Aerobic Exercise Prior to Word Recognition and Its Effect on Long Term Cognitive Recall

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Key Points Summary:

- Tested the hypothesis that aerobic exercise has a positive effect on cognitive recall
- Used experimental groups with exercise prior to or after exposure to a word list
- The results suggest no significant increase in word recall using exercise as a beneficial aid
- These results are somewhat biased based on the small sample sizes of the experimental groups
- These findings should be further tested using larger sample sizes to eliminate sample size error in order to possibly provide another positive reason for exercise

Word Count: 87

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Abstract

The implications of physical activity having a positive correlation to enhanced memory would give an additional reason to promote exercise. The issue we addressed was whether aerobic exercise enhanced cognitive recall. We hypothesized that aerobic activity prior to exposure to a word list would enhance the ability to recall this world list one week post-recall, compared to a group which was exposed to the word list without exercise. For completeness, we also tested whether recall was enhanced in a group that was exposed to a word list prior to aerobic exercise. The results suggest that there is no correlation between aerobic exercise and an increased ability in word recall one week following exposure. One limitation to our research was the small sample sizes and therefore research should continue with larger sample sizes to eliminate sampling error.

Introduction

It has been well established that exercise is important for the body. Some physiological effects on the body, as mentioned by the Mayo Clinic, include: helping to control weight, elevating mood, boosting energy, and promoting better sleep (Mayo Foundation for Medical Education and Research, 2011). Its effects have also been compared to antidepressants, which improve mood and anxiety disorders (Corbett, D., et al., 2011). Additionally, exercise has a positive influence on neurogenesis, which is the creation of new neurons. Although the exact mechanism behind this process is still being studied, the majority of newly created neurons are located in the hippocampus. The hippocampus is one the main centers for learning and memory. These new neurons not only aid in learning and memory, but also play a role in the amount of neurotransmitters in the brain (Labban, J.D., et al., 2011). Exercise helps increase concentrations of neurotransmitters, such as norepinephrine, by acting as a stress in the body. It influences the central dopaminergic, noradrenergic and serotonergic systems. These systems are directly related to "reward-based" regions of the brain. Relating exercise to a word list should improve the memorization of that word list based on memory areas of the brain relating the word list with reward. Therefore, individuals who are exposed to a list of words after performing aerobic exercise at their target heart rate will have stronger recall ability than subjects that perform no exercise one week post-exposure to the word list.

In recent times, research has started to investigate correlations between cognitive function and exercise. Acute exercise has a positive impact on word and list recall (Cian, C., et al., 2001). Many studies have looked at the differences between high-impact exercise and light-to-moderate aerobic exercise. Studies concerning high impact and duration exercise found some detrimental effects on cognitive function. High-duration exercise can lead to dehydration and overall muscle fatigue and can impact cognitive function (Tomporowski, P.D., et al., 1987). Another study found that intense exercise led to exhaustion in participants and an inability for adequate recall (Potter, D., et al., 2005). Exhaustion, along with dehydration, can prevent the brain from being able to function at its optimal ability. While long duration and high intensity exercise did not consistently show beneficial effects on memory, light-to-moderate exercise has shown positive impact on recall abilities. Ten minutes of light-to-moderate aerobic exercise had positive effects on a recall task incorporating aspects of working and long-term memory (Coles, K., et al., 2008). Other studies found that while exercise prior to list learning did not improve immediate recall, there was improvement in a 12-minute period following (Cameron, K., et al., 2004). Overall, exercise can have a positive impact on memory function if done at the right intensity. By stimulating neurotransmitters in the brain and circulating oxygen and blood flow throughout the body, it can help improve the recall process for individuals.

Working memory is the collection of cognitive systems that assist with task-relevant information throughout the performance of a task. It functions as an integrating center where recently acquired sensory information and information from long-term memory are processed. Cameron et al. (2004) used ERP responses to test the premise that retention of words in short-term memory involves activation of the words' semantic representations in long-term memory (i.e. activated long-term memory provides a representational basis for short-term maintenance of information). As words are processed, their representations in long-term memory are activated. The depth of processing of these words determines the level of activation. Due to the physiological mechanisms of neurotransmitter release related to exercise and their impact on reward centers that are related to memory, there should be improved activation and depth of processing into long-term memory. It has also been shown that providing a mnemonic helps enhance the memorization process (Goossens, L., et al., 1992). This will give a basis on which to measure our test subjects and the affect of exercise on their ability to memorize. The negative control group will provide an additional measurement to be compared against and they will be presented with a word list and no tool for memorization.

Materials and Methods

In this experiment exercise bikes will be used along with Biopac© patches and electrode cables, which are connected to the computer to analyze data. An electronic blood pressure meter was used to analyze blood pressure and pulse.

Subjects were randomly selected in the age group of 20-29 to participate in this study. There were four test groups established: positive control, negative control, along with two experimental groups. The exercise groups will be tasked with aerobic exercise at a target heart rate. This heart rate will be determined using the formula: (220-Age of Subject)*.75, which provides for 75% of the subject's maximal heart rate and is categorized within the moderate aerobic zone for exercise. All groups will be given the following word list: Ethiopia, Gabon, Zimbabwe Tanzania, Congo, Angola, Cameroon, Mali, Rwanda, and Botswana.

Each group will have ten different participants that will be randomly selected from multiple lab groups. Subjects will not be allowed to participate in multiple study groups because multiple exposures to the word list will skew our results. Participants for exercise groups are pulled from University of Wisconsin – Madison human physiology lab 435 sections 601, as well as lab 335 sections 303 and 304, for the experimental groups. Negative and positive control groups are randomly selected people from the university and will contain twenty participants. Gathering data usually takes up to twenty minutes per participant for the experimental group. The negative and positive control groups usually last twelve to fifteen minutes. For each participant being tested, there are at least two people working in an assembly line fashion for efficiency.

Experimental Group One: One experimental group will be exposed to the word list before performing one and a half to two minutes of jumping jacks and ten minutes of moderate aerobic exercise on an exercise bike and then asked to recall the list of words immediately following the twelve minute exercise; this group will be referred to as 'exposure first'.

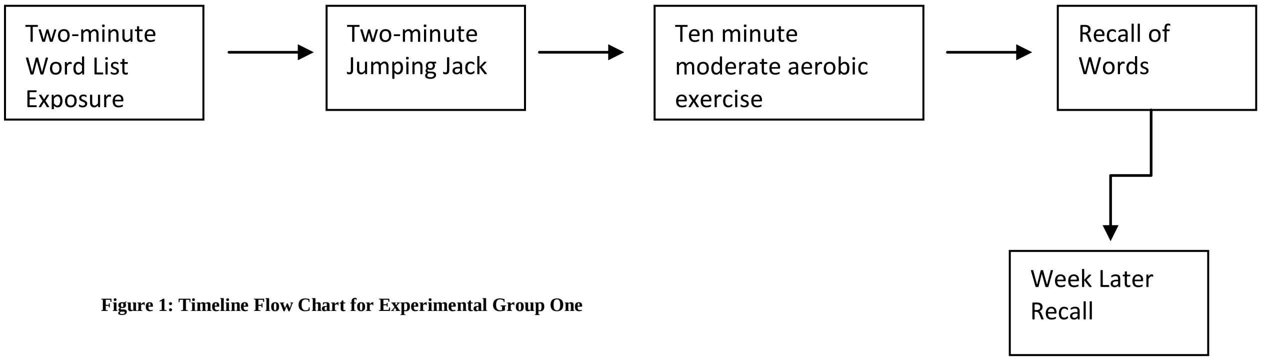

Figure 1: Timeline Flow Chart for Experimental Group One

Experimental Group Two: The other experimental group will perform two minutes of jumping jacks and ten minutes of moderate exercise on the exercise bike. Once the participant is done with the exercise they will be given two minutes of exposure to the word list. After those two minutes, the participant will be given a ten-minute waiting period, where the words cannot be discussed. Once those ten minutes have passed, the participant will be asked to recall the list of words that they were exposed to; this group will be referred to as 'exercise first'.

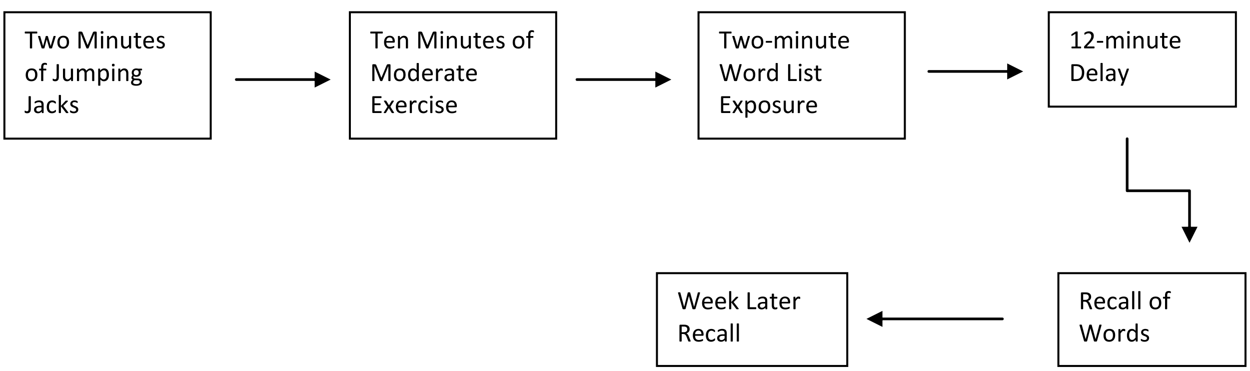

Figure 2: Timeline Flow Chart for Experimental Group Two

Although the second experimental group has a longer experimental time, the exposure, exercise, and recall are all the same amount of time. This does not change our hypothesis that the experimental group exposed to the words after aerobic exercise will have stronger memory retention, even though they have a longer experimental time.

Negative Control: The negative control is exposed to the word list for two minutes with a ten-minute wait period before recalling the word list. The negative control will not participate in the exercise regime.

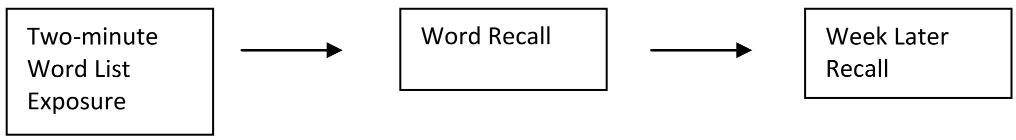

Figure 3: Timeline Flow Chart for Negative Control Group.

Positive Control: The positive control is exposed to a word list for two minutes with the aid of a mnemonic, which had no relevance to the original word list. The mnemonic is: Edna gave Zebras tender care and coke making rabid babies. Then the participant would be asked to recall the word list ten minutes following the exposure to the word list, along with the mnemonic that was given.

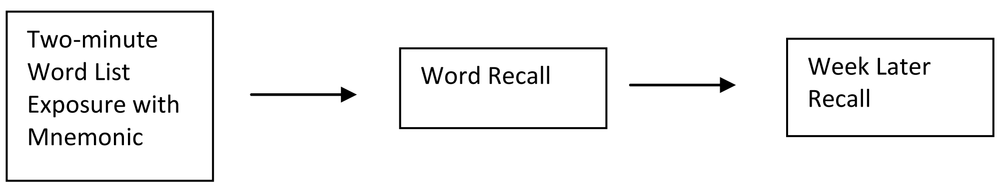

Figure 4: Timeline Flow Chart for Positive Control Group.

Measurements

GSR (Galvanic Skin Response) and Polygraph: Will be used for monitoring the person's heart rate. This is a non-invasive method of allowing us to make sure the person gets to the target heart rate and stays there during the course of the exercise. The heart rate was measured via the Galvanic Skin Response over a period of ten minutes.

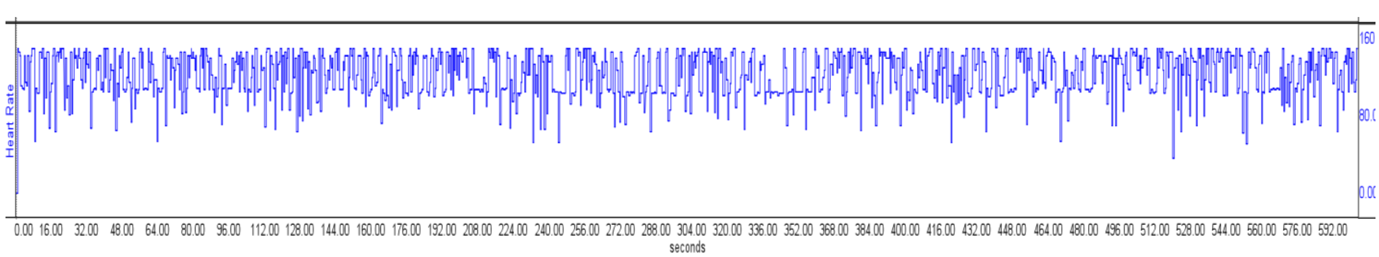

Figure 5: Heart rate during aerobic exercise for Participant #10 (Exercise First)

Blood pressure meters: Will be used to check the person's blood pressure before and after aerobic exercise to ensure the physical activity is slightly altering their homeostatic state.

ECG (Electrocardiography): Will be utilized to measure the electrical activity of the heart after the time of exercise.

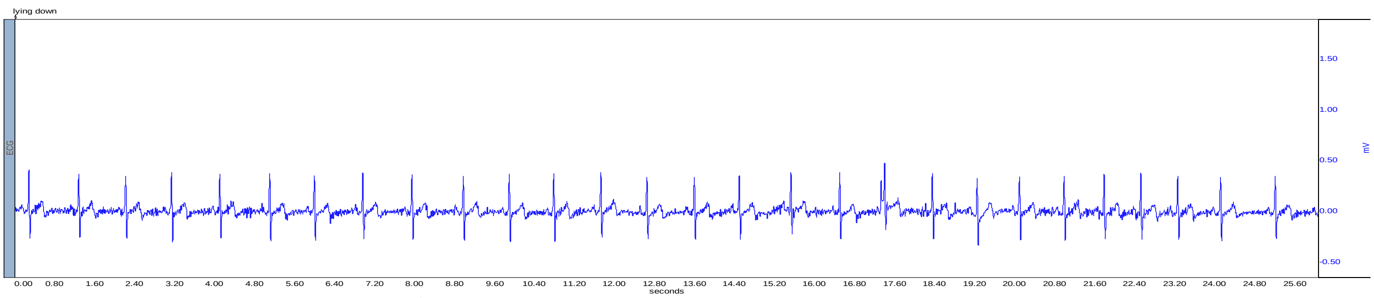

Figure 6: Electrical activity during aerobic exercise for Participant #10 (Exercise First)

The three measurements help monitor and ensure that the participant was able to achieve the necessary target heart rate for the experiment. Measuring blood pressure and EKG after the exercise will help ensure exhaustion was not obtained, which can negatively affect cognitive ability. What is actually being tested in this experiment is the effect of the various neurotransmitters being released during exercise on memory. However, we cannot directly measure the neurotransmitters; therefore, the measurements being used are to ensure achievement of aerobic exercise and the neurotransmitters that are generally associated with that.

Results

	Combined Experiment Groups	*Negative Control*
Mean Word Recall	5	4
Variance	4.7368421	5.47368421
Observations	20	20
df	38	
t Stat	1.3995581	
P(T<=t) one-tail	0.0848783	
P(T<=t) two-tail	0.1697566	

Table 1: Experiment Groups vs Negative Control. Data points from the Negative Control were run in a t-test assuming unequal variance in comparison to data points from the Experiment Groups, which contained both exercise groups.

In regards to the relationship between the negative control and experimental groups, there is no correlation between the two (Table 1). The p-value is 0.08 (1.399, 38), which is greater than the significant alpha value (0.05). The p-value fails to reject the null hypothesis.

	Positive Control	*Negative Control*
Mean Word Recall	7.5	3.4
Variance	2.722222	5.155556
Observations	10	10
df	16	
t Stat	4.619362	
P(T<=t) one-tail	0.000142	
P(T<=t) two-tail	0.000284	

Table 2: Positive Control vs Negative Control. Data points from the negative control were run against points from the positive control in a t-Test assuming unequal variances.

In reference to the comparison between the negative control and positive control data, there is correlation between the week later recall abilities (Table 2). The p-vale is 0.0001 (4.619, 16), which is less than the significant alpha value (0.05). The p-value symbolizes the rejection of the null hypothesis.

	Negative Control	*Exposure First*
Mean Word Recall	3.4	5
Variance	5.155556	3.555556
Observations	10	10
df	17	
t Stat	-1.71429	
P(T<=t) one-tail	0.052324	
P(T<=t) two-tail	0.104648	

Table 3: Negative Control vs Exposure First. Data points from negative control were run against points from exposure first in a t-test assuming unequal variances.

In regards to the relationship between negative control and the exposal first experimental group, there is no correlation between the two (Table 3). The p-value is 0.052 (-1.71, 17), which is greater than the statistically significant alpha value of 0.05. The p-value infers that the null hypothesis cannot be rejected.

	Negative Control	*Exercise First*
Mean Word Recall	3.4	5
Variance	5.155556	6.444444
Observations	10	10
df	18	
t Stat	-1.48556	
P(T<=t) one-tail	0.077349	
P(T<=t) two-tail	0.154699	

Table 4: Negative Control vs Exercise First Group. Data points from the negative control were compared in a t-Test, assuming unequal variance, to points from exercise first experimental group regarding week later recall.

Concerning the correlation between the negative control and the exercise first experimental group, there is no correlation (Table 4). The p-value is 0.077 (-1.49, 18), which is greater than the statistically significant alpha value of 0.05. The p-value indicates that the null hypothesis cannot be rejected.

Discussion

The statistical analysis between the negative control and experimental groups indicated there is no correlation. The p-value is much higher than the statistically significant value of 0.05, failing to reject the null hypothesis. The degrees of freedom show a high amount of variation between points with a value of 38 (Table 1). Although there was no correlation between the two variables found, the experimental group had a slightly higher mean for the week later recall. Participants who performed moderate physical exercise were able to recall five words on average in comparison to four words for those who didn't. While there is no direct correlation between the idea of improved recall accompanied with exercise, exercise can still be beneficial for the human body. It can promote a better wellbeing by reducing stress levels, maintaining a healthy weight, or elevating hormones critical to mood. Although there was no correlation, moderate aerobic exercise did not have a negative effect on recall ability.

Regarding the negative control and positive control data, there is a correlation (Table 2). The p-value is lower than the statistically significant value of 0.05, which rejects the null hypothesis. The null hypothesis is that there was no correlation concerning week later recall between the two groups. The degrees of freedom show a high amount of variation between points with a value of 16. The correlation shows the usefulness between mnemonics and memory. The group that was able to use a provided mnenomic was able to have a greater recall ability in comparison to the group that was just given a list. When rehearsing mnemonic devices, the scheme can become implanted in the memory and is easily brought back into use.The device becomes similar to visual image used for memorizing (Youngblood, 1986). Through the use of the provided mnemonic and other memorizing capabilities, participants in the positive control were able to recall words at a significantly higher rate after one week.

In reference to the negative control and exposure first group, there is no correlation between recall ability (Table 3). The p-value is higher than the alpha value of 0.05, which fails to reject the null hypothesis. The degrees of freedom shows a high amount of variation between the two sets of data points with a value of 17. The p-value from these two groups was .052 which is almost statistically signifcant. The variables showed that the exposure first group had a higher average week later recall and lower variance compared to the negative control group. Participants that were exposed to the words before moderate exercise remembered 1.6 words more on average. Even though there was no direct correlation seen, exercise is essential to promoting a healthy lifestyle which is important to a person's memory and alertness.

Concerning the negative control and exercise first group, the statistical analysis shows no correlation between data points (Table 4). The p-value is higher than the statistically significant value of 0.05, failing to reject the null hypothesis. The degrees of freedom show a high amount of variation between the points with a value of 18. While the variables showed no correlation, the participants that moderately exercised before being shown the word list were able to recall about 1.6 more words on average. Although there was no direct correlation found, exercise did not negatively affect recall.

In summary, the correlation between the positive and negative control shows the usefulness for mnenomics in memory. Those who were provided with the mneonmic were able to recall more than those who did not. There is no correlation between the negative control and both experimental groups. Although no statistical correlation exists, there are greater mean recall values for those that did moderate aerobic.

A problem we encountered early on with the experimental design was not being able to get the participant to their target heart rate before the exercise regime started. After realizing this detail, the design was slightly adjusted with having the participant do a minute and a half to two minutes of jumping jacks to get their target heart rate. Once we realized this, we quickly corrected the issue within the first few participants. As the experiment continued, average values for actual heart rate were low in comparison to the calculated target heart rates. This was partially explained by faulty measurement equipment. Values were impacted by movement of the legs as the participant was biking. Values would jump from low values to high values throughout the ten minute period of moderate exercise.

Another problem that we came across was the size of our experimental groups. The small size of the experimental groups does not provide enough data to show definitive evidence to prove to disprove our hypothesis. When running statistical analysis, the results can be inadequate because of a small sample size. The larger the sample size, the more powerful the results because of the fact that small sample sizes are more susceptible to slight changes in variation (Moore, et al., 2012). An increased number of participants in the experimental group could change the statistical significance when compared to the negative control.

Areas for future research could exhibit better results that would prove the hypothesis that moderate aerobic exercise increases long-term cognitive recall. The primary issue that was discussed in the study was the size of each experimental group. Another aspect of future research would be the method used to measure the pulse during the moderate aerobic exercise. A more accurate approach to measure the heart rate on a participant, as they are biking, is to use machines that have built in heart monitoring devices. This allows the researchers to constantly have a reading of the pulse during the exercise. Lastly, environmental conditions are also an important aspect when participants that are given word lists to memorize. A quiet environment is crucial to participants when they are given a limited amount of time to review the list.

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Author Contributions

All authors of *Aerobic Exercise and Word Recall* contributed to all components of the data collection and the publication process.

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Additional Tables and Figures

Participant	Gender	Age	Target HR	BP (before)	HR (before)	BP (after)	HR (after)	Initial	Week Later	Exercise 1st
1	F	20	154.5	155/84	87	117/67	86	10	9	Exercise 1st
2	M	20	150	125/69	72	147/72	82	10	7	Exercise 1st
3	F	20	154.5	126/66	65	122/69	67	10	3	Exercise 1st
4	F	21	153.75	132/86	79	122/90	106	10	9	Exercise 1st
5	F	21	153.75	124/77	61	131/82	69	7	3	Exercise 1st
6	M	20	150	145/84	64	120/75	74	3	3	Exercise 1st
7	F	21	153.75	117/77	73	120/78	90	9	5	Exercise 1st
8	F	21	153.75	128/82	85	117/76	86	6	6	Exercise 1st
9	F	20	154.5	116/79	74	120/76	75	9	3	Exercise 1st
10	M	29	143.25	116/73	62	113/71	70	6	3	Exercise 1st
Average +/- SD								8 +/- 2.404	5.1 +/- 2.514	
Participant	**Gender**	**Age**	**Target HR**	**BP (before)**	**HR (before)**	**BP (after)**	**HR (after)**	**Initial**	**Week Later**	**Exposure 1st**
11	F	21	153.75	132/72	72	136/87	79	9	7	Expo. 1st
12	M	21	149.25	140/89	101	129/82	108	6	4	Expo. 1st
13	F	21	153.75	128/62	78	133/63	81	10	3	Expo. 1st
14	F	21	153.75	116/77	65	120/81	90	7	4	Expo. 1st
15	F	20	154.5	105/61	62	112/64	67	6	3	Expo. 1st
16	M	20	150	142/88	74	117/69	69	8	6	Expo. 1st
17	M	20	150	119/70	70	125/67	82	7	5	Expo. 1st
18	M	21	149.25	126/94	98	121/80	90	8	4	Expo. 1st
19	F	22	153	118/83	89	110/80	98	9	9	Expo. 1st
20	M	21	149.25	118/73	62	122/86	101	9	5	Expo. 1st
Average +/- SD								7.9 +/- 1.370	5 +/- 1.886	

Figure 7: Experimental Groups; containing information about gender, age, target heart rate, blood pressure before and after, initial recall, and week later recall.

Word List
Ethiopia
Gabon
Zimbabwe
Tanzania
Congo
Angola
Cameroon
Mali
Rwanda
Botswana

Figure 8: World list used for both experimental groups

Mnemonic	
Ethiopia	Edna
Gabon	Gave
Zimbabwe	Zebra
Tanzania	Tender
Congo	Care
Angola	And
Cameroon	Coke
Mali	Making
Rwanda	Rapid
Botswana	Babies

Figure 9: Mnemonic used for Positive Control

Positive	Initial	Week Later	Negative	Initial	Week Later
1	10	9	1	8	7
2	8	8	2	8	3
3	6	6	3	4	3
4	9	9	4	10	7
5	8	10	5	5	2
6	9	5	6	1	0
7	10	4	7	10	5
8	9	8	8	8	3
9	9	3	9	7	2
10	7	6	10	8	2
11	7	5	11	10	4
12	10	10	12	9	5
13	8	6	13	7	3
14	10	8	14	8	4
15	10	5	15	8	3
16	8	5	16	9	5
17	6	4	17	10	4
18	6	3	18	7	9
19	9	3	19	7	5
20	5	5	20	6	4
Average +/- SD	8.2 +/- 1.58	6.1 +/- 2.31		7.5 +/- 2.24	4 +/- 2.05

Figure 10: Date information for Positive and Negative Control. Figure contains initial and week later recall values.

Members of Experiment Group 1 (Exposure First)	10
Age Range	20-22
Average Age	20.8
Standard Deviation of Age	0.63
Average Age +/- SD	20.8 +/- 0.63
Sex (Female:Male)	1:1
Members of Experiment Group 2 (Exercise First)	10
Age Range	20-29
Average Age	21.3
Standard Deviation of Age	2.75
Average Age +/- SD	21.3 +/- 2.75
Sex (Female:Male)	7:3

Figure 11: Summary Tables for Experimental Groups. Figure includes the number of participants, age range, average age, standard deviation, and sex ratio.

Participant	Average HR
1	135.0767
2	129.211
3	124.8249
4	113.6185
5	108.3547
6	118.2833
7	102.9483
8	129.9363
9	130.6837
10	123.0512
11	123.3508
12	124.7766
13	105.8209
14	118.7316
15	116.5299
16	84.60774
17	106.9173
18	120.4213
19	93.24869
20	106.2011
Overall Average	115.829 +/- 13.09
Standard Deviation	13.09592295

Figure 12: Heart Rate Averages between Experimental Groups.