The Effects of Moderate Aerobic Exercise on Memory Retention and Recall

Lab 603 Group 1

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Key Points Summary

- We hypothesize that aerobic exercise increases the ability to learn, memorize, and reaction time, due to stimulation of the hippocampus and cardiovascular system.
- Increase of long term and short term working memory can both be studied via recall of information including pictures or phrases.
- In this study we focused on whether aerobic exercise increases college age student's ability to recall a series of pictures over the course of a week.
- The results will enable us to better comprehend the consequences that exercise can have on learning and memory, and to educate college students on the benefits of exercise.

Word count: 102

Abstract

Previous literature has emphasized the importance of exercise on cognitive function and memory. Exercise is an accessible tool available to anybody that can improve memory retention. Stress is a common occurrence in the atmosphere on the UW-Madison campus, and makes it a struggle to make time to participate in exercise. Our study will focus whether exercising college students are more able to recall flashcards in a memory test, in hopes of encouraging more physical activity. Subjects were divided into two groups; a control group of non-exercising subjects, and a treatment group of exercising subjects. Twenty flash cards were presented to each subject (either sitting or on an exercise bike) in 5 second intervals, afterwards subjects were asked to determine which twenty cards they saw out a random mix of forty. Short-term and long-term memory were both of interest so we tested recall accuracy three times; once right after the initial exposure, another 2-3 days after, and the final test was 7-10 days from initial exposure. We did not find any significant differences between the exercising group and control (non-exercising) group. We did however note that the exercising group had higher accuracy of recall of the flashcards after a 7-10 day period, although this was not significant. Even though our study failed to encounter significant results, adjustments to our current study have the potential to yield results similar to the literature. Suggestions, including longer test duration and a more formal exercise routine, have been proposed and considered in the conclusion.

Abbreviations

HR, heart rate; BP, blood pressure; BDNF, brain derived neurotrophic factor.

Introduction

A healthy lifestyle has been a major concern in our society. Kids are being encouraged to be active, adults are being instructed on what to eat and college students are constantly being advised by their parents and other adults to get enough sleep. Sleep, water, diet and exercise are some of the most controllable aspects of living a healthy lifestyle. The average college student usually has a multitude of homework, studying, and various other stressors to consider on top of being active. Only one fifth of college students take part in moderate exercise suggesting that exercise is not a priority to many college students (Carels, 2002). Aside from improving physical health, exercise has been shown to positively impact memory retention (Alves, 2011). If exercise engages the brain and enables stronger recall ability, heading to the gym may become more appealing for students. Studies on the subject of exercise and memory retention have presented many hypotheses, results, and designs in measuring the effect on exercise (Etnier, 2011) (Alves, 2011). These experiments have been considered and have helped us to shape the approach to our study.

According to the Center for Disease Control and Prevention only 18% of young adults are meeting the Physical Activity Guidelines (Frieden, 2010). Physical activity is widely believed to improve overall health, physical appearance, and internal workings of our body. The brain is a key organ that physical activity can affect. It can enhance cognitive functions and in response to physical activity, can maintain and even improve those functions (Masley, 2009).

Previous research has compared different age groups and the effects of physical activity on cognitive performance. One of the most commonly studied groups have been young adults due to large populations and a demand for research participation on college campuses (Arcelin, 1997). Reaction time has offered interesting results in cognitive performance. One study has

shown a 9.1% decrease in reaction time in the aerobically exercising group, compared to the control (Masley, 2009). Memory retention is a valuable and very important skill for young adults, especially in the college setting. Studying for exams, taking notes in class, and listening to presentations, all in a high stress environment is enough to overwhelm students. With such a large bank of information, students must process the important pieces to remember.

The hippocampus was found to be the main region of the brain involved in memory formation and storage, emotional response, and spatial navigation by neuroimaging. Neuroimaging is a powerful and informative tool used for studying the brain. A study has shown significant improvements in the aerobic exercise group compared to that of the control group in hippocampal volume and in the levels of brain derived neurotrophic factors (BDNF), neurons that contribute to the survival of striatal neurons in the brain, were observed. The exercise treatment group participants showed an increase in hippocampus size by 2% while the control group showed a decline by 1.4%. Discussions in this study indicated a belief that the increase in number of dendritic branches, stimulated by the increased amounts of BDNF in the brain, provided the reason for the increase in volume (Alves, 2011).

Studies also use the Stroop task to measure impact of exercise. Measurements of cognitive flexibility, which are the abilities of an individual to see different aspects of ideas, objects, and situations, were found to increase by up to 31.7% in the exercise group. This study lasted ten weeks and along with improvement mentally, subjects also reported physical improvements as well (Etnier, 2006). Additional tools of measuring cognitive function are working memory and long-term memory. A study by Bue-Estes, *et al.* (2008) showed that working memory initially declined after exercise in both groups but then rebounded past the baseline for the aerobically exercising group.

The main focus of our study will be the assessment of short and long-term memory retention, facilitated through a flash card recall task. Utilizing a memory exam we created, will enable us to determine if information can be stored into long-term memory more efficiently during aerobic exercise. A heart rate monitor and blood pressure measurements are being incorporated into our data collection to give us insight into interactions between memory recall and aerobic physical exertion. Our aim is to investigate if a brief exercise session is efficient in aiding the recall of images, on both a short-term and long-term scale. We hypothesize that moderate aerobic exercise will positively affect college students' short and long-term memory storage and their ability to recall information more accurately than the non-exercising control group.

Methods

In all tests, informed consent in writing was given by each participant. The study conforms to the guidelines in the Declaration of Helsinki and was approved by the University of Wisconsin-Madison.

Due to limited time constraints, our experiment will only study whether one instance of moderate aerobic exercise can improve memory retention for one examination. Upon obtaining participants for the study, each person is to be randomly placed into one of two groups, either the control or the experimental group. The control group consists of participants who will take the memory test without participating in moderate exercise and the experimental group consists of those who take it while participating in moderate exercise.

Prior to experimentation, each participant is given a survey consisting of basic questions to assess his or her current level of fitness and exercise habits. The survey should also take note of each participant's age, gender, hours of exercise per week and types of exercise. Participants

are then given a detailed summary explaining what is required of them throughout the duration of the experiment. The experimental group will only receive information pertaining to their group and should have no knowledge about the control group, and vice versa.

To begin the first experimental memory test, the heart rate and blood pressure, tested with a sphygmomanometer and a pulse oximeter, respectively, of each participant in the experimental group should be taken. The participants are then asked to exercise on a stationary bike until they reach 65% of their maximum heart rate, determined by subtracting their age from 220. When this heart rate value is reached, participants, while working to maintain the target heart rate, are shown a set of 20 flash cards (8.5" x 11") consisting of one image each, refer to Supplement 1. Each image covers the entire flash card and varies in difficulty from simple shapes to complex equations and diagrams. The goal of the participants is to memorize these images to the best of their ability during the 5-second interval during which each card is shown. Immediately after the participants have seen each card once, they stop exercising, move to a comfortable position, and are then tested on their recollection of the images they were just shown. To test this, participants are shown 20 flash cards consisting of a random collection of either flash cards from the original set, which they just saw, or cards from a set of 20 new flash cards (Supplement 2) that were not shown. In total, the pool of cards to choose from for testing contains 40 different flash cards. The new set contains images that are both completely different from those in the original set and also images that are very similar but vary by slight details. The slight variations of images, including minor color changes or missing objects, serve the purpose of increasing the difficulty of the memory test. During the test, the participants must answer whether or not they saw the images in the initial memorization event. The amount of correct answers given by each participant should

be recorded. The control group is to complete the exact same tests as above, however they are to be given the initial set of flash cards while seated comfortably, without doing any exercise.

The second memory test should be given to all participants of both the control and experimental groups 2-3 days after completion of the first memory test. This test is structured like the first recollection test, and the flash cards are once again selected at random. This is only a recollection test; participants should not exercise, memorize new images, or review images that they saw during the first test. The scores of each participant during this test should be recorded.

The third memory test is administered to the participants 7-10 days following the initial recollection test, and follows the same procedure as the second memory test. The set of flash cards from the pool of 40 flash cards used in this test should be randomized as before. The scores of each participant will be recorded.

To finalize the experiment, the scores of each participant during the three tests, and of the experimental and control groups as a whole, are compared in tables and figures. ANOVA tests are conducted to test for significant results.

Results

The experiment yielded 11 sets of data for the experimental and control groups. The data is summarized in Table 1. The subjects in the experimental group consisted of 54.54% females and the mean age was 20.45 years, whereas the subjects in the control group also consisted of 54.54% females and the mean age was 20.33 years. From the participant surveys, the average hours participants spent exercising per week in the experimental group was 4.77 hours with 72.72% of the participants exercising more than three hours, whereas the average hours spent exercising in the control group was only 3.14 hours, with one participant exercising zero hours per week and one with 10+ hours per week. A graph representing each subject's change in

percent correct between testing times is shown in figures 1 and 2 respectively. These graphs show the similarity between the results for the exercise and control groups. An ANOVA test was performed for both the experimental group and control group to test for any significant change in percent correct between testing times. The averages of each testing time were compared against each other in the exercise group and the same was done with the control group. When the exercise group was analyzed based on the averages of the time intervals it yielded a p-value of 0.17 which shows that there is no significant difference in each trial for the exercise. Similarly, the control group was analyzed based on their averages for the time periods had a p-value of 0.16 which also shows no significant results between the initial, the 2-3 day, and the 7-10 day test scores. The average percent correct for each testing times were also similar between the two groups. This was plotted in a graph and shown in figure 3. Within both the experimental exercise group and the control group there was a slight increase in the average percent correct from the 2-3 days test to the 7-10 days test. An ANOVA test was also performed between the exercise and control groups based on the average accuracy of recall for all time points taken together. This yielded a p-value of 0.82 and corresponds to the lack of significant differences in the percentage correct between the exercise and control group. The heart rate and blood pressure for each subject is shown in Table 2. The increase in heart rate accompanied with the exercise was not found to cause any significant differences in recollection of the images. Due to there being no significant differences in correctly identified images between the control and exercise group, the increase in heart had negligible effect on their retention of the images. This comparison is shown in figures 4 and 5. Blood pressure levels remained relatively stagnant throughout the study, so correlation in this area could not be found.

Table 1.
Experimental

Subject	Gender	After Exercise	After 2-3 Days	One Week	Percent Correct	Percent Correct 2-3 days	Percent Correct-1 week
1	m	16	12	14	0.8	0.6	0.7
2	f	18	15	15	0.9	0.75	0.75
3	m	18	14	16	0.9	0.7	0.8
4	f	18	13	12	0.9	0.65	0.6
5	f	16		14	0.8	0	0.7
6	m	14	14	14	0.7	0.7	0.7
7	f	14	13	14	0.7	0.65	0.7
8	f	20	19	18	1	0.95	0.9
9	m	16	15	12	0.8	0.75	0.6
10	f	16	18	19	0.8	0.9	0.95
11	m	16	17	17	0.8	0.85	0.85
				Avg	0.827273	0.681818	0.75

Control

Subject	Gender	After Exercise	After 2-3 Days	One Week	Percent Correct	Percent Correct 2-3 days	Percent Correct-1 week
11	m	17	12	12	0.85	0.6	0.6
12	f	19	18	18	0.95	0.9	0.9
13	m	8	11	12	0.4	0.55	0.6
14	f	17	15	14	0.85	0.75	0.7
15	f	16	15	13	0.8	0.75	0.65
16	f	16	17	18	0.8	0.85	0.9
17	f	16	12	12	0.8	0.6	0.6
18	m	19	14	16	0.95	0.7	0.8
19	m	16		17	0.8	0	0.85
20	f	20	14	12	1	0.7	0.6
21	m	18	18	15	0.9	0.9	0.75
				Avg	0.827273	0.663636	0.722727

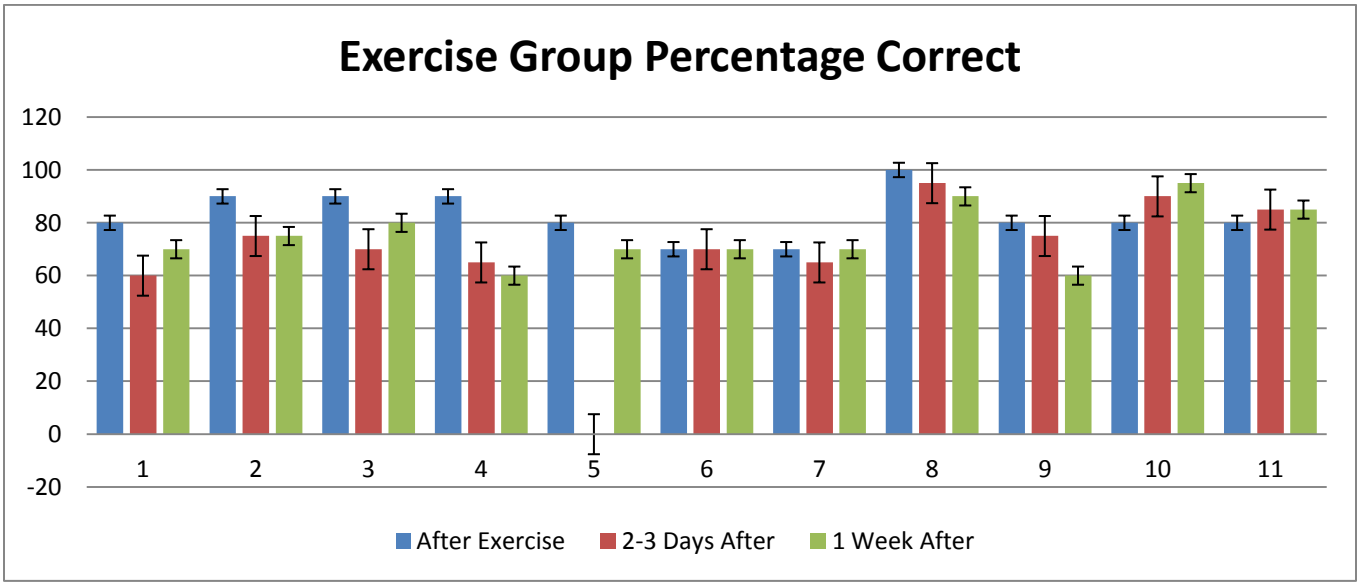
This table is a summary of the number of pictures recalled from the original 20. It is broken down between the experimental exercise group and the control group. The table shows the results from each testing period and the corresponding percents. The average percent correct of each trial was calculated.

Table 2.

Experimental					**Control**				
Subject	HR (before)	HR (after)	BP (before)	BP (after)	Subject	HR (before)	HR (after)	BP (before)	BP (after)
1	63	114	130/70	135/70	11	71	77	126/76	120/70
2	65	102	120/60	125/60	12	78	71	91/60	97/59
3	62	112	130/70	170/80	13	60	55	104/75	116/85
4	65	113	120/80	123/60	14	63	62	120/79	122/80
5	62	54	110/60	115/60	15	65	70	137/73	135/79
6	66	96	118/55	131/61	16	73	72	125/77	127/79
7	75	74	115/80	110/70	17	70	73	124/79	123/77
8	73	86	110/60	110/60	18	68	72	120/80	121/83
9	56	74	126/84	134/84	19	53	56	116/80	115/78
10	64	56	123/75	120/75	20	72	67	104/75	97/66
11	67	89	127/80	140/77	21	52	81	120/70	123/69

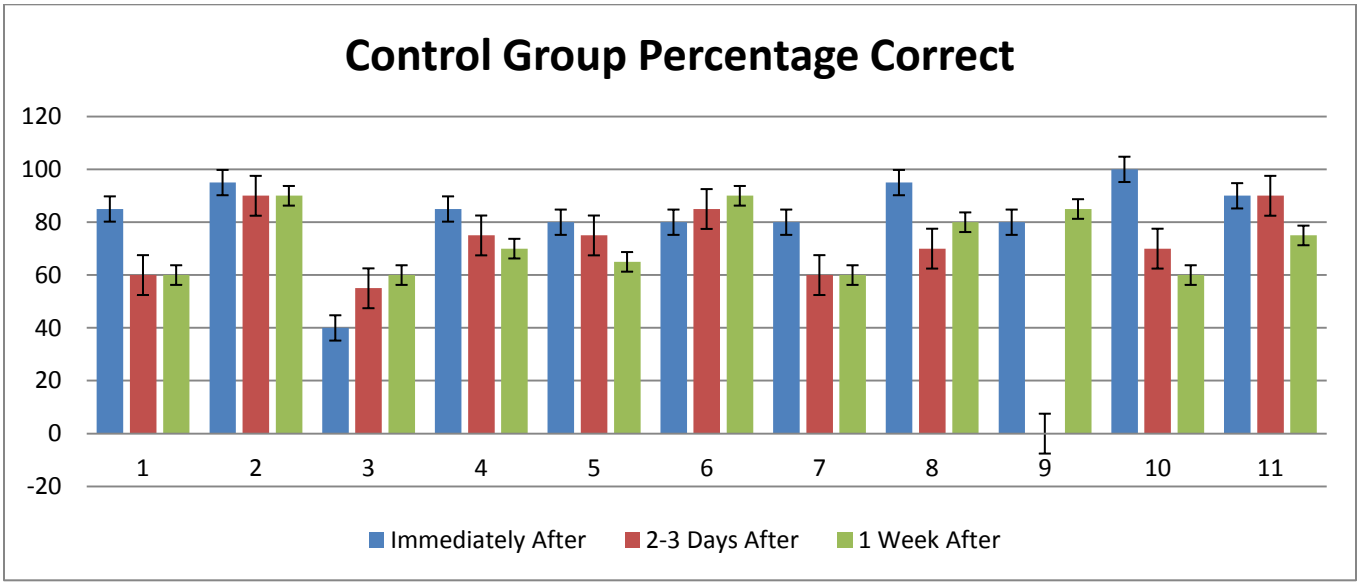
This table shows the heart rate (HR) and blood pressure (BP) for each subject both before and after the showing of the cards. Subjects are divided between the experimental and control groups.

Figure 1.



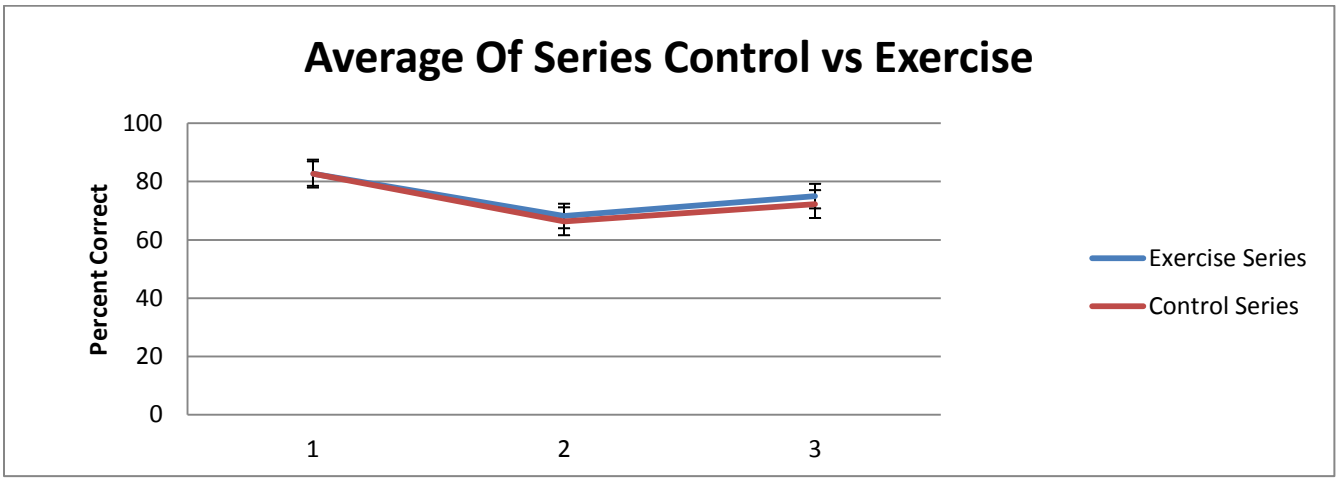
This figure shows the percentage correct after each memory test for each subject in the exercise group. The percentage is calculated by taking the number of correctly identified images and dividing it by the total number of images shown which was 20, then multiplying by 100 to convert to percent.

Figure 2.



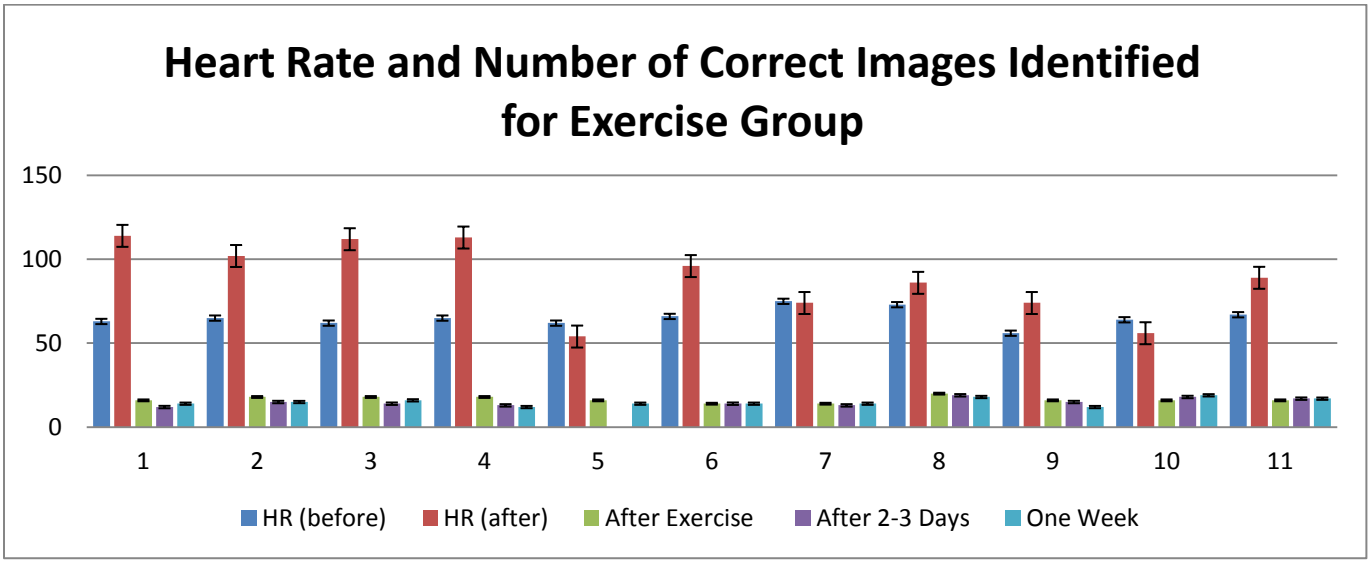
This figure shows the percentage correct after each memory test for each subject in the control group. The percentage is calculated by taking the number of correctly identified images and dividing it by the total number of images shown which was 20, then multiplying by 100 to convert to percent. Error bars represent the standard error.

Figure 3.



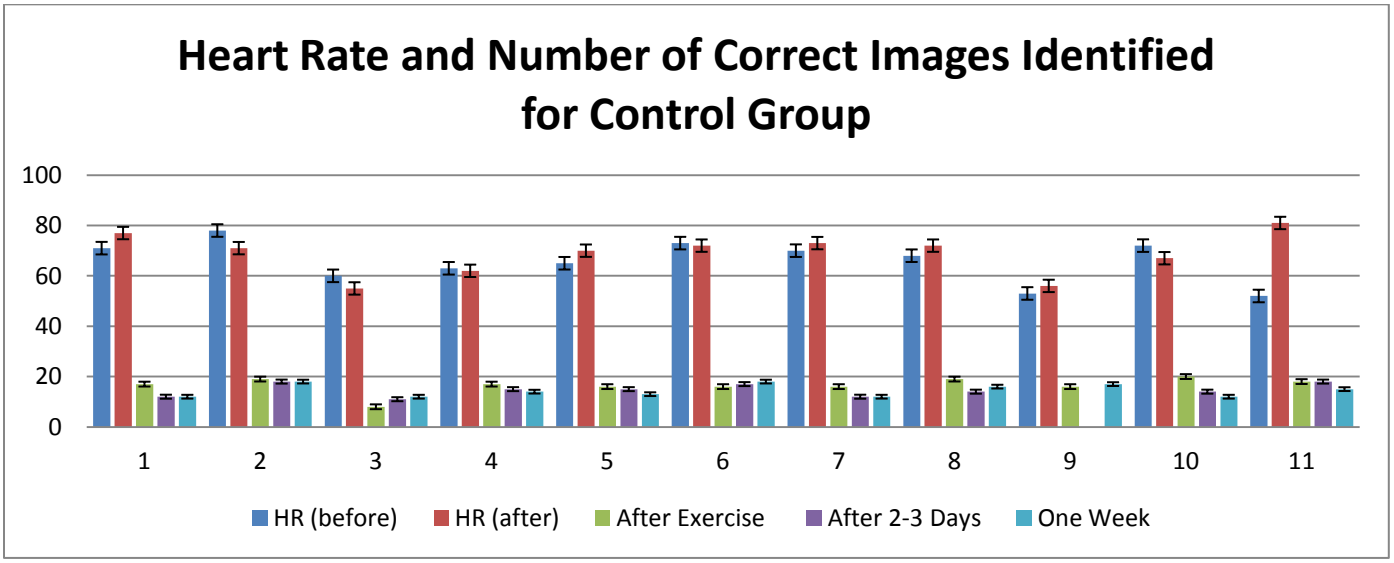
This figure shows the average percent for all subjects correct for each testing time period between the exercise and control groups. Period 1 is the test given immediately after. Period 2 is 2-3 days after the initial images are shown. Period 3 is 1 week after the initial images are shown. Error bars represent the standard error.

Figure 4.



This figure shows heart rate before and after the initial images were shown along with the number of correctly identified images in each of the three trials for each subject of the exercise group. Heart rate is in beats per minute. Error bars represent the standard error.

Figure 5.



This figure shows heart rate before and after the initial images were shown along with the number of correctly identified images in each of the three trials for each subject of the control group. Heart rate is measured in beats per minute. Error bars represent the standard error.

Discussion

Our study's aim was to find whether or not there is any significant improvement in memory retention in individuals who exercise while memorizing a set of images in both the short-term (2-3 days) and the long-term (7-10 days). We hypothesized that exercising while memorizing a set of images would lead to increased memory retention and higher scores on our memory test. However, due to the findings in our study, there is no statistical evidence that indicates exercise either improves or deters memory retention. We cannot conclude that exercise has any effect on an individual's ability to memorize. With average recall values that were very similar, p-value of 0.82, the data did not show any impact of exercise on memory retention. We had no significant results that indicated either an increase or decrease in average scores between the exercise and the control group. In addition, there were no significant results within each group at the different testing times.

During experimentation, we measured the subjects' heart rate and blood pressure. The exercise group was asked to reach a heart rate of 65% of their maximum heart rate. As the participants were solely college students, they were all of similar age, so the exercise group tried to maintain a heart rate near 130 beats per minute during memorization of the cards. When coupled with our findings and average test scores, we can also conclude that increased heart rate played no significant role in memory retention. Blood pressure, as well, was incorporated into our study. Blood pressure was measured before and after memorization and between both the exercise and control group and it remained steady. Therefore, we cannot determine whether blood pressure played an active role in the memorization process as it did not change for the individual in both the exercise and control groups.

As a result of our findings, at this time we cannot state that exercise is a factor in memory retention. Within the scope of our experiment we may conclude that exercise does not affect memory retention, neither positively or negatively. However, in a broader scope, our study is not strong enough to suggest that regardless of exercise, memory retention will remain the same in the short and long term. Our study only included 11 individuals in each group and the exercise was limited to only the duration of reaching a heart rate of 130 and memorizing the cards, an approximate time length of 5 minutes. The subjects exercised for a very limited amount of time, suggesting that the small duration of exercise played no role in their ability to memorize the cards. Our three memory tests were conducted within a time frame of 7-10 days. The duration of the study was too short to make any declarative statements about the impact of exercise on memory retention, but within our own experiment we can say that exercise has no impact memory retention when an individual exercises while memorizing images. Longer amounts of exercise may hold a more significant impact. Waiting a longer amount of time to show the participants the memory test may have led to more variance among individuals, even within their respective groups. The study conducted by Alves H, *et al*. (2011), found a significant relationship between exercise and memory, however the study was conducted under different circumstances. The study was conducted over a longer period of time with an older sample. The participants in this study exercised for the whole duration of the experiment and for a longer amount of time.

Another limitation in the study was that it only included one isolated exercise event and one set of images to memorize. Using different memory tests would provide greater validity to the study as the subjects would be tested multiple times in different ways in order to cover a broad range of memorization. The participants in our study only exercised aerobically during our

test runs, but different forms of exercise may lead to changes in results as well. In a study conducted by Tomporowski (2002), subjects did both aerobic and anaerobic exercise. For some of the subjects memory retention increased with anaerobic exercise as well as results showing improvement with aerobic exercise. Adding in these factors into our study may have been beneficial to create a more conducive study. A concern in our study as well was that preoccupation with the aerobic exercise may have lead to decreased ability to memorize; however, our p-value was so high that decreased memory retention was not observed either.

Human error could have contributed greatly to our results. For the exercise group, blood pressure measurement was not conducted with a computer, only by hand with sphygmomanometer. We were not trained professionally to measure blood pressure so there may be slight error in the values. In addition, the blood pressure values are not exact because it was determined by ear and are mostly whole number values. Some of the heart rates were taken by hand as well due to equipment malfunction which could also have contributed to errors in the results. For heart rate, the heart rate monitor was highly sensitive and often misread while subjects were exercising. This contributed to large variances in heart rate, affecting our results greatly. The control group blood pressure and heart rate were measured with a wrist device. This sometimes did not record individual's blood pressure well and may have been off by large values. As a result, we checked the blood pressure many times using this equipment and in that time period the blood pressure may have changed.

Conclusion

We hypothesized that a group of college students who moderately exercised for a short duration of time while memorizing a series of 20 flash cards would be able to recall these images more accurately during follow-up testing than the control group of college students who did not

exercise. Our results did not support our hypothesis as there were no significant differences between our experimental and control groups on any aspect of our study. In the future, to make a more conducive argument on the relevance of exercise to memory retention, we suggest designing a longer duration study, ideally lasting at least 6 months with a larger sample size, consisting of at least 100 participants in each group and possibly measurements of reaction time. Because of time constraints, our study could only be conducted on a very small sample size and for a short amount of time. A more in-depth study is needed to find more accurate results, including distinguishing specific results between genders. Though our study may be limited, this topic on memory in relation to exercise is being extensively reviewed and discussed. While the majority of the literature we reviewed suggests results opposite of ours, meaning the experimenters concluded exercise does positively influence memory retention, other studies showed that exercise may deter memory retention. While no conclusion has been made in the field, continuous research may lead us to a definite answer on whether exercise helps to improve memory retention. In the future if significant results are found that reveal that exercise improves memory and cognitive function, it will be another great reason to encourage people of all ages to be active and remain active throughout their lives.

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Supplement

Supplement 1.

Original Set

Supplement 2.
New Set