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Physiology 435

Section # 601 Group 7

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The Effect of Exercise on Long-term Memory

Introduction

The human body is an extremely complex system, controlled mainly the brain which has a wide range of crucial cognitive functions. One of its most intriguing processes is memory retention. In short, memories are retained by the creation and connection of new neurons in the brain, a process called neurogenesis. The hippocampus, the center of the limbic system, plays a significant role in neurogenesis, and, therefore, a significant connection between its function and cognitive memory retention is established (Erickson, et al., 2010). In this experiment, we are analyzing long-term memory by targeting stimuli recollection over a week duration as opposed to short-term memory which systematically involves stimuli over a much shorter duration caused by interface by active neural patterns of ensuing stimuli which leads to decreased synaptic activity as a function of stimuli and degradation active neural firing (Jonides, 2008)

Many variables that affect memory retention have been studied. One of particular interest, due to its physical and emotional benefits, is exercise. Exercise is beneficial in many biological systems, including muscle development, lymphatic operations, cardiovascular health, improved metabolism, and neurogenesis (Tong, et al., 2001). Physical exercise also increases the generation of new neuronal cells in the hippocampus (Curlik, 2013). Exercise intensifies many metabolites and hormones throughout the body, including glucose, oxygen, and neurotransmitters, which leads to increased neurogenesis and synaptogenesis. The changes in hormone levels, such as serotonin, epinephrine, and acetylcholine, affect cognitive function (Potter, 2005). Despite support for the connection between exercise and memory retention, studies exist that contradict this relationship. One study that evaluated 24 college students for

memory retention after strenuous exercise found no differences between the experimental and control groups (Tomporowsky, 2007). Another study that evaluated 18 young adults for the effects of exercise on executive function, short-term memory and long-term memory tests suggested that exercise did not facilitate short-term memory but might facilitate the consolidation of information into long-term memory. (Coles, 2008).The contrasting research for the association of memory recall and exercise provides an intriguing topic that this experiment seeks to evaluate.

If subjects learn information directly after exercising, will they have a stronger recollection of information compared to the control subjects? The analysis of this question will be the basis for the experimental procedure. Experimental subjects will be exposed briefly to a short story immediately after exercise. After a week long period, the subjects will complete a series of questions that will test memory recollection about the story. Blood pressure, heart rate, and breathing rate will be tested during exercise to standardize the amount of physical exercise being put forth by each subject. Immediately after exercise, an EEG will be used to analyze cognitive function while the subjects are reading the short story. The results from the memory test will be used to evaluate memory retention. The control group will be exposed to the same tests, the only difference being the removal of exercise preceding the memory test. Overall, we hypothesize that the experimental group will show increased memory retention and cognitive function due to increased brain activity during the exercise.

Materials

Pulse Oximeter

To measure heart rate and oxygen saturation of hemoglobin, a pulse oximeter was used. It was placed on the subject's index finger and allowed to take measurements.

Sphygmomanometer

A sphygmomanometer was used to measure participants' blood pressure. The blood pressure cuff was placed around the participant's left arm in line with heart level with the arm resting on the table. A stethoscope was placed at the inner elbow to record the systolic and diastolic blood pressures. This was

determined through standard procedures. The systolic blood pressure was recorded when the first sound of the blood flowing through the artery was able to be heard. The diastolic blood pressure was recorded when the blood flowing through the artery was no longer able to be heard.

Spirometer

A spirometer was used to measure participants' breathing rate. It was placed around the diaphragm and was attached to the Biopac software. The spirometer would take measurements when the subjects inhaled or exhaled.

Electroencephalography

In order to measure brain activity and various types of brain waves (Alpha, Beta, Gamma waves), electroencephalography (EEG) was used. EEG data was obtained for each participant using Biopac software. Three EEG leads were attached to the participants head, one above and one behind the left ear and one on the neck below the left ear. A bandage was used to keep the EEG leads in place during measurements. Alpha waves were of special interest in this experiment because they play an active role in network coordination and communication. Occipital alpha waves during periods of eyes closed are the strongest EEG brain signals.

Methods

A total of ten participants were chosen randomly in this experiment, aging between 19 and 23, all from a Physiology 435 lab section at the University of Wisconsin-Madison. The ten subjects showed no health issues and were asked to sign a consent form (Appendix I) which stated confidentiality and requirements for the experiment. In order ensure that we had two similarly exercised groups of individuals, we asked how often and what type of activity each subject exercised per week (Appendix V and Figure 6).

One experimental group and one control group were analyzed in this experiment. The experimental group were asked to run up and down a flight of stairs, then go on an exercise bike until each subject's heart rate was increased by 100% from their resting heart rate, which was determined

immediately before exercising. A pulse oximeter was used to measure heart rate to ensure each participant was changing their heart rate in a similar fashion. The subjects maintained the increased heart rate for three minutes, then proceeded into a one minute resting period. During this period, breathing rate was measured using a spirometer and blood pressure was measured using a sphygmomanometer. After the resting period, each subject was given a maximum of ten minutes to read a short anecdote (Appendix II) by the Grimm brothers that was found on the Internet. Seven days later, we connected the participants to an EEG while they were asked a series of fifteen questions of varying difficulty pertaining to factual details of the anecdote (Appendix III). The mean and area of the alpha waves taken during this time were measured. The questions were used to measure memory recollection and not reading comprehension of the story. The procedure for the control group was identical to the experimental group, varying only in the exercise phase. The control group remained stationary for a duration of the average experimental exercise period. Graphical relationships between memory test accuracy and the physiological measurements are displayed below. ANOVA tests were performed to determine the statistical significance of the data.

Results

The effects of exercise on memory retention were examined. The control group averaged 4.4 answers correct out of 15, while the experimental group averaged 3 answers correctly out of 15 (Figure 1). The individual results of participants are shown in Figures 4 and 5. There was no significant difference between the number of correctly answered questions between the two groups tested (p-value = 0.25). Concurrently, the EEG showed that the control group's average mean alpha waves were 0.096 μV, while the experimental group's were 0.067 μV. There was no significant difference in the mean alpha waves (p-value = 0.35) [Figure 2]. The average area under the curve for the alpha waves for the control group was 9.92 μV/sec, while the average area under the curve for the experimental group was 10.16 μV/sec. This data was also shown to be not significant because the p-value = 0.97. One data point for the average change in area of the alpha waves for the experimental group was identified as a potential outlier. In

order to determine if this was indeed an outlier, a Grubb's Test was performed (Appendix IV). The Grubb's test determined that this data point was an outlier, so we struck it from our data.

Discussion

Based on the data obtained in this study, no significant correlation could be observed between exercise and long-term memory. As seen in Figure 1, the number of correct answers to the memory test was 4.4 for the control group and 3.0 for the experimental group. While the control group scored slightly higher, the ANOVA tests for the change in mean alpha waves and change in area of the alpha waves yielded p-values of 0.35 and 0.97, respectively. As this indicates, there was no statistical significance, and so no correlation could be drawn on the relationship between exercise and memory retention.

While there was no statistical significance, the results did show a trend of particular interest. Using the EEG, it was expected that the change from baseline values for mean alpha waves and for the change in area of the alpha waves would be similar. However, in Figure 2, it was observed that while the control group had a higher change in mean alpha waves, the average change in area under the alpha waves was higher for the experimental group. Inspecting this result further, we found that although the spikes of activity measured by the EEG were higher overall for the control group, they were far thinner than those of the experimental group. These thin peaks are due to the stimulation of fewer neurons being activated, as opposed to a larger number of neurons causing the wider peaks in the experimental group. Although the number of correct answers in each group was similar, the differences in peaks show that the control group was able to retrieve answers more deliberately and elevate their mean alpha waves further than the experimental group. In contrast, the experimental group retrieved the same correct answers by activating a larger number of neurons and "searching" for the answers while maintaining a lower increase in mean alpha waves. This relationship is one that should be pursued in future research.

Improvements that could be made to determine if a relationship between exercise and long-term memory exists include a greater number of participants, different memory tests, and changes to the experimental setting.

This experiment only included five participants each for both the control and experimental groups due to time constraints. Additionally, the participants were all selected from the same Physiology 435 class. If the experiment were to be repeated, this number should be increased to at least ten participants for each group, and the participants should be selected from a broader group of individuals.

Another confounding variable could have been the nature of the memory test. The story the participants were asked to read was fairly intensive with many details. Though the questions were all straightforward and based on details directly stated in the story, the story was likely too long and full of too many details to allow the subjects to retain all the information a week later. In future experiments, it would likely be more beneficial to give the subjects a word list to remember with a longer exposure time. Increasing the duration of the exercise from ten to thirty minutes would be beneficial because it would allow the participants a longer period of time to increase their heart rate. It is possible that the shorter duration used in this experiment was insufficient for the subjects to double their heart rates without overexertion, impacting their ability to become stationary and retain information during their recovery period. Finally, due to circumstances outside of the experimenters' control, the experimental setting had to be changed midway through the study to a less than ideal location. The setting was changed from a quiet, isolated room to a laboratory classroom with different auditory and visual stimuli. An ideal setting without any external stimuli should be maintained throughout the experiment in future studies to ensure there are no confounding variables for the results.

As a group, we initially faced some logistical issues with our experimental procedure; however, the majority of these issues were solved by group collaboration. We initially struggled with our means of elevating the subjects' heart rate and maintaining that heart rate for an extended period of time. To expedite the process, we decided to have the subjects run on the stairs to elevate their heart rate, then go on the bike to achieve double that rate. The difficulty of the questions given during the recollection period could pose another potential problem, however as long as these questions are unchanged throughout the experiment, the results could still demonstrate a connection between exercise and memory, if such a relationship exists. As mentioned above, our major concern is the memory recollection test assessing

subjects on reading comprehension instead of factual recollection; however the simplicity of the questions should account for this potential problem.

Overall, our experiment ran relatively smoothly. We were not able to harbor any data that was clearly indicative of exercise, or the lack thereof, leading to better memory retention.

Tables and Figures

	Mean Pulse Rate [bpm]	Mean Breathing Rate [bpm]	Mean Arterial Blood Pressure [mmHg]
Control	60.6	13.26	91.6
Experimental	136.4	24.00	100.9

Table 1: Illustrates our primary sources of data throughout our study.

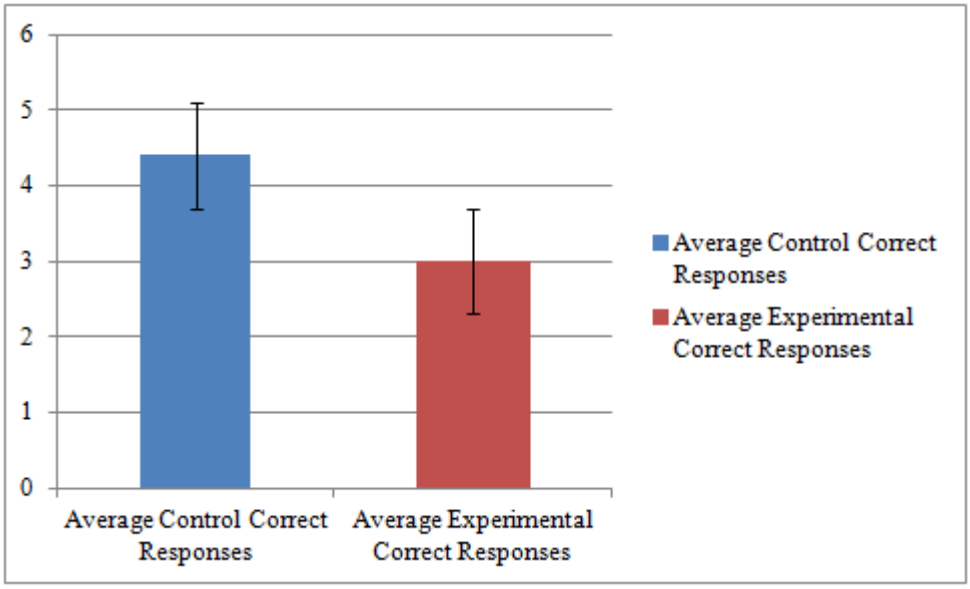

Figure 1: Shows how many correct answers each test subject achieved.

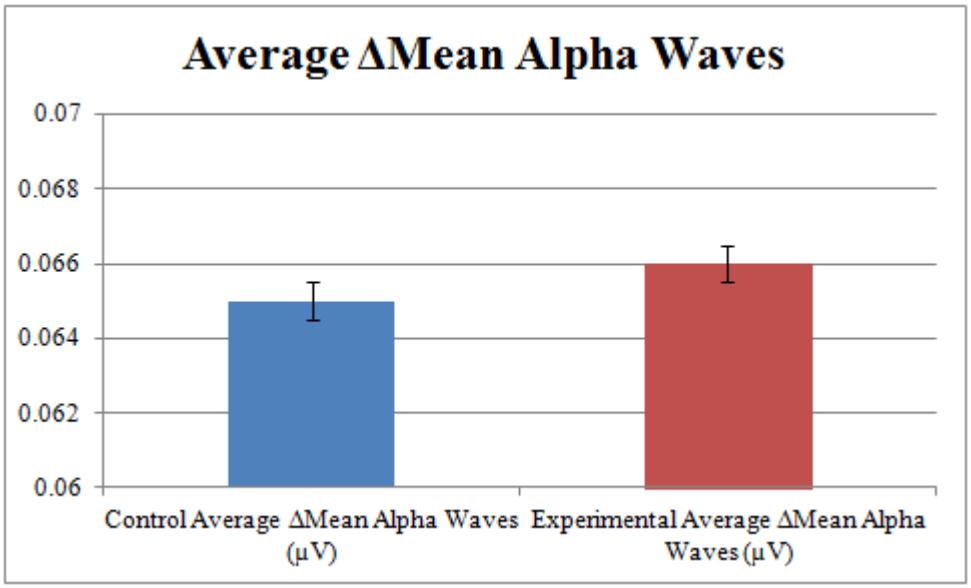

Figure 2: Shows the average change in mean alpha waves for the groups

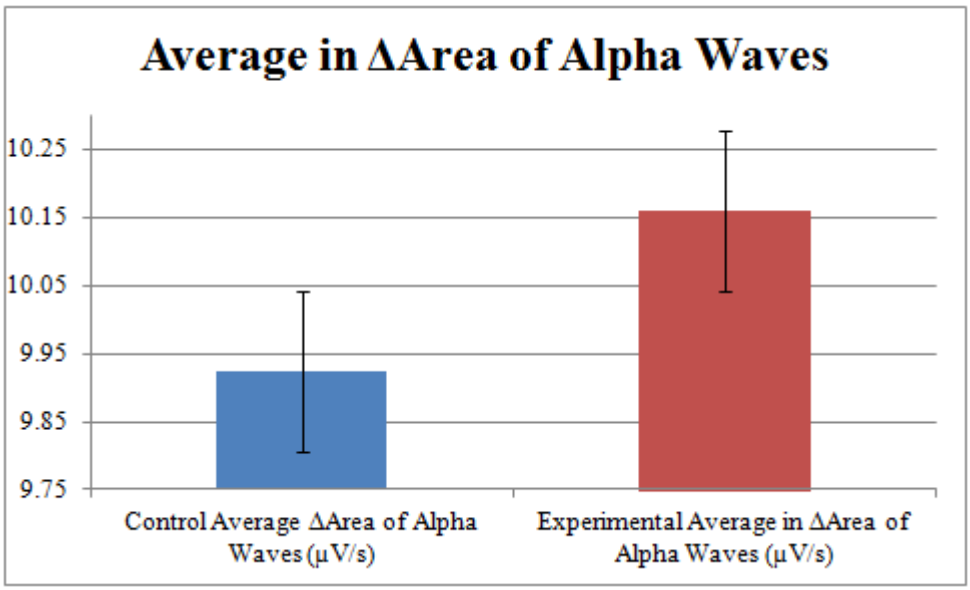

Figure 3: Shows the Average change in area of alpha waves of the groups.

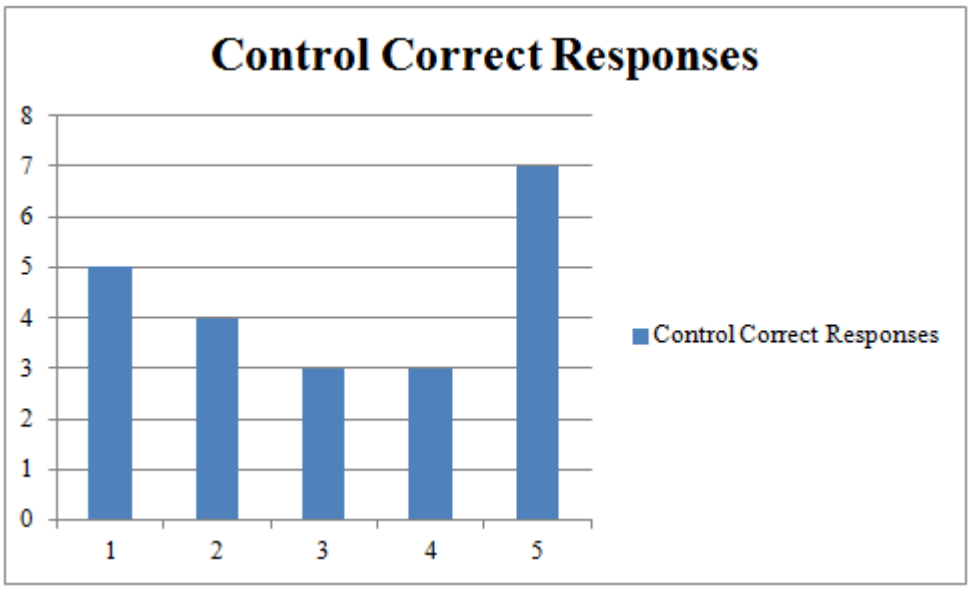

Figure 4: Shows the correct number of responses of control participants

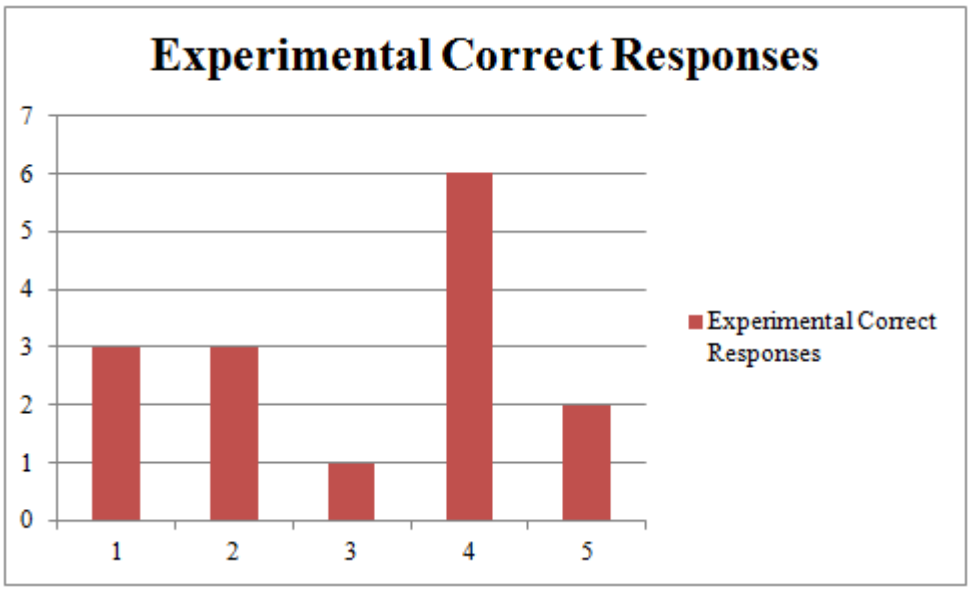

Figure 5: Shows the correct number of responses of experimental participants.

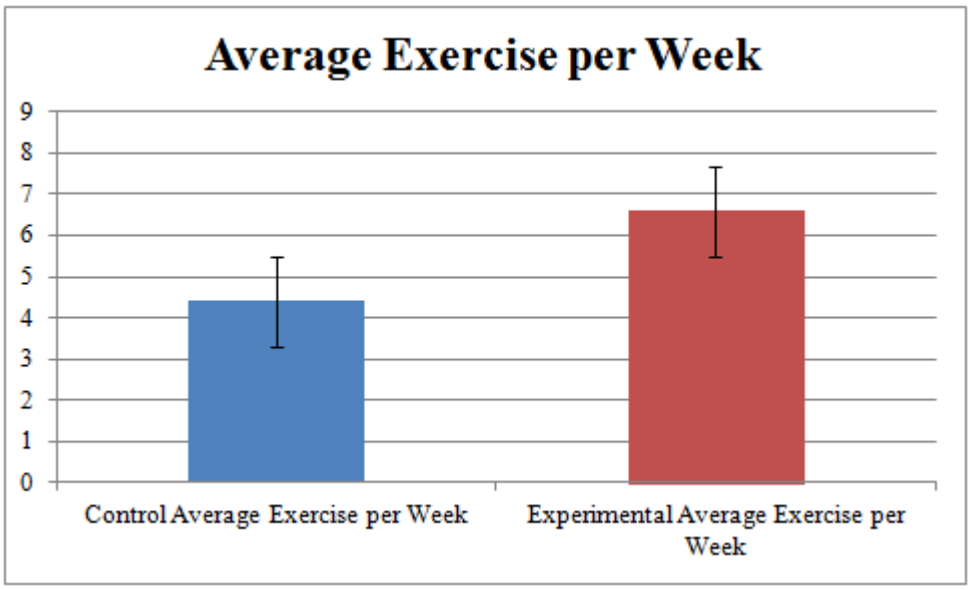

Figure 6: Shows average exercise per week of participants

Appendix I

UNIVERSITY OF WISCONSIN-MADISON

Research Participant Information and Consent Form

Title of the Study: The effects of Exercise on Long-term Memory

Principal Investigators: Rolf Ieuter, James Peculis, Dorothy Ho, Hannah Myles, and Benjamin Poenitsch

DESCRIPTION OF THE RESEARCH

You are invited to participate in a research study about the effect of physiological factors from exercise on memory.

You have been asked to participate because you are enrolled in Physiology 435.

The purpose of the research is to _____discover if there is a direct connection between the body's response to exercise and long-term memory.

This study will invite the participation of all students enrolled in Physiology 435.

This research will take place within Physiology 435 laboratory sections.

WHAT WILL MY PARTICIPATION INVOLVE?

If you decide to participate in this research you will be asked to perform aerobic exercise followed by the reading of a short story; then, a week later, complete a short questionnaire about the reading.

Your participation will last approximately fifteen minutes and two minutes the following week.

After the semester is completed, you will be able to view the experimental results.

No credit will be assigned for your complete and voluntary participation. If you do not wish to participate, simply return this blank consent form.

.**ARE THERE ANY RISKS TO ME?**

All the risks associated with this experiment are the typical risks involved in cardiovascular exercise. If you have a known medical condition in which your doctor or physician has advised you not to participate in cardiovascular exercise, please do not participate in this study.

ARE THERE ANY BENEFITS TO ME?

The benefits associated with this experiment are increased cardiovascular strength, catabolism of stored glycogen and lipids, and increase of myofibrils.

HOW WILL MY CONFIDENTIALITY BE PROTECTED?

While there may be reports as a result of this study, your name will not be used. Only group characteristics will be reported – that is results with no identifying information about individuals will be used in any reported or publicly presented work.

WHOM SHOULD I CONTACT IF I HAVE QUESTIONS?

If you have any questions regarding this specific experiment, please contact Rolf Ieuter, ieuter@wisc.edu, 847-917-4652.

If you are not satisfied with response of research team, have more questions, or want to talk with someone about your rights as a research participant, you should contact Dr. Andrew Lokuta, 608-263-7488, ajlokuta@wisc.edu.

Your participation is completely voluntary. If you decide not to participate or to withdraw from the study it will have no effect on your grade in this class.

Your signature indicates that you have read this consent form, had an opportunity to ask any questions about your participation in this research and voluntarily consent to participate.

Name of Participant (please print):_____

Signature _____ Date _____

Appendix II

A long time ago there lived a king who was famed for his wisdom through all the land. Nothing was hidden from him, and it seemed as if news of the most secret things was brought to him through the air. But he had a strange custom; every day after dinner, when the table was cleared, and no one else was present, a trusty servant, Fred, had to bring him one more dish. It was covered, however, and even Fred did not know what was in it, neither did anyone know, for the king never took off the cover to eat of it until he was quite alone.

This had gone on for a long time, when one day Fred, who took away the dish, was overcome with such curiosity that he could not help carrying the dish into his room. When he had carefully locked the door, he lifted up the cover, and saw a white snake lying on the dish. But when he saw it he could not deny himself the pleasure of tasting it, so he cut of a little bit and put it into his mouth. No sooner had it touched his tongue than he heard a strange whispering of little voices outside his window. He went and listened, and then noticed that it was the sparrows who were chattering together, and telling one another of all kinds of things which they had seen in the fields and woods. Eating the snake had given him power of understanding the language of animals.

Now it so happened that on this very day the queen lost her most beautiful ruby ring, and suspicion of having stolen it fell upon Fred, who was allowed to go everywhere. The king ordered Fred to be brought before him, and threatened with angry words that unless he could before the morrow point out

the thief, he himself should be looked upon as guilty and executed. In vain he declared his innocence; he was dismissed with no better answer.

In his trouble and fear Fred went down into the courtyard and took thought how to help himself out of his trouble. Now some ducks were sitting together quietly by a brook and taking their rest; and, whilst they were making their feathers smooth with their bills, they were having a confidential conversation together. Fred stood by and listened. They were telling one another of all the places where they had been waddling about all the morning, and what good food they had found; and one said in a pitiful tone: ’Something lies heavy on my stomach; as I was eating in haste I swallowed a ruby ring which lay under the queen’s window.’ Fred at once seized her by the neck, carried her to the kitchen, and said to the cook: ’Here is a fine duck; pray, kill her.’ ’Yes,’ said the cook, and weighed her in his hand; ’she has spared no trouble to fatten herself, and has been waiting to be roasted long enough.’ So he cut off her head, and as she was being dressed for the spit, the queen’s ring was found inside her.

Fred could now easily prove his innocence; and the king, to make amends for the wrong, allowed him to ask a favour, and promised him the best place in the court that he could wish for. Fred refused everything, and only asked for a horse and some money for travelling, as he had a mind to see the world and go about a little. When his request was granted he set out on his way, and one day came to a pond, where he saw three fishes caught in the reeds and gasping for water. Now, though it is said that fishes are dumb, he heard them lamenting that they must perish so miserably, and, as he had a kind heart, he got off his horse and put the three prisoners back into the water. They leapt with delight, put out their heads, and cried to him: ’We will remember you and repay you for saving us!’

He rode on, and after a while it seemed to him that he heard a voice in the sand at his feet. He listened, and heard an ant-king complain: ’Why cannot folks, with their clumsy beasts, keep off our bodies? That stupid horse, with his heavy hoofs, has been treading down my people without mercy!’ So he turned on to a side path and the ant-king cried out to him: ’We will remember you–one good turn deserves another!’

The path led him into a wood, and there he saw two old ravens standing by their nest, and throwing out their young ones. 'Out with you, you idle, good-for-nothing creatures!' cried they; 'we cannot find food for you any longer; you are big enough, and can provide for yourselves.' But the poor young ravens lay upon the ground, flapping their wings, and crying: 'Oh, what helpless chicks we are! We must shift for ourselves, and yet we cannot fly! What can we do, but lie here and starve?' So the good young fellow alighted and killed his horse with his sword, and gave it to them for food. Then they came hopping up to it, satisfied their hunger, and cried: 'We will remember you–one good turn deserves another!'

And now he had to use his own legs, and when he had walked a long way, he came to a large city. There was a great noise and crowd in the streets, and a man rode up on horseback, crying aloud: 'The king's daughter wants a husband; but whoever seeks her hand must perform a hard task, and if he does not succeed he will forfeit his life.' Many had already made the attempt, but in vain; nevertheless when the youth saw the king's daughter he was so overcome by her great beauty that he forgot all danger, went before the king, and declared himself a suitor.

So he was led out to the sea, and a gold ring was thrown into it, before his eyes; then the king ordered him to fetch this ring up from the bottom of the sea, and added: 'If you come up again without it you will be thrown in again and again until you perish amid the waves.' All the people grieved for the handsome youth; then they went away, leaving him alone by the sea.

He stood on the shore and considered what he should do, when suddenly he saw three fishes swimming towards him, and they were the very fishes whose lives he had saved. The one in the middle held a mussel in its mouth, which it laid on the shore at the youth's feet, and when he had taken it up and opened it, there lay the gold ring in the shell. Full of joy he took it to the king and expected that he would grant him the promised reward.

But when the proud princess perceived that he was not her equal in birth, she scorned him, and required him first to perform another task. She went down into the garden and strewed with her own

hands ten sacks full of grain on the grass; then she said: 'Tomorrow morning before sunrise these must be picked up, and not a single grain be wanting.'

The youth sat down in the garden and considered how it might be possible to perform this task, but he could think of nothing, and there he sat sorrowfully awaiting the break of day, when he should be led to death. But as soon as the first rays of the sun shone into the garden he saw all the ten sacks standing side by side, quite full, and not a single grain was missing. The ant-king had come in the night with thousands and thousands of ants, and the grateful creatures had by great industry picked up all the grain and gathered them into the sacks.

Presently the king's daughter herself came down into the garden, and was amazed to see that the young man had done the task she had given him. But she could not yet conquer her proud heart, and said: 'Although he has performed both the tasks, he shall not be my husband until he had brought me an apple from the Tree of Life.' The youth did not know where the Tree of Life stood, but he set out, and would have gone on forever, as long as his legs would carry him, though he had no hope of finding it. After he had wandered through three kingdoms, he came one evening to the woods, and lay down under a tree to sleep. But he heard a rustling in the branches, and a golden apple fell into his hand. At the same time three ravens flew down to him, perched themselves upon his knee, and said: 'We are the three young ravens whom you saved from starving; when we had grown big, and heard that you were seeking the Golden Apple, we flew over the sea to the end of the world, where the Tree of Life stands, and have brought you the apple.' The youth, full of joy, set out homewards, and took the Golden Apple to the king's beautiful daughter, who had now no more excuses left to make. They cut the Apple of Life in two and ate it together; and then her heart became full of love for him, and they lived in undisturbed happiness to a great age.

Appendix III

1. What is the servant's name?
2. What color was the snake?
3. What did the servant first hear when he ate the snake?
4. What kind of ring did the queen lose?
5. Who found the ring?
6. Where was the ring found?
7. What did the servant ask from the king?
8. What were the first animals he met on his trip?
9. Why was the ant-king angry?
10. How did the servant help the ants?
11. What did the servant give the ravens?
12. Where specifically was the princess's ring?
13. What did the princess throw in the garden?
14. What was the final trial the princess set him?
15. Where was it?

Appendix IV

Grubbs Test Calculation:

G (test) at 95% confidence for 5 observations = 1.672

G = (Questionable Value - mean) / standard deviation

G = (102.398 - 28.609) / 42.5618

G = 1.7336; 1.7336 > 1.672

G > G (test); Identified point is therefore an outlier

Appendix V

Experimental 1: 10-15 hours/week; running, core exercise, rowing and weight lifting

Experimental 2: 8 hours per week; weightlifting and running

Experimental 3: 7 hours per week; weights, run and soccer

Experimental 4: 5 hours per week; running, yoga, weightlifting and walking to class

Experimental 5 was stricken from the data

Control 1: 0 in past few weeks

Control 2: 5 hours per week mainly running

Control 3: 8 hours per week; mainly run sometimes lift

Control 4: 2 hours per week; walking

Control 5: 6-7 hours per week; baseball soccer football games, running, weightlifting

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