Effects of Meditation on Working Memory

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Abstract

Long-term mindfulness meditation has been suggested to positively alter biological processes and to improve attention in previous studies. The purpose of this study is to test the effects of mindfulness meditation on short-term memory through a self-created visual memory test administered in two parts, once before the experimental group was guided into a meditative state and once after being in the meditative state for 5 minutes. Blood pressure, heart rate, and breathing rate were measured to determine the physiological implications of a meditative state. The recorded changes during these memory tests were analyzed for statistical significance. While there was a statistical significance in the decreased breathing rate of the experimental subjects (p-value of 0.0138), decreases in heart rate and blood pressure were not significant. The results show that subjects who reached a meditative state performed statistically worse on the second working memory task than those who did not, an opposite trend to that of our hypothesis.

Introduction

Meditation has not been considered an effective treatment by allopathic medicine and it is generally utilized as part of alternative medicine or palliative care. However, it is important to recognize the full potential of meditation as a stress-reduction method, not only for patients undergoing intensive clinical therapy or suffering from chronic pain (Rosenzweig et al., 2009), but also for those stressed by daily life events. Aside from its proven therapeutic effects on psychological states, much scientific-based evidence demonstrating the various positive effects of mindfulness meditation are now surfacing. Mindfulness meditation has been suggested to alter biological processes such as those in the brain and immune system, to alter central and autonomic nervous system interactions in a positive manner, and to improve attention (Davidson et al., 2003, Tang et al., 2009, and Tang et al., 2007). Long-term positive effects of meditation on age-related cognitive functions have also been shown (Prakash et al., 2011).

Mindfulness meditation is a mental exercise that focuses on the sensations of breathing while in a relaxed state of mind. During a meditative session, participants are taught to return attention onto their breathing through moment-to-moment awareness of self and the environment (Zeidan et al., 2009). By closing their eyes and continually focusing on the flow of their breath, participants actively recognize irrelevant thoughts, acknowledge them, but ultimately return their attention back to their breathing.

Recently, a lab group at the UCLA School of Medicine showed that an underlying biological basis for long-term meditation correlated with larger hippocampal and frontal volumes of gray matter. The frontal lobe is known to be the part of the brain that controls working memory; therefore these previous study results led our laboratory group to hypothesize that working memory improves after mindfulness meditation. We will utilize several parameters to test improvement in working memory as a function of meditation in our research study. Our test for working memory will be a memory recall task based on visual stimuli, as meditation training has been demonstrated to improve perceptual discrimination and sustained attention (Maclean et al., 2010). The physiological response to relaxation includes decreased respiration rate, heart rate, and blood pressure; therefore these will be the metrics by which we measure whether the test subject has entered a relaxed state.

Materials and Methods

Blood pressure, heart rate, breathing rate, and depth of breathing were measured in order to determine the physiological implications of meditative state. Blood pressure was measured manually using a blood pressure cuff and heart rate measured using a pulse oximeter. A respiratory depth strap connected to the BioPac computer program measured the rate and the depth of breathing. A self-created visual memory test was administered to subjects to display any variance in their working memory.

There were two separate groups of subjects, a control group and an experimental group. Each group consists of 8 participants, who were all students at University of Wisconsin-Madison. Because the variable of interest was change in working memory with or without meditation, the experimental group was instructed to perform focused meditation and the control group was not. Each subject was required to give informed consent.

Subjects in both groups were taken to a quiet room with the necessary measuring equipment in the Medical Sciences Building. Each subject's blood pressure and heart rate of breathing were first recorded as baseline results. Subjects were then administered a visual memory test to provide a baseline measurement of their working memory and were verbally instructed to remember as many pictures as possible from the test. The test consisted of 20 random objects in pictorial form all assembled in a PowerPoint, which flashed sequentially across the screen at 2-second intervals. This was followed by 15 seconds of silence for the subjects to gather their thoughts and then write as many names of objects as they could possibly recall, on a blank piece of paper in the subsequent minute. The control group subjects were instructed to return to their normal routine for 10 minutes, and then brought back to perform a second round of memory testing, with the same procedure as stated above but different, analogous memory test.

The experimental group subjects were guided to achieve a meditative state. The respiratory depth strap was placed around the chest of the experimental group subjects, and was connected to a computer program, which can distinctly show the subjects' rate and depth of breathing. At first, the subjects were instructed to take a deep breathto give a baseline measurement of their usual rate and depth of breathing. Next, subjects were instructed to close their eyes and calmly focus their breathing until the computer program displayed the depth of breathing as half of its maximum during normal breathing. This serves as an indication of achieving a meditative state. As soon as the meditative state was achieved, the subject's blood pressure and heart rate were once again measured, while the subject was instructed to continue their meditative breathing. The subject then was given a five-minute session of mindful meditation in the form of focused breathing while listening to a guided meditation script being read by one of the testers; this standardization allowed for consistency in time for meditation. Immediately afterwards, a second visual memory test consisting of different pictures with the same rules was administered to measure any variance in their working memory as compared with their baseline results. Meanwhile, the control group was also asked to return to the quiet room and take the same second memory test after their blood pressure and heart rate are recorded.

In order to determine if meditation improved working memory, paired and unpaired t-tests were performed on the memory test results both recorded before and after the meditation state for experimental group, and the no-meditation session for control group.

Results

Mean arterial blood pressure. Blood pressure, initially measured as a diastolic and systolic reading, was converted to mean arterial blood pressure (MABP) using the equation MABP = DP + .333(SP-DP). A paired t-test was performed on each individual's blood pressure before the first and second tests. MABP did not show a statistical significant difference ($p < 0.05$) for either the control or experimental group, with p-values of 0.1451 and 0.8957 respectively (Table 1 and 2).

Heart rate. Heart rates were recorded before and during both memory tests for the control and experimental groups. A paired t-test was performed on each individual's heart rates recorded before the first and second tests, independently for the control group and the experimental group. A P-value of 0.676 indicated that there is no statistical significance between the two measurements within the control group (Table 1). No statistical significance was also found for the experimental group based on a P-value of 0.760 (Table 2), suggesting that heart rate did not decrease immediately after a meditative state (Figure 4B). Change in heart rate before and during the tests for each individual was then calculated by subtracting the heart rate recorded during the test from the baseline heart rate as recorded before the test, and an unpaired t-test was performed to show any statistical differences between the control group and the experimental group. A P-value of 0.587 was found for the difference in heart rate before subjects took test 1 (which is also before meditation for experimental group), indicating a lack of statistical significance between the control and the experimental group. A P-value of 0.858 was found for the difference in heart rate before subjects took test 2 (which is also after meditation for experimental group), indicating a lack of statistical significance between the control and the experimental group.

Breathing Rate. Breathing rates were determined by the difference between two consecutive peaks (at three different intervals) before the first and second memory tests were administered, as well as for both the control and meditative groups (Figure 2 A, B). No statistically significant differences were found for the control group, with a p-value of 0.7763 (Table 1). Breathing rates for the experimental group showed a statistically significant decrease after reaching a meditative state, with a p-value of 0.0138 (Table 2).

Memory test scores. Individual test scores on both the first and second tests for the control and experimental groups were graphed (Figure 3A, B). Within the control group, besides subject 1 (who received the same score on both tests) and subjects 4 and 6 who scored higher on the second test, all other subjects performed slightly worse on the second test relative to the first test. A paired t-test was used to analyze any statistical difference between scores on the first test and scores on the second test. A P-value of 0.6444 (Table 1) indicated that at a

95% confidence interval there is no significant statistical difference between test 1 scores and test 2 scores in the control group, and therefore the control group did not perform better on the second test than on the first test as a whole. Within the experiment group, every subject scored lower on the second test, and a paired t-test proved this trend to be statistically significant at a 95% confidence interval (P = 0.0002). An unpaired t-test was used to compare any statistical difference between the control and the experiment groups based on numbers found by subtracting the first test score from the second test score for each individual. A P-value of 0.008shows the test scores between the two groups is statistically significant.

Discussion

The purpose of our experiment was to test the effects of meditation on working memory. We hypothesized that meditation would improve working memory. However, our findings displayed an opposite trend. Results showed that subjects who underwent meditation performed statistically worse on the second memory task than those who did not. Several explanations could be given for these findings.

One possible source of error could have arisen from the process of achieving meditation. Previous studies investigating the effects of mindful meditation involved participants in meditation for longer periods of time per session and more than one session over the course of research. Often subjects were also given the opportunity to train in meditative techniques. Furthermore, meditative sessions were guided by skilled facilitators. Given the short duration of our meditation period and lack of multiple sessions, it is possible that our subjects did not reach a true meditative state which could have increased working memory performance.

This opposite trend shown in our results posed some interesting questions. T-tests performed on the differences in scores on Test 1 and Test 2 between control and experimental groups showed a statistically significant decrease in working memory post-meditation. As previously discussed, this could be because subjects did not enter a meditative state. One hypothesis to explain this decrease was that subjects were induced to enter the early stage of sleep, most likely hypnosis as characterized by theta waves. This, along with abrupt awakening after a standardized five minute session of meditation immediately followed by a memory test, could have prevented executive function from reaching normal levels to effectively perform the memory task. In effect, subjects were in a state of fatigue instead of alertness. Future studies may utilize EEG to examine brain wave activity as a possible indicator of hypnosis.

Another potential explanation as to why the subjects that underwent meditation did worse on the working memory test is flaw in our instruments of measure. We heavily depended on one instrument, the respiratory depth strap, to identify if the subject reached a meditative state. Based on findings that breathing rate and depth of breath decreased when subjects achieved meditative state, we set breathing depth to half its normal maximum value; breathing rate reflected this change as achievement of a meditative state. However, it is possible that in a true meditative state, breathing depth reaches a value lower than half the normal maximum.

Breathing rate, heart rate and blood pressure were expected to decrease after reaching a meditative state, based on previous studies. T-tests on breathing rate values show a significant decrease in breathing rate in the experimental group and no significant difference in the control group. However, heart rate and blood pressure did not decrease as expected. T-tests show that there was no statistically significant difference between heart rates before and after reaching a meditative state. One potential source for this discrepancy could have risen from the reliability of using the pulse oximeter as a heart rate monitor (8). We experienced some difficulties in reading the oximeter, as values for heart rate fluctuated continuously. Another potential source of error regarding measurement of heart rate concerns the point in time at which readings were taken; in our experiment, we recorded heart rate readings at times set to when blood pressure was recorded but not at quantitatively standardized time points.

It should be mentioned that literature on similar research, with longer meditation times, suggested statistically significant decreases in heart rate following meditation. This fact, along with a lack of statistically significant difference in blood pressure before and after reaching a meditative state, suggests that subjects either did not achieve meditative state or meditative state was not held long enough to detect any changes in heart rate or blood pressure but was sufficient to detect changes in breathing rate.

In conclusion, our study results did not support our initial hypothesis. It remains uncertain if in fact a meditative state increases short-term memory responses. However, the opposite trend we observed in our results poses intriguing questions concerning the effects of sleep, short-term relaxation, and the characterization of meditation on working memory recall.

Acknowledgments

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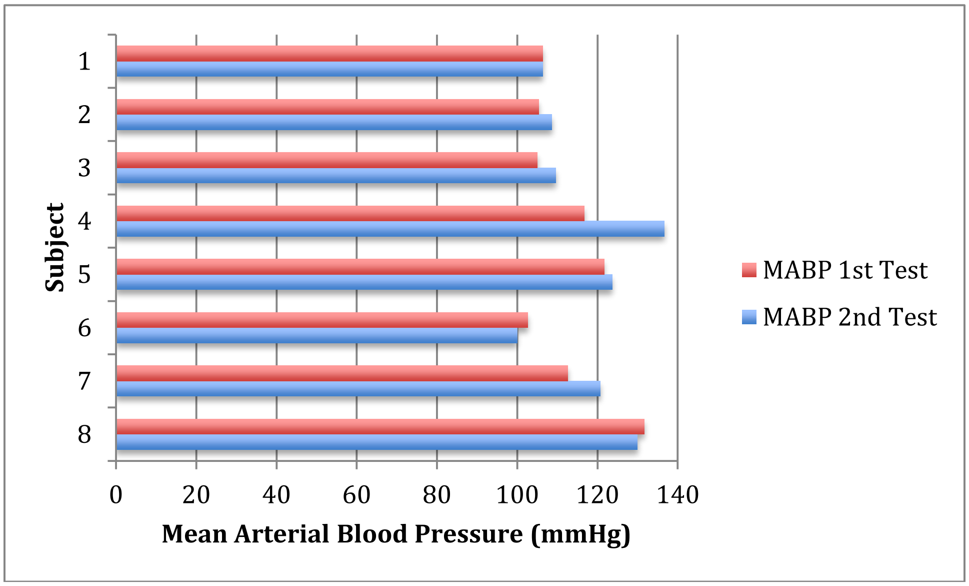
Appendix I

A



B

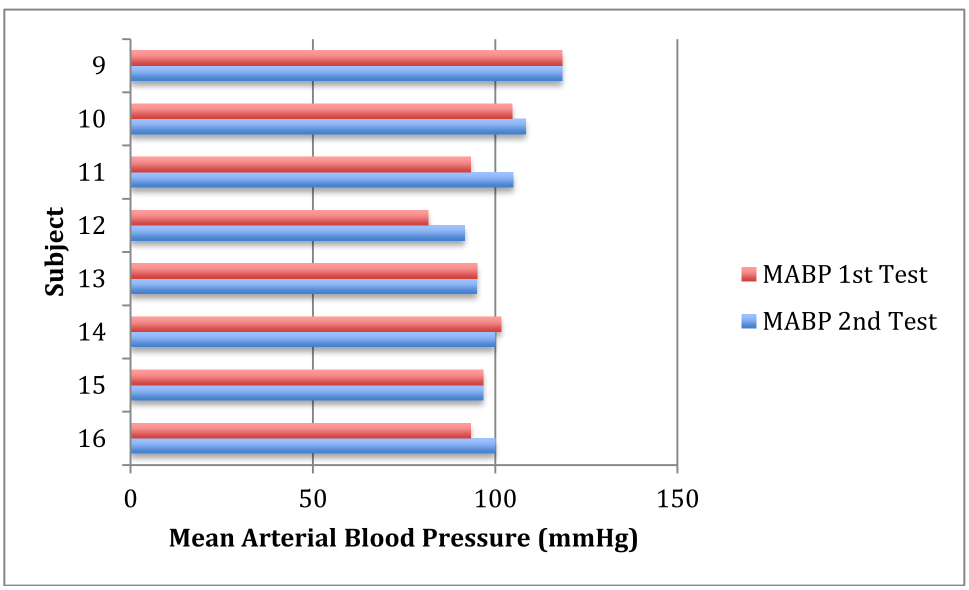
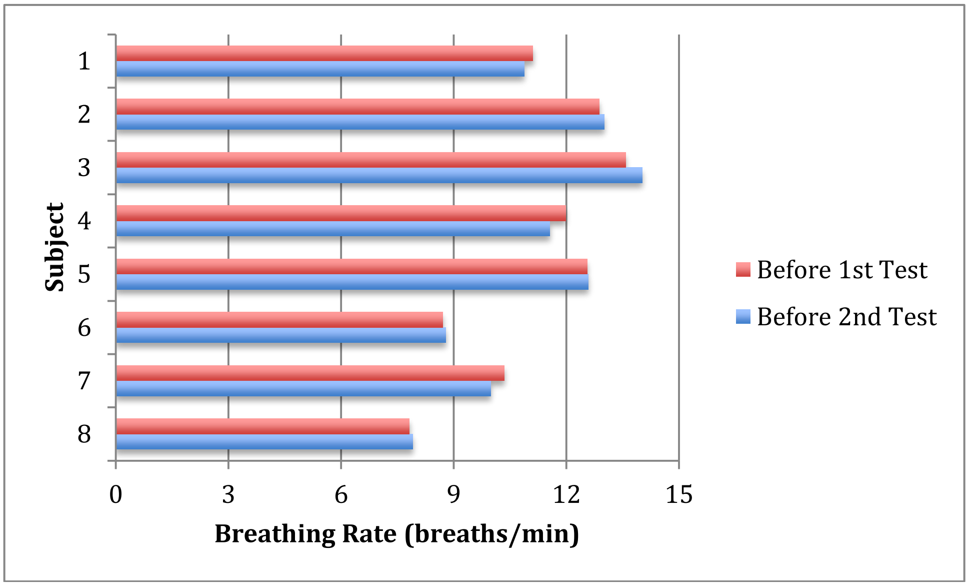


Figure 1. Mean arterial blood pressure for the subjects in the control group (A) and for those in the meditative state (B). Blood pressure was measured using a blood pressure cuff before each memory test was administered. There was no statistical significance within groups.

A



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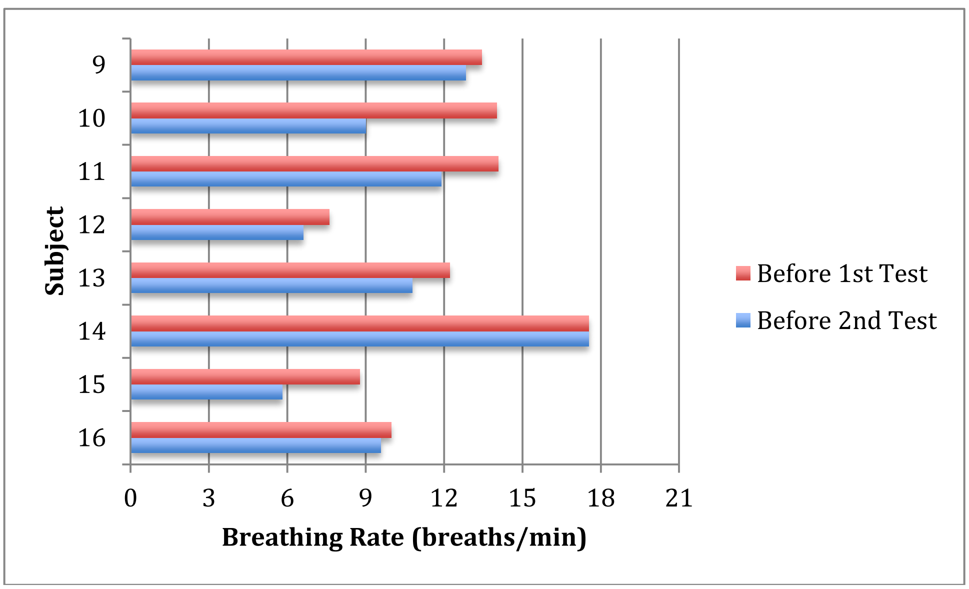
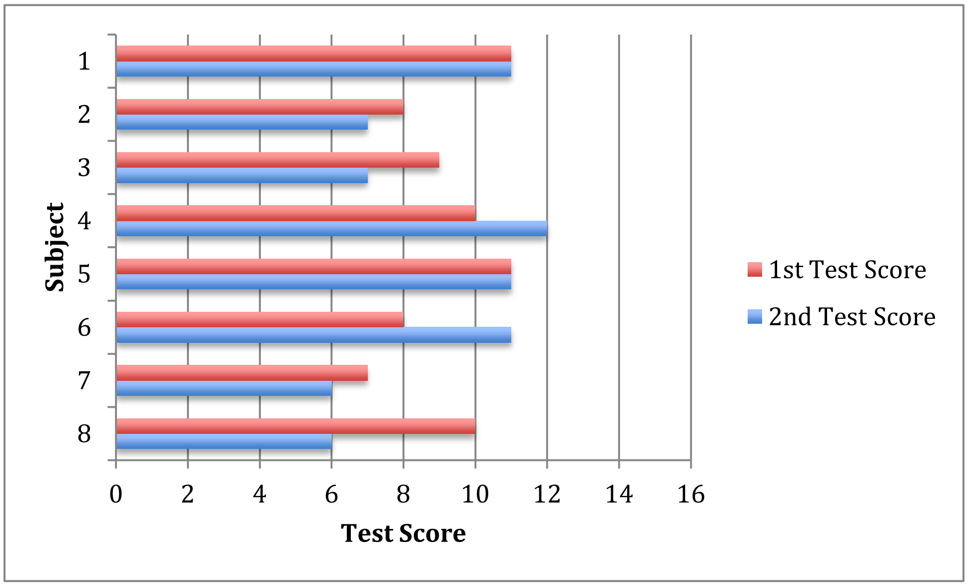


Figure 2. Breathing rate for subjects in the control group (A) and for those in the meditative group (B). Breathing rate was measured with a chest strap before each test was administered. A statistical significance was observed within the meditative group, showing a significant decrease in breathing rate before the second test was administered.

A



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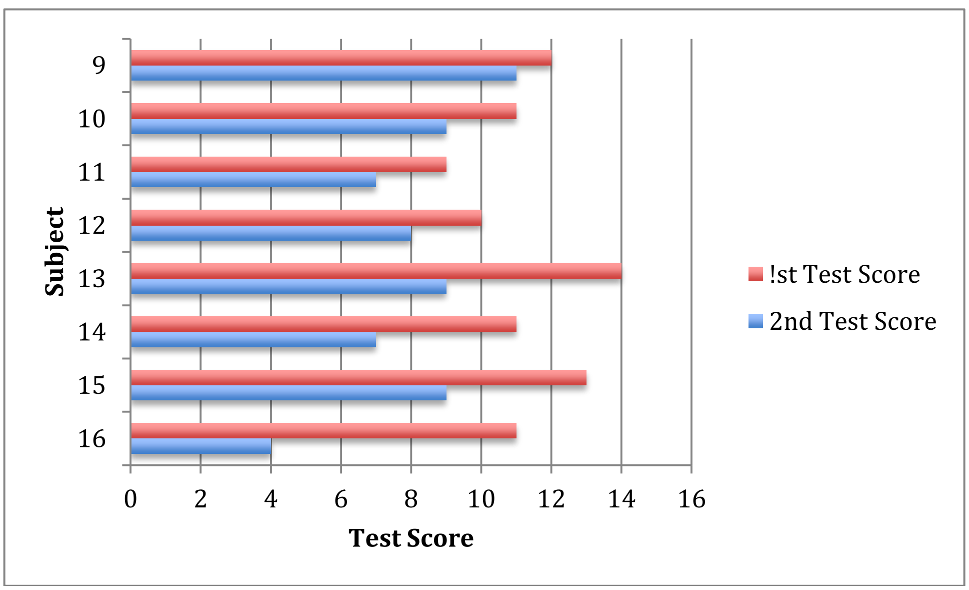
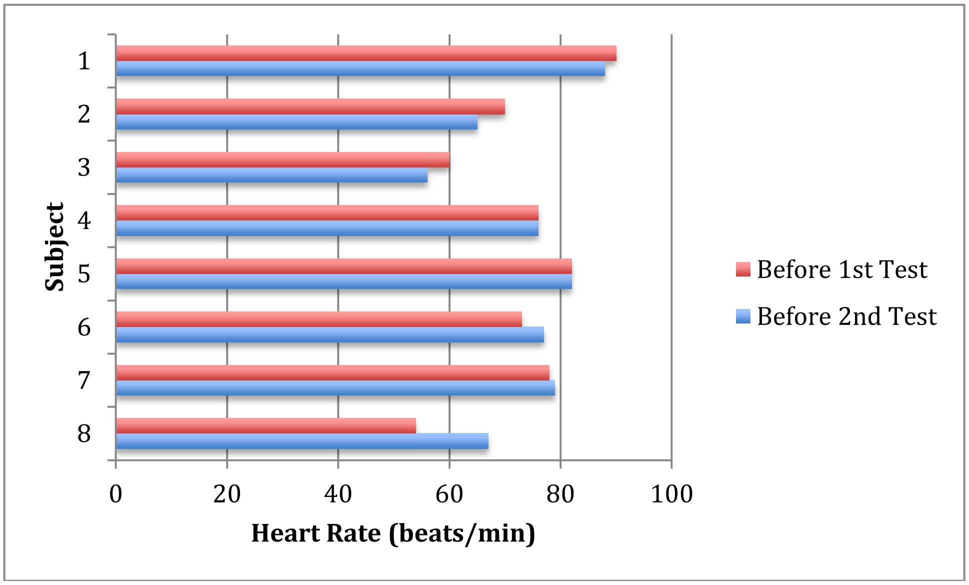


Figure 3. Memory test scores (out of 20) for subjects in the control group (A) and the experimental group (B). Blue bar represents 1st test score. Red bar represents 2nd test score. No remarkable difference is observed between two test scores for each subject for the control group, while a significant decline in 2nd test score relative to 1st test score is observed for the meditative group.

A



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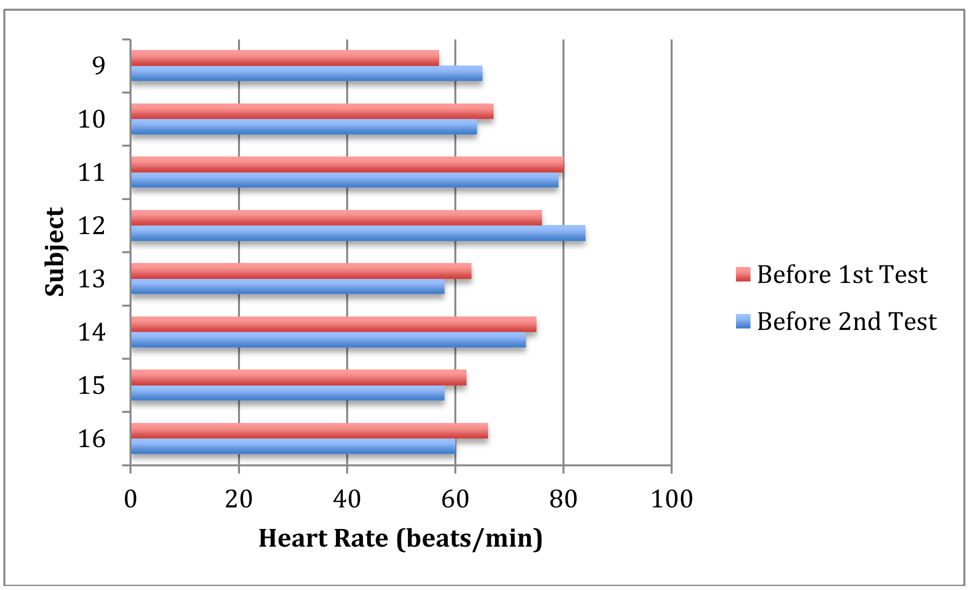

Figure 4. Heart Rate for subjects in the control group (A) and experimental group (B). Blue bar represents heart rate recorded before test 1. Red bar represents heart recorded before test 2. No remarkable difference is observed between the two heart rates for each subject for either group.

Table 1. P-values calculated using Paired T-test for heart rate, mean arterial blood pressure, breathing rate, and memory test scores for 1st and 2nd memory test for control group. Values are means ± standard deviation.

	HR	**MABP**	**BR**	**Test Score**
Control (1st test)	73.50±7.19	112.76±10.07	11.12±2.04	9.25±1.49
Control (2ndtest)	72.13±7.75	116.97±12.76	11.09±2.12	8.87±2.59
P-value	.164	.145	.776	.644

Table 2. P-values calculated using Paired T-tests for heart rate, mean arterial blood pressure, breathing rate, and memory test scores for 1st and 2nd memory test for experimental group. Values are means ± standard deviation.

	HR	**MABP**	**BR**	**Test Score**
Experimental (1st test)	68.88±11.83	98.1±10.64	12.21±3.26	11.38±1.60
Experimental (2ndtest)	69.75±9.87	101.89±8.52	10.51±3.73	8.00±2.07
P-value	.696	.073	.023	.002

Appendix II

Using the same procedure as previously stated, a supplementary experiment was performed using natural sounds instead of guided meditation to induce a meditative state on 5 additional subjects.

Table 3. P-values calculated using Paired T-test for heart rate, mean arterial blood pressure, breathing rate, and memory test scores for 1st and 2nd memory test for natural sounds experimental group. Values are means ± standard deviation.

	HR	**MABP**	**BR**	**Test Score**
Natural Sounds (1st Test)	78.2 ± 11.7	103.35 ± 14.53	13.00 ± 4.39	14.4 ± 2.51
Natural Sounds (2nd Test)	91.6 ± 18.9	101.35 ± 3.80	12.09 ± 4.21	11.6 ± 2.97
P-value	0.512	0.778	0.258	0.101

The results showed that there was no statistical significance in any of the measurements. Unlike the previous experiment, even breathing rate did not have a statistical significance ($p<0.05$).