Effects of Acute Aerobic Exercise on Short Term Memory

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Abstract

College students are constantly damaging their short term memory through high risk behavior such as consuming alcohol (Ryback, 1971). It would be much more beneficial for students' studies if the students performed memory improving tasks instead. This paper details an experiment testing the affects of acute aerobic exercise on short term memory. Three groups of participants, 19-22 year old students, were asked to memorize and recall a set of flashcards: the control group did no physical exercise and memorized, the during group exercised for 5 minutes on a stationary bike and then memorized, and the after group memorized while exercise biking. After card memorization, the participants were allotted a mandatory 5 minute break and then asked to recall the flashcards. No significant difference was found in the number of cards correctly memorized between any of the groups. The results showed the control group had a significant difference between their baseline beta wave electroencephalogram (EEG) readings and the beta waves while recalling the flashcards. Furthermore, females were found to have a significantly higher difference between resting and recall mean absolute value of EEG beta waves than males. Experimental limitations require further study to elucidate the effects of acute exercise on short term memory.

Introduction

Graduate and professional schools, as well as employers, have put great pressures on college students to do well in school and maintain a high grade point average. Students often struggle with retaining difficult information they are learning for an exam. Caffeine, herbal

supplements, and energy drinks which contain sugar and a combination of caffeine and vitamins offer students an unhealthy option to try to improve memory. Caffeine has been shown to cause disruption of sleep and anxiety, and in combination with alcohol has been a cause of death (Grus, 2003). However, a healthy and possible natural alternative for improving memory is emerging and currently being studied: exercise. We hypothesize an improvement in memory test performance following brief aerobic exercise compared to no exercise.

It is commonly known that exercise reduces heart disease, increases weight loss, strengthens muscles including the heart, and improves overall health. What is less known is that exercise may increase memory. In a study performed on a group of male shift workers with a median age of 32, moderate exercise was shown to improve the recall of a previously studied list of words (Potter and Keeling, 2005). Another study showed rats that were running on a treadmill had higher numbers of dendritic intersections with concentric rings than sedentary rats which is evidence of more brain activity in the rats that were exercising (Lin et al., 2012). A prior study of rats provided evidence that exercise increases brain-derived neurotropic factor (BDNF) mRNA/protein in the perirhinal cortex compared to the hippocampus while in non-exercising rats, the BDNF was higher in the hippocampus. Elevated levels of BDNF in the perirhinal cortex correlated to better memory for the rats (Hopkins et al., 2011). Although the study presented in this paper will not examine the mechanism by which exercise affects memory, exercise biking could result in elevated levels of BDNF in the perirhinal cortex which may be the underlying factor causing improved memory. In contrast to the studies mentioned above, Stroth and colleagues concluded from their study on exercise in young adults that verbal memory is unaffected by exercise (Stroth et al., 2009).

Little research has been done on the short term memory of either gender of college age students. Experiments analyzing the effect of acute exercise on long term memory in young adults show that the sequence of exercise and a memorizing task mattered in improving long term memory; performance on long term memory test improved the most when participants had memorized items after exercise (Labban and Etnier, 2011). The research presented in this paper will discuss the effects of moderate aerobic exercise on college students' short term memory. The moderate aerobic exercise in this study will be five minutes of stationary biking with the subjects' heart rate within the training heart rate as determined by the American Heart Association, which can be found in the "methods" section (American Heart Association). Based on the results from previous studies, we expect that the performance on memory tests will increase when the memorization task is immediately following exercise (as oppose to during the exercise or with no exercise).

Methods

Subjects and Ethical Approval

A total of 18 participants were chosen between the ages of 19 and 22. The participants were University of Wisconsin- Madison students who volunteered after hearing about the study from word of mouth. The participants were randomly chosen to participate in one of the three different groups. The participants did not have any health issues affecting their cognition or ability to raise their heart rate. The participants were randomly divided into three groups: control, memorization after cycling, and memorization during cycling. All participants signed a consent form which stated confidentiality and requirements for the experiment (Appendix A).

Experimental Tests Performed

Heart Rate

Each participant's heart rate was monitored using a NONIN Incorporated heart rate monitor in order to maintain consistency in the aerobic exercise among participants. If the participant was placed into a group in which exercise was required, the participant was required to keep his/her heart rate above 100 beats per minute (bpm). The 100 bpm was determined from the American Heart Association's formula for maximum heart rate and the definition of aerobic exercise as being 50% to 85% of the maximum heart rate:

Maximum heart rate (MHR) = 220 – age

Lower bound of target heart rate = MHR * 0.50

Upper bound of target heart rate = MHR * 0.85

Participants placed into a group requiring no exercise also had their heart rates monitored in order to be sure it was below their target exercising heart rate.

Electroencephalography

To measure brain activity and different types of brain waves, electroencephalography (EEG) was used. An EEG data was obtained for each participant using Biopac software. Three EEG leads were attached to the participants head, two behind the right ear and one on the right earlobe. A silicon swim cap was used to keep the EEG leads in place.

EEG data included data for all three types of brain waves (alpha, beta and gamma) as well as overall brain activity. Beta waves were of special interest to this experiment because they are associated with cognitive tasks including learning and memory (Bastien et al., 2000). Baseline measurements during rest and recall periods were examined in order to compare possible changes in beta wave activity during memorization.

Recall Test and Reaction Time

A memory test involving flash cards was used to determine directly if exercise had an effect on short term memory. During the memorization part of the test, participants were shown 15 flashcards with a car logo and the company name for 20 seconds per card (Figure 1).

After a rest period of 5 minutes, during which participants were allowed to think and talk as they wished, a recall test was performed. Participants were shown 15 similar flashcards with the exception that these flashcards included only the car logo and no company name. The participants were asked to recall the company as fast as possible (Figure 1). A maximum recall period of 10 seconds per card was allotted after which the participant's response was considered incorrect.

Two measurements of memory were obtained from the recall test. The first measurement was the number of correctly recalled cards for each participant, which was recorded to determine if memorization of the flashcards increased with exercise. The second measurement was the recall time and was used to determine if exercise caused faster recall (and therefore better memory).

Experimental Groups

Participants were randomly divided into three groups with 6 participants in each group, 3 males and 3 females. All tests were administered by the investigators.

Group 1: Control Group

Participants sat at rest for the duration of the experiment. EEG leads and a heart rate monitor were placed on the participant at the beginning of the experiment. Participants performed the previously described memory test while sitting.

Group 2: Experiment Group – Memorization during exercise

EEG leads and a heart rate monitor were placed on participants as they sat at rest on a Schwinn Ergonometer. Participants were asked to begin biking. Once their heart rate rose above 100 bpm, the memorization task began. After memorization, participants dismounted the bike and sat at rest for 5 minutes. The recall test was then administered.

Group 3: Experimental Group – Memorization after exercise

Group 3 was included to control for possible distraction that exercise could cause during memorization. EEG leads and a heart rate monitor were placed on participants as they sat at rest on a Schwinn Ergonometer. Participants were asked to begin biking at a moderate intensity so that their heart rate rose above 100 bpm. After the target heart rate was obtained, participants exercised for a 5 minute period while keeping their heart above 100 bpm.

Participants dismounted the bike and performed the same memory test as the control group after the five minute exercise period.

Data and Statistical Analysis

The mean absolute value of the baseline beta amplitude was calculated from EEG data for each participant as well as the mean absolute value of the recall beta amplitude. The difference between these two measurements was calculated.

The total number of correctly recalled company names was calculated for each participant. Also, the average recall time for correctly recalled company names was calculated for each participant.

Analysis of data was performed on R software and using ANOVA tests. Correctly recalled company names, average recall time, and difference in beta waves was compared between groups and p-values were obtained. Also, analysis of the beta wave amplitude between males and females was performed.

Upon further examination of data, it was found that there were two obvious outliers who recalled significantly more company names than other participants (RS, a control participant who recalled 14 companies, and JW, an experimental participant who, after exercise, recalled 15 companies). Statistical analysis was performed again omitting these two outliers.

Results

The effects of exercise biking on memorization of flashcards were examined. The mean of correctly recalled flashcards for the control group was 7.6, the during group was 7.83, and the after group was 5.5. There was no significant difference between the number of correctly recalled flashcards across the three groups tested ($p = 0.904$, Figure 2). There was also no statistical significance in the magnitude of the beta waves during recall across the three groups ($p = 0.8341$). However, the control group showed a significant difference between their baseline beta wave EEG readings and the beta waves while recalling the flashcards ($p = 0.0217$, Figure 3). The difference between resting and recall mean absolute value of beta wave amplitude was calculated for all participants in the study, and females were found to have significantly higher values than males ($p = 0.020765$, Figure 4). Heart rate was monitored for all participants , and all of the participants, who were required to exercise, had values within the prescribed range of above 100 and below 170 (Figure 5).

Discussion

Based on the observed p-values for number of cards correctly recalled and the magnitude of beta waves, the hypothesis, that acute aerobic exercise increases working memory, is not supported by the data obtained from this experiment. Further experiments should be performed in order to elucidate the relationship between exercise and memory. Some suggestions for further directions and improvements on this experiment are described as follows.

In order to make a more convincing conclusion, a study involving a greater number of subjects should be conducted. Furthermore, the subjects should be random – all subjects in this study, although randomly assigned to experimental conditions, were students at UW-Madison either in Physiology 435 or friends/roommates of the investigators. A larger number of participants randomly selected from a university population would be an improvement for a similar study in the future.

Second, there are better options for memory tests. In the study presented, the memorization test consisted of memorizing flashcards with car logos and car companies, and then attempting to recall the car companies when shown a separate set of cards with no company name. Although foreign and obscure car companies were selected for the test, it became apparent that some participants were already more familiar with cars and car companies than other participants. In order to create a more controlled experiment, in which the memorization test is novel to all participants, a different test should be used. Other previously used memory tests include the free recall test (Coles and Tomporowski, 2008), which would control for previous knowledge by requiring participants to recall as many objects as possible from a common list. Using such a test may present more novel stimuli to each participant and thus give better data.

The set up of the study could also be improved. Due to the time allotted for this experiment, six different participants were used in each of the conditions. This did not control for memory differences naturally occurring between people – some people innately have better short term memory than others. A methodological change that would control for these memory differences among individuals would be to have each participant complete each of the three

manipulations and analyze if the participant's memory improved with exercise. If, across all participants, memory increased after exercise, a convincing conclusion could be drawn.

Another consideration is the amount of time for exercise. Due to time constraints, the participants in this study exercised for a total of five minutes after their heart rate rose to 100 bpm or greater. This period of exercise was perhaps not adequate enough to observe a difference. Even though there is no time period defined for acute exercise, previous experiments involving acute exercise include exercise periods ranging from 10 minutes to 2 hours (Hamer et al., 2006). If this experiment is to be repeated in the future, a longer period of exercise should be used.

Also the participants performed the memory test during a noisy laboratory class period with many auditory, visual and other stimuli around them. The environment could have distracted the participants from the memory task at hand. There was no way to discern if distraction was due to exercise (the two manipulations with exercise were included to see if exercise might distract from memorization) or due to the uncontrolled environment. An improvement for future experiments would include performing the entire experiment in a controlled environment with no extra external stimuli to prevent outside distractions from affecting the test.

A significant finding in our experiment was discovered in a comparison of all participants in the study. The difference between resting beta wave mean absolute value and the recall beta wave mean absolute value was calculated and compared between male and female participants. It was found that females had a larger difference between their resting and recall beta wave amplitude than males did. This finding does not support our hypothesis and arose from data and statistical manipulations, but it does provide an interesting basis for further studies. Sex

differences in physiological measurements are of special interest in research and it would be interesting to examine the sex differences in difference EEG waves during certain activities.

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Figures and Legends

Figure 1: Figure 1 shows one of the fifteen car logos used that were pasted on note cards. The logo on the left with the company name was used for memorizing, and the logo on the right was used for memorization test.

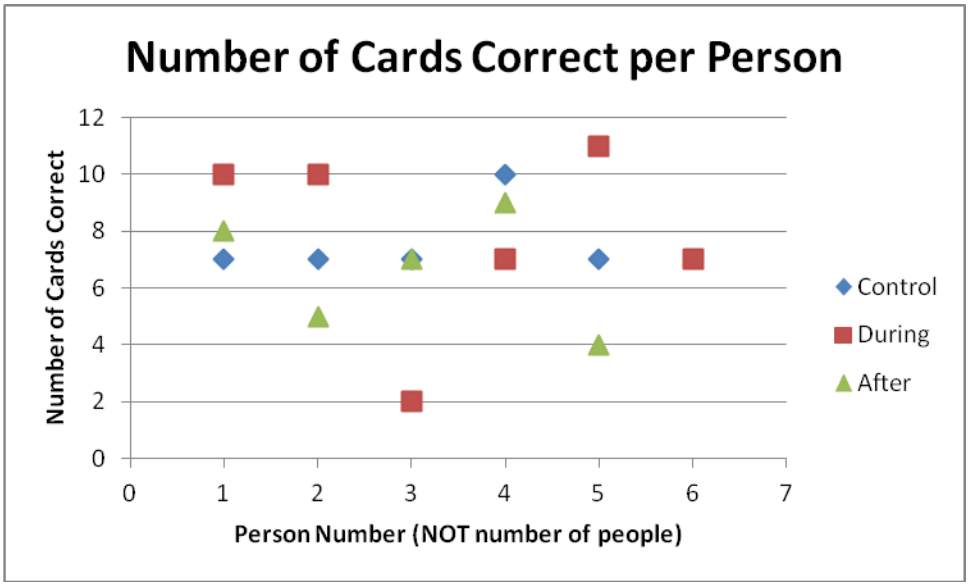

Figure 2: Figure 2 shows the number of cards correct for all of the participants (excluding the 14 and 15 card outliers). The x-axis corresponds to the person number (there were 5 people tested for the control and the after group, and 6 people tested for the during group). The y-axis corresponds to the number of cards that were correctly answered. The p-value ($p = 0.904$) indicates there is no significant difference between exercise and recall of the cards as evident in this graph.

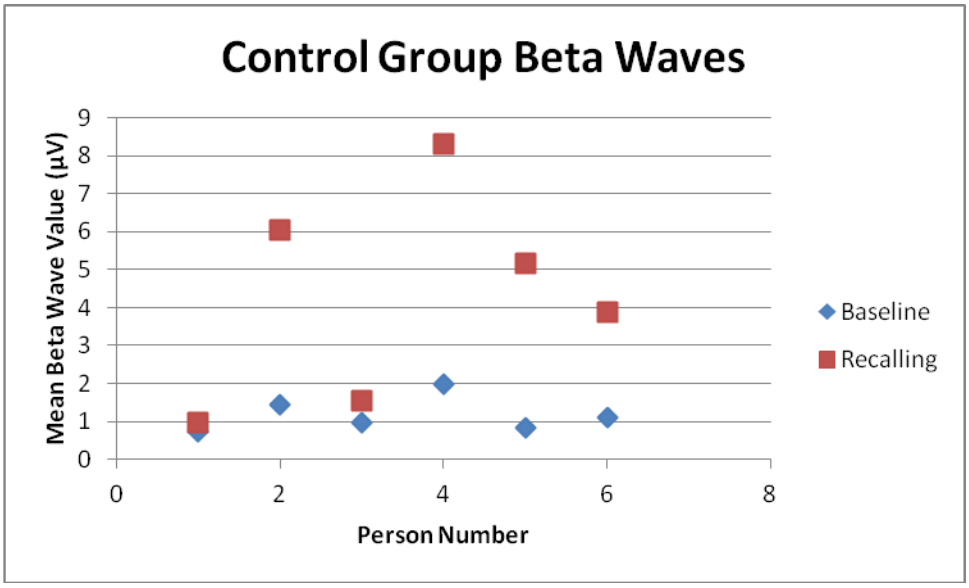

Figure 3: Figure 3 shows the control group's beta waves both at rest and during recall of flashcards. The p-value (p = 0.0217) shows a significant difference between rest and recall as evident in the graph.

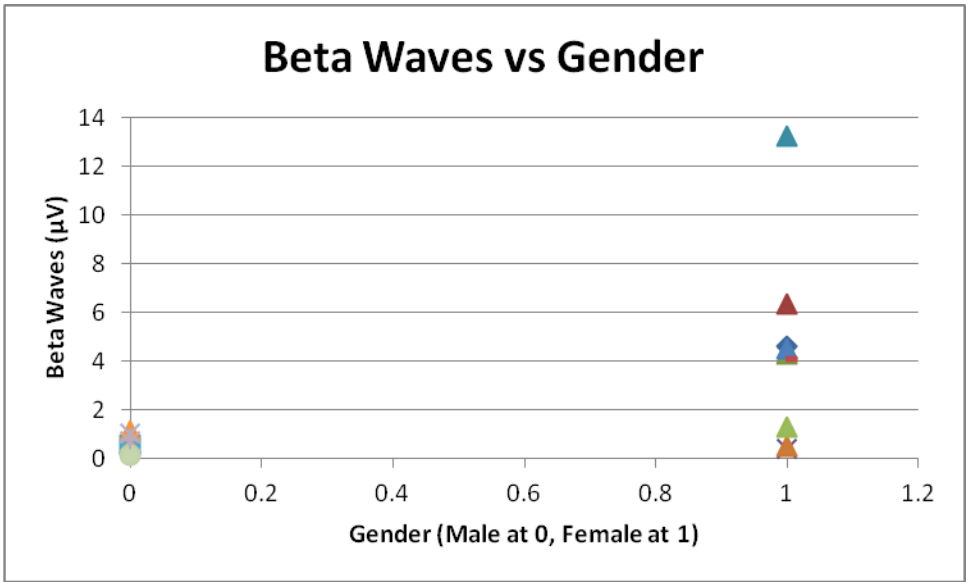

Figure 4: Figure 4 shows a plot of beta waves versus gender where males are plotted at x=0 and females at x=1. The beta wave value used in the graph is the difference between resting and recall mean absolute value for each participant. The p-value (p = 0.020765) indicates a significant difference in the mean absolute value difference between male and female, and the female have considerably higher values.

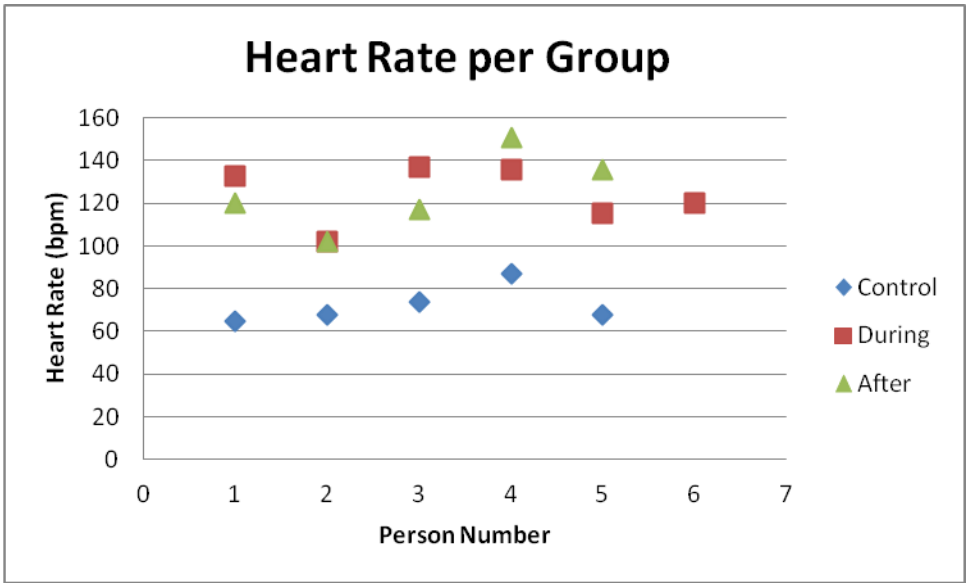

Figure 5: Figure 5 shows heart rate for each participant (excluding the outliers). The x-axis corresponds to the person number (there were 5 people tested for the control and the after group and 6 people tested for the during group). The y-axis corresponds to the heart rate of the person.

Appendix A

Consent to Participate in this Student-Led Research Project

On this date of _____ I, _____, hereby allow the students of Physiology 435 to utilize the data collected during their experimental testing.

The purpose of this experiment is to investigate the effect of acute aerobic exercise on short term memory. The identity of all participants will be kept confidential.

The experiment will require all participants to perform a memory task in which they will be asked to memorize twenty car logos. The final part of the experiment will require participants to perform a recall test of the car logos. Depending on the experimental group, participants may be required to complete ten minutes of moderate aerobic exercise (50 to 85 percent of maximum heart rate, as determined by age). Heart rate will be monitored during the entire exercise period. Participants will also be required to where an EEG monitor during the entire experiment, so as to get both baseline readings and experimental readings.

I acknowledge and agree that I am healthy enough and physically fit enough to complete these measurements/experiments without undo physical harm to myself.

Signature_____