Running Title: THE EFFECT OF EXERCISE AND MEDITATION ON SHORT TERM RECALL

Physical and Mental Activity and Their Effects on Short Term Recall and Task Anxiety

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Abstract

Stress and anxiety impact long term and short term recall, as people who experienced stress showed a decreased performance on word recall task in past studies. Mindful meditation is associated with reduced stress and an increased ability to concentrate. Physical activity is hypothesized to contribute to cognitive ability. This study examines how meditation and exercise impact acute testing anxiety, and works to explore manipulated anxiety's direct, yet conjectural, effects on short term recall. Participants filled out a word search puzzle, and then participated in either a short exercise activity, meditation activity, or passively waited. Afterwards, their heart rate (HR), skin conductance (GSR), and blood pressure (BP) were measured while they were, without prior warning, asked to recall the words from the word search to determine their stress response and recall performance. A one-way ANOVA resulted in significant changes for heart rate, but not for skin conductance or blood pressure. There was no significant difference in the number of words recalled based on experimental treatment, but observational trends suggest that more intensive studies could find meditation to be effective in impacting short term recall. Overall, however, we cannot confirm a significant correlation regarding the effect of meditation and exercise on short term recall.

Introduction

Stress and anxiety are known to have large effects on both long term and short term (working) memory (Okon-Singer et al., 2015). Activities such as meditation and exercise impact the ability to adequately store memories by counteracting factors responsible for impairing working memory (Banks et al., 2015; Chao et al., 2015), especially when performed in tandem (Stein et al., 2014). Some studies have demonstrated an increase in memory performance under these conditions, while others have not proven their effectivity (Sandi & Pinelo-Nava, 2007).

A study by Kuhlmann, Piel and Wolf (2005) found that stress levels can impact the working memory and thus affect word recall. Subjects who underwent a stress treatment experienced elevated cortisol levels and consequentially displayed decreased abilities in word recall tasks compared to those in a control group. While the literature is extensive in demonstrating that stress can both positively and negatively affect long term memory (Lynch, 2004), many questions remain unanswered regarding the mechanisms and extent to which stress influences short term recall. In this study, we propose to further examine how a person's immediate state of mind affects word recall by utilizing meditative relaxation and physical exertion as treatments.

Mindful meditation is a widely practiced activity employing unperturbed mental focus on breathing rhythm, and has been shown to decrease levels of stress and anxiety, resulting in a greater sense of well-being and ability to concentrate (Banks & Welhaf et al., 2015). Due to its abstract and subjective interpretations, the concept of mindfulness as a medical and physiological tool is still vaguely defined and not thoroughly studied (Chiesa, Calati & Serretti, 2010); however, recent reviews suggest mindful meditation has positive effects on grey matter thickness as well as cerebral blood flow, all of which is speculated to improve recall (Marciniak & Sheardova et al., 2014). Supportingly, other studies have found that healthy and depressed patients both significantly improve their abilities to recall specific memories when subjected to meditation treatments (Chiesa, Calati & Serretti, 2010). The main goal of meditation is to indirectly benefit cognitive abilities by increasing the capacity to concentrate and remain attentive (Marciniak & Sheardova et al., 2014).

Physical activity is another hypothesized contributor to cognitive abilities, and has received greater empirical attention from literature seeking to link exercise and memory. Overall, the effects of physical activity on cognitive function remain unclear, as several reviews of the exercise literature (Tomporowski & Ellis, 1986; Etnier et al., 1997) found only scant evidence for a significant, empirical relationship. Studies yielded contradictory results, finding correlations both positive and negative, as well as conclusions of insignificant effects. The researchers noted that, while their meta-analyses demonstrated slight positive relationships between brief “bouts” of exercise and cognitive function, such stresses are unlikely to produce practical or useful improvement, when compared to comprehensive, regular exercise plans (McMorris & Graydon, 2000). In contrast, there are various studies suggesting the enhancement of learning in response to physical activity, as a means to promote physical education in schools (Sattelmair & Ratey, 2009). When followed by a recovery period, physical exercise acts as a physiological stressor that stimulates brain growth in pre-adolescent children and prevents cognitive degeneration in the elderly (Sattelmair & Ratey, 2009). Rather than as a stressor, we define physical exercise as a practice affecting the mental stress that may affect recall.

The aim of this study is to determine the physiological impacts of both meditation and physical exercise on mental stress, and establish how induced anxiety levels impact short term recall. Our experiment will require subjects to perform short term recall immediately after participating in either a meditation group, an exercise group (serving as a positive control for increased BP, HR, and GSR), or a passive waiting group (negative control). The meditation treatment is distinct from the “passively waiting” control group because during mindful meditation, the mind is actively focused on a specific task with a desired goal, whereas the waiters are not given any instruction. During the recall, measurements on blood pressure, skin conductance, and heart rate were recorded.

Our three physiological response variables were selected to evaluate the acute stress response, defined as the autonomic nervous system’s reaction to a perceived threat (Cannon, 1932). The adrenal medulla releases catecholamines into the bloodstream (Cannon, 1915), which stimulate increases in blood pressure and heart rate (Gleitman, Fridlund & Reisberg, 2004). Sweat gland activity also increases, altering skin conductance and thus providing the basis for the galvanic skin response (Carlson, 2013). Numerous studies show that skin conductance initially increases at the start of a stressful task and decreases throughout the task (Renaud & Blondin, 1997; Chen et al., 2014). Although this habituation response for skin conductance is likely to occur in our study, the initial skin conductance measurements could be indicative of task-related anxiety and stress. Previous experiments indicate elevated heart rate during a Stroop word task, which was specifically designed to induce stress. Heart rate levels were higher during task performance than during the initial rest period (Renaud & Blondin, 1997). This study will exploit the surprise of a "pop quiz" to induce acute stress and thus determine the impacts of exercise and meditation on the presentation and magnitude of the acute stress response, and by extension, on the quality of short term recall. We hypothesize that stress response levels are inversely correlated with the number of words recalled by study participants. We also hypothesize that the meditation and exercise will both reduce stress, but meditation will have a greater stress reduction effect and lead to better recall. Exercise is nonetheless expected to induce moderate improvements in word recall and stress reduction. By examining the relationship between mental and physical activity, the acute stress response, and short term recall, we hope to provide a base on which continued research may further insight on effective pedagogical and neuroprotective methods.

Methods

Materials

The experiment utilized the following devices: Dell® Inspiron 530 Desktop Computer running Windows Vista™ for data collection, Biopac Systems® Student Lab™ Unit MP36, Biopac Systems® SS3LA, Electrodermal Activity Finger Transducer for measuring galvanic skin reactivity, Omron® BP791IT Heart Rate Monitor for measuring blood pressure, Nonin® 9843 Pulse Oximeter / CO_2 Detector for measuring heart rate, and a stopwatch.

The words selected for the word search were randomly selected by the experimental team. Restrictions were placed on word categories and pronunciations to avoid the appearance of many related or similar sounding words on the word list. Once the list order was randomized, the selected words were entered into a word search generator. The dimensions of the puzzle were set to 12 letters by 12 letters.

The meditation and exercise subjects were guided with the assistance of two five-minute instructional videos found on YouTube.com. The meditation video used was selected for its simplicity and soothing mood, and is entitled "The Five Minute Miracle - Daily Guided Meditation." The exercise video was a low cardio workout video that required no extra equipment. Five minutes of the material was used. The video is entitled "Low Impact Cardio Workout for Beginners - Beginner Cardio & Toning Workout Routine."

Subjects

A total of 24 subjects, nine males and fifteen females, between the ages of 20-25 (μ = 21.75, SD = 1.36) participated in the study. Participants were randomly selected from the Spring 2015 Physiology 435 course, preferentially drawn from lab section 602 as a convenience sample. Participants were classified as high or low exercise based on responses to a brief pre-study questionnaire, and both groups were randomly assigned to experimental conditions to ensure statistical accuracy.

Design

The study tested the impact of exercise, meditation, and passive waiting on short term recall in college students exposed to test anxiety. The exercise condition was selected as the positive control because exercise is known to directly increase blood pressure, skin conductance, and heart rate. The passive waiting condition was the negative control because the mind is not expected to be actively involved in higher-order central or somatic nervous functions during the absence of new or stressful stimuli. The dependent variables are the correct number of words recalled, the change in systolic and diastolic blood pressure from after the activity to the end of the recall task, the change in galvanic skin reactivity during the recall task, and the change in heart rate during the recall task.

Surveys and Questionnaires

A pre-experimental survey was sent electronically to all members of the Spring 2015 Physiology 435 course. The survey included questions identifying lab section information and discrete, multiple choice questions (Figure 1) regarding exercise and meditation habits. This distinction between individuals' exercise frequency was necessary in order to block the participants for statistical analysis. Subject responses for meditation frequency were used in data analysis to determine if previous meditation experience was a confounding variable. Subjects filled out a post-experimental questionnaire to establish whether or not they had expected the word recall activity after their treatment regimen.

Experimental Procedure

The first twelve individuals from lab section 602 who responded with either 3-4 or 5+ hours per week were classified as high exercise subjects. These subjects were randomly assigned to the experimental conditions. Then the first twelve individuals from lab section 602 who responded with 0-2 hours per week of exercise were classified as low exercise subjects and also randomly assigned to the experimental conditions. Eight subjects completed the exercise activity, eight subjects completed the meditation activity, and eight subjects completed no activity. Within each condition, four subjects were high exercise and four subjects were low exercise to control for fitness level, ensuring an even grouping to promote statistical accuracy.

Each trial consisted of one participant at a time. Subjects sat at a desk and were instructed to complete a provided word search within a five minute time slot. They were told if they did not complete the activity within the time frame, the experiment would continue on. Subjects were then instructed to participate for a five minute period in either a guided meditation video, a low cardio exercise video, or to passively wait. Only one team member was present for subject guidance during the five minute exercise and meditation activities, and the lights were turned off during the meditation session. Participants sat alone during the passive wait time without their cellular phones, so they would not be distracted by or tempted to interact with the experimenter. After the allotted time, subjects were instructed to return to the desk and were informed about the various measurements that would be taken during the rest of the experiment. A heart rate monitor was attached to calculate blood pressure in the dominant arm, while a pulse oximeter and electrodermal transducer were installed on the non-dominant hand to measure heart rate and GSR, respectively. After the devices' completed calibration and a 15 second baseline window, participants were instructed to begin the free recall task. During the 15 second GSR device calibration, baseline heart rate was measured. After the two minutes allowed for the task, the paper was collected and the participants were given a post-experimental questionnaire. After completion of the questionnaire, the study was completed. The total experiment lasted 15 minutes (Figure 2).

Measurements

The subjects were hooked up to the blood pressure cuff on their dominant bicep and the blood pressure was immediately taken following the experimental condition. A team member connected the GSR and the heart rate monitor. The GSR was placed on the index and middle finger of the non-dominant hand and the heart rate monitor was placed on the pinky finger of the non-dominant hand. The GSR was then calibrated, followed by a fifteen second reading of skin conductance and heart rate to establish a baseline. The data collection for GSR skin conductance and the heart rate began concurrently with the free recall task. Skin conductance and heart rate was recorded at fifteen second intervals throughout the designated time period. After the two minutes, the participant was told that the allotted time was over, skin conductance and heart rate recordings stopped, and a final blood pressure reading was recorded. All devices were removed and wiped with a Purell sanitizing wipe.

Results

Initial analysis of our data indicates no significant overall effects on short term recall due to meditation or exercise treatments prior to word recall. However, when looking at the individual physiological characteristics that were measured, there are some observable trends that are important to note.

Each participant's baseline heart rate was subtracted from the heart rate at each time interval to account for individual differences in heart rate. These new values are the changes in heart rate from baseline. The changes in heart rate data was used for analysis. A one-way ANOVA shows there was a significant difference between the changes in heart rate (not absolute heart rate values) among treatment groups. Further analysis shows a significant difference in mean change of heart rate over time between both the meditation and control group (p value of 0.019), as well as the exercise and control group (p value of 0.042). However, there was no significant difference in the mean change of heart rate between the exercise and meditation groups (p value of 0.98).

An additional one-way ANOVA found no significant difference between the changes in galvanic skin conductance among treatment groups (p value of 0.865). However, at $t = 0$, there was an observable spike in skin conductance among all groups when subjects were alerted that they had to recall the words. Skin conductance began to decrease immediately for all groups, but at different rates. The meditation group had a decrease in skin conductance at a rate of -0.0834 ΔGSR/sec. The exercise group had a decrease in skin conductance at a rate of -0.0522 ΔGSR/sec. The control group had the slowest rate of decrease in skin conductance at -0.0331 ΔGSR/sec (Figure 4). Interestingly, 30 seconds after announcing the pop quiz, a p value of 0.051 indicated there was a significant difference between the mean GSR values of each treatment group. Further analysis showed that the only two groups statistically different from each other at 30 seconds (p value .048) were meditation and exercise.

An ANOVA test for blood pressure indicated that no p values were below 0.62 (Table 1). Thus, it can be concluded that there is no statistically significant difference in the systolic and diastolic differences between the three treatment groups. The differences seen are likely due to random chance.

With a p value of 0.442, there is no statistical evidence to suggest there is a difference between the number of correct words recalled among all three treatment groups (Figure 5). Blocking for exercise did not result in significant p values either.

Discussion

Our hypothesis that stress will have an inverse relationship with recall performance was not supported by the data. Subjects who meditated, exercised, or passively waited had similar performance on the word recall task. The lack of significance in recall performance may be due to the short study duration from the time they were exposed to the words to the time they began recall. Our hypothesis that the meditation and exercise groups would reduce stress was supported because the controls experienced significantly more stress during recall, as the increased changes in heart rate suggest, and the control group had the slowest rate of decrease in skin conductance following the emotional trigger. There is not enough evidence to determine whether meditation leads to greater stress reduction and better word recall than exercise.

It is interesting to note that both the meditation and exercise groups had overall significantly lower changes in heart rate from the baseline in comparison to the control group, although the two treatment groups were not significantly different from each other. A meta-analysis of heart rate variability as a marker of stress and health discusses that the body responds to environmental stress through changes in heart rate (Vrijkotte, 2000). This relationship relates to our data in that it suggests that subjects who underwent exercise and meditation treatments were overall less stressed than those in the control group, aligning with our hypothesis. However, one treatment is not suggested to better reduce stress over the other in regards to heart rate.

The data indicating no significant difference in the changes in galvanic skin conductance is not surprising, as past studies have noted quick habituation responses to stress (Renaud & Blondin, 1997; Chen et. al., 2014). As expected, there was a habituation response across all treatment groups, so noting the initial spike in skin conductance is most important. This spike suggests that at the moment when subjects were asked to recall all the words, they experienced a test stress. Although there were no statistically significant differences in the spike among the three groups, it can be observed that the meditation group experienced the highest spike, followed by the exercise group and then the control group. This was not a predicted result; however, the meditation group experienced the quickest habituation, so we can speculate that after the initial spike they became more relaxed than the other treatment groups. Exercise could also lead to increased resilience, but the change in GSR over time from 15 seconds to 30 seconds suggests the effects may be greater for meditation. This indicates that individuals who meditate may have more resilience after being triggered by stress, although further studies need to be conducted in order to confirm this inference.

Because skin conductance measurements and heart rate measurements denote that subjects did experience task anxiety, we are assuming the acute stress is not substantial enough to impact a change in blood pressure from the beginning to the end of the word recall.

A variety of factors could have resulted in possible sources of error in our experiment. During certain trials we had people occasionally walking in and out of our room which may have acted as a distraction for the subject. In particular, a person entering the room during a trial caused the subject to turn their head towards the distraction, which may have impacted their ability to focus on the task at hand. This deviation from the trial may have altered the physiological variables being measured. Another potential large source of error was differing personnel operating the data collection equipment. Each group member recorded the same measurements for each trial unless absent, in which case another group member would take over. More consistency among the measurement personnel could have made the results more reliable. Furthermore, the amount of effort put into each activity could have varied by subject which would also contribute to error in our results. In addition, the blood pressure cuff used in the experiment often reported errors, resulting in a delayed measurement. Our experiment also was restricted by time and available subjects. We were only able to perform a single trial per subject, which makes significant results difficult to achieve. It would be beneficial to perform further studies that analyze the long term effects of exercise and meditation on stress levels and short term recall. Due to the size and availability of the students taking this course, our total number of subjects for the experiment was limited. Expansion upon our experiment should include a larger sample size to ensure the probability of statistically significant results. Another potential study to look into could investigate the gender difference and note how meditation and exercise affects stress in males versus females. The results from this experiment prove to be relevant in the scientific field and could infer a correlation between stress and short term recall. The results could also provide a basis for exploring the relationship between the effects of exercise and meditation on stress.

Appendix

Pre-experiment Questionnaire

1. In a typical week, how many hours do you exercise?
2. In a typical week, how often do you meditate?

Figure 1. These questions were asked of subjects before they completed the experiment. This allowed subjects to be blocked into low and high exercise categories, and then appropriately placed into treatment groups, ensuring statistical accuracy.

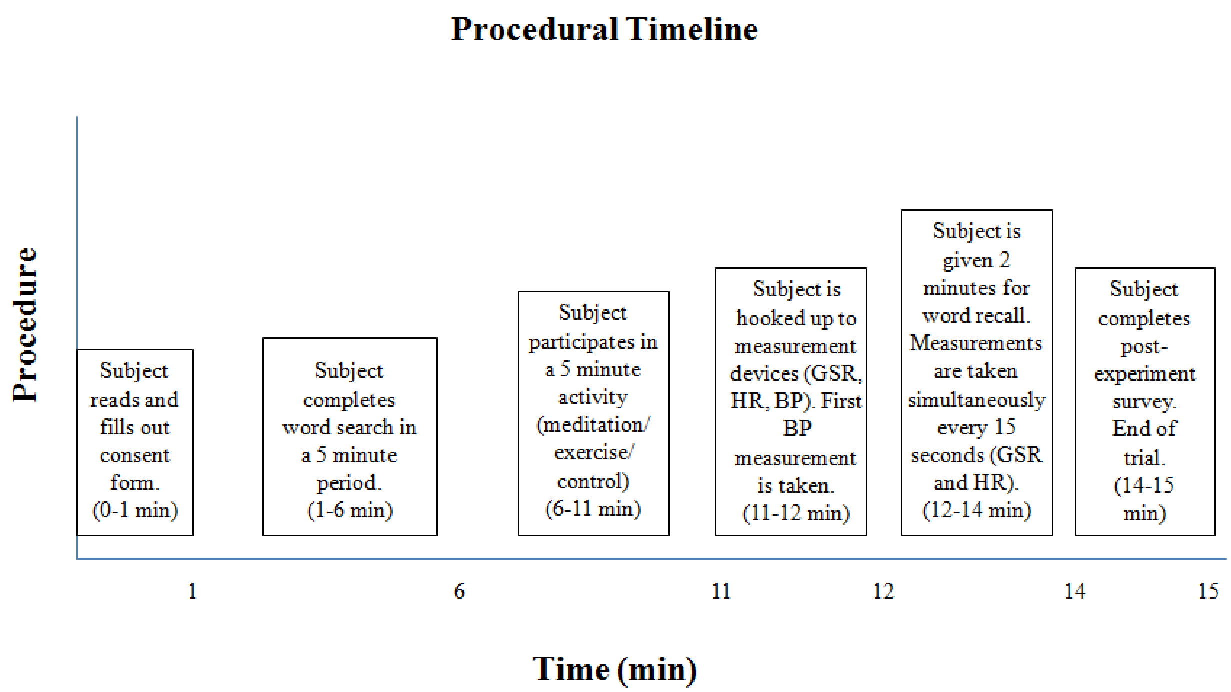
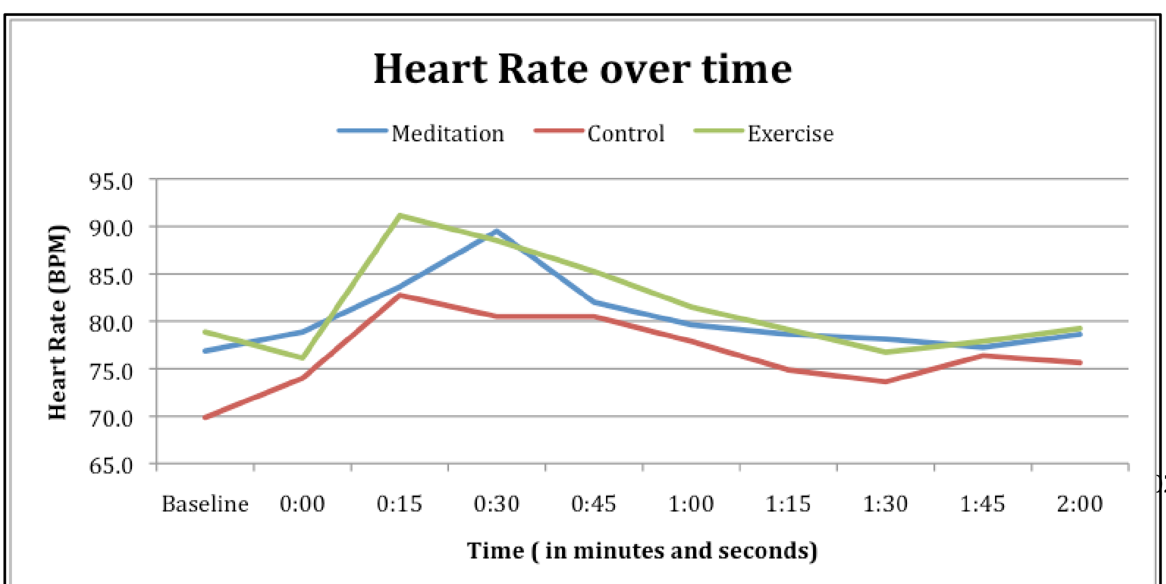


Figure 2. This figure represents the time spent during each portion of the trial, with a total duration of 15 minutes. All measurement and computer equipment was set up prior to the subject beginning the experiment.



2, Group 7

Figure 3. This figure represents the mean absolute heart rate measurements at 15 second intervals during the 2 minute word recall session. This data was used to calculate the mean changes in heart rate for the analysis. The time 0:00 was when subjects were instructed to start the recall task. The Baseline indicates a 15 second interval to establish normal skin conductance measurements.

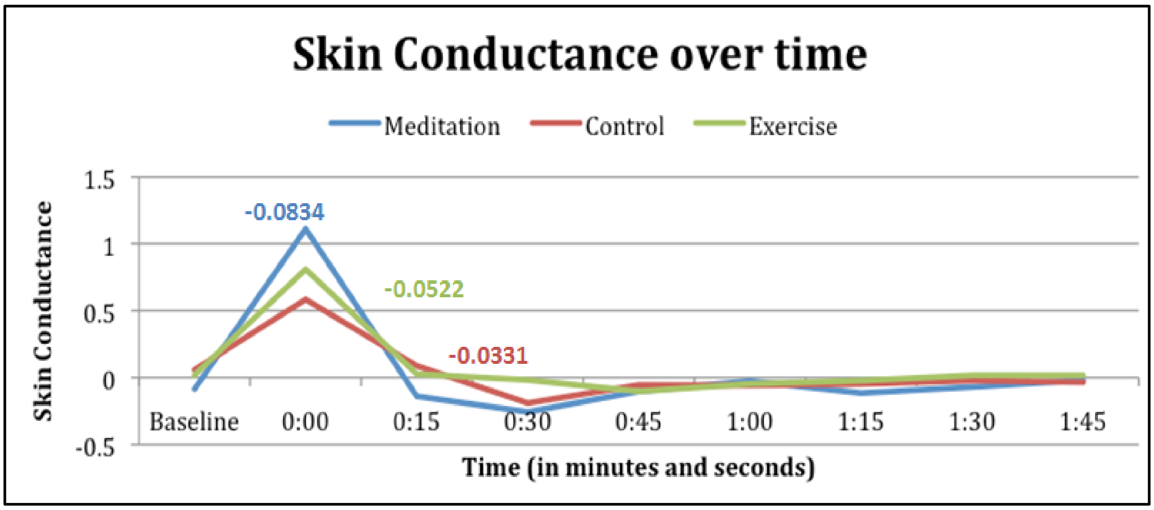


Figure 4. This figure represent the mean skin conductance measurements at 15 second intervals during the 2 minute word recall session. Time 0:00 was when subjects were instructed to start the recall task. The Baseline indicates a 15 second interval to establish normal skin conductance measurements. Slopes of the decline from the initial spike are denoted next to each line in the corresponding color.

Differences in Blood Pressure	**Change in Systolic**	**Change in Diastolic**	**Mean Initial BP (Systolic/ Diastolic)**	**Mean Final BP (Systolic/ Diastolic)**
Meditation	-3.25	-3.63	109.88/71.13	106.63/67.5
Control	-1.00	-3.63	105.63/70.88	104.63/67.25
Exercise	0.00	-4.38	111.88/74.5	111.88/70.13

Table 1. This table indicates the mean difference between the initial and final blood pressure (taken before and after recall) measurements for each treatment group, as well as the mean of the initial and final absolute blood pressure values. Initial blood pressure was recorded prior to word recall and final blood pressure was recorded after word recall.

Treatment Group	**Average Number of Correct Words Recalled out of 15 words**	**Standard Deviation**
Meditation	7.13	2.03
Control	6.13	2.17
Exercise	5.88	1.89

Table 2. This table indicates the mean number of correct words recalled from the word search after subjects completed one of the treatments.

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