players a novel way to interact with video games. This project takes a different approach by instead using video game technology as a tool to encourage a sensible workout regime in line with recent developments in “exergaming” products, such as the Eyetoy, Dance Dance Revolution and Maya Personal trainer. The aim was to design and optimize VAE, with specifically designed VR content in the form of a computer game for older adults who are not elite athletes. For this purpose, three versions of the same underwater VE were developed to promote distraction and enhance presence during physical exercise. Tests were conducted in a controlled environment in or-
der to eliminate or at least reduce the effects of external factors on test outcomes.

**METHOD**

*Research design and participants*

A repeated measures design was used to assess the effect of different types of game activity in an underwater VE on exercise outcomes. A sample of 22 healthy adults (12 male, 10 female) aged 50 or over was recruited through local advertisements. The following three types of game activity were used (see Figure 1a, 1b, and 1c): following targets within the VE by altering cadence, selecting and following targets to answer puzzles not related to VE content by altering cadence, and selecting and following targets to answer puzzles related to VE content by altering cadence. For each condition, smaller targets, with no puzzles associated, were used among the actual targets as approximate guides to their positions. In both puzzle conditions, statements were visually presented to the participants in addition to two targets, one representing agreement with the statement (that they would have to pedal faster to hit) and the other disagreement (that they would have to pedal slower to hit). A Latin square was used to counterbalance the order of game activity. A non-VAE control group was not included because the research aimed to optimize VAE rather than compare VAE with non-VAE.

Outcome measures included perceived mood, perceived exertion, presence, perceived duration of exercise (compared to actual duration of exercise), and final performance (based on success at “hitting targets”). In addition, physical fitness, potentially related to outcome measures, was measured.

*Materials and equipment*

An industry-standard recumbent exercise bicycle was used, interfaced using a serial-port interface with a PC (NVIDIA GeForce4 graphics card, Intel Xeon CPU 2.66GHz, and 2GB RAM) with an LCD 12-inch TV display (PAL format, resolution 720 x 568 pixels) on which the exercise computer game ran. The VE represented an underwater seascape with participants’ power output and cadence controlling their height from the seabed.

Three versions of the VE were created, each with a different type of game activity, integrated with physical exercise. In the target-following version, on the display a target appeared in the distance and participants had to adjust their cadence to alter the height of their avatar in the environment so that it would travel through the target. If this maneuver was successful, then a reward was presented on the display as well as through an audible signal. In the nonrelated-puzzle version, two targets appeared in

![FIG. 1. Virtual augmented exercise display. (A) Target following. (B) Nonrelated puzzles. (C) Content-related puzzles.](image-url)
the distance and an arithmetic puzzle appeared on the screen. The participants’ task was to solve the puzzle and adjust their cadence to hit the target corresponding with the correct answer. In the related-puzzle version, the task was to solve a puzzle related to VE content and adjust cadence to hit the target corresponding with the correct answer.

The following psychometric scales were used: the Borg scale to measure rate of perceived exertion (RPE) (range: [0; 20] for each subscale),3 the Profile of Mood States-Short Form (POMS-SF) (range: [6; 20]) for each subscale,4 and the IP Group Presence Questionnaire (IPQ) (range: [−3; +3] for each subscale).5

Procedure

At the beginning of all exercise sessions, the participants’ blood pressure was again measured and they completed the POMS-SF. They were also asked to indicate how much sleep they had the night before the session, and it was ascertained that they had not felt unwell since their previous session. Next, participants were fitted with a heart rate monitor. Participants were tested in three following exercise sessions in three consecutive weeks, each time exercising with a different version of the VE (targets, nonrelated puzzles, related puzzles) (see Figure 1). Time and day were the same for each session in order to negate their possible influence on outcomes.

Measurements taken from the exercise bicycle (such as heart rate, cadence, and power) were sampled five times per second over the 22-minute duration of each exercise session, and the data were stored on a computer. After each exercise session, participants estimated the amount of time they had been exercising, indicated their feelings of fatigue using the Borg scale, and completed the POMS-SF and presence questionnaire. On their last session, they were also asked to indicate whether they preferred using the VAE bicycle to a traditional exercise bicycle and to rank the three VAE versions in terms of preference.

RESULTS

Effect of type of VAE

Participants underestimated the duration of their exercise sessions by, on average, 38% irrespective of type of VAE. A repeated measures analysis of variance showed that the effect of estimation (estimated versus actual duration) was significant, \( F(2, 21) = 118.55, \) very large effect size, \( \eta^2 = 0.77, p < 0.001. \) The effect of VAE type on rate of perceived exertion, \( F(2, 42) = 1.31, p > 0.05, \) and on performance in the game (measured as a score at the end of an exercise session), \( F < 1, \) was not significant.

The effect of VAE type on spatial presence was significant, \( F(2, 42) = 3.81, \) medium effect size, \( \eta^2 = 0.10, p < 0.05. \) For spatial presence, the difference between nonrelated puzzles (mean = 0.57; SD = 1.62) and both target following (mean = −0.28; SD = 1.47) and related puzzles (mean = 0.24; SD = 1.25) was close to significance, both \( 0.05 < p < 0.10, \) demonstrating a tendency toward less spatial presence for VAE with nonrelated puzzles.

Analysis of covariance, with pre-exercise score and participant as covariates, showed that the effect of VAE type on confusion was close to significance, \( F(2, 61) = 2.91, \) \( 0.05 < p < 0.10, \) and confusion appeared to be higher with nonrelated puzzles (mean = 3.27; SD = 0.98) than in the other experimental conditions (mean = 2.68; SD = 0.84).

There was a strong preference for the VAE bicycle over a standard exercise bicycle, mean = −2.82 (where −3 indicated the strongest possible preference for VAE and +3 the least preference), SD = 0.50. Furthermore, the adherence rate was 100% in all participants. Exercise with nonrelated and related puzzles was most frequently chosen as the most preferred VAE type (9 times each), followed by exercise with target following (4 times). Exercise with target following was most frequently chosen as least preferred (17 times), followed by exercise with related puzzles (4 times) and exercise with nonrelated puzzles (once).

Association between outcomes and participants’ characteristics

Fitness level (measured as estimated VO\(_2\) max) was not significantly correlated with performance in the game. However, the correlation of performance with estimated duration of exercise was significant, but only with target following, \( r = −0.53, p < 0.05; \) that is, better performance was associated with shorter estimated duration.

The correlation of preference for type of exercise (degree to which VAE was preferred over using a traditional exercise bicycle) with performance in the game and fitness level was not significant. These results support the notion that those who are fitter and perform better do not judge VAE more favorably.

DISCUSSION AND CONCLUSION

Overall, our results indicate that participants welcomed VAE irrespective of their fitness level and ex-
Exercise performance. VAE was preferred over standard exercise, and there was complete adherence with the VAE programmed. VAE types with puzzles were most preferred, and target following was least preferred.

Participants underestimated their duration of exercise, irrespective of VAE type. Therefore, all types of VAE were effective at distracting exercisers. Spatial presence was affected by VAE type and tended to be lower with nonrelated puzzles, and confusion appeared to be higher with nonrelated puzzles. Therefore, nonrelated puzzles may reduce the development of a spatial-visual model of the VE.

The result that fitness level was not associated with performance in the game is encouraging because it indicates that those who are less physically fit can expect to perform similarly well to those who are more physically fit. Likewise, the lack of correlation of performance with perceived duration with VAE with puzzles (related or nonrelated)—but not with (standard) target following—suggests that those who have more negative perceptions of their exercise session can still expect to perform similarly to those who have more positive perceptions. These findings suggest that VAE exercise with puzzles changes or negates the negative associations between performance and estimated duration. Puzzles (related and nonrelated) seem advantageous in terms of being more “equitable” for those with lower performance and those with more negative perceptions of exercise (in terms of duration).

Previous research claimed that the combined use of VR and exercise resulted in better psychological outcomes than the use of VR or physical exercise alone. The findings from the current project build on this claim and suggest that cognitive exercise (solving simple puzzles and hitting targets based on the answer) during physical exercise, as opposed to target following without additional cognitive exercise, can break the negative link between perception of time spent exercising and performance by increasing distraction from physical exercise.

In conclusion, the research found some evidence for the benefits of VAE with cognitive exercise (solving simple puzzles and hitting targets based on the answer). This type of exercise appears to be a promising method of exercise for older adults.

ACKNOWLEDGMENT

The research was support by a grant from the Centre of Digital Excellence CODEWORKS.

REFERENCES


Address reprint requests to:
Dr. Paul van Schaik
Psychology Section
School of Social Sciences and Law
University of Teesside
Borough Road, Middlesbrough, TS1 3BA, UK

E-mail: p.van-schaik@tees.ac.uk