Effects of Physiological Relaxation on Response Time

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Three key words: Reaction time, Relaxation, EEG

Word Count: 3,099

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KEY POINTS

- We investigated whether a state of relaxation as measured by EEG and heart rate decreases reaction time during a task consisting of visual input and motor output integration.
- The hypothesis was evaluated using: an EEG recording, heart rate and performance of a color discrimination reaction task from http://topendsports.com/testing/reaction-timer.htm.
- Subjects included in this study were both female and male students that ranged from ages 18-29 who submitted informed consent before participation.
- Groups were randomly assigned to control and experimental groups.
- Experimental groups were instructed to relax in supine position in a dark room for the duration of three minutes.
- Control group subjects were engaged in conversation with a lab technician for the same duration, while sitting in a well lit room.
- Heart rate and EEG were recorded during the three minute interval.
- Each participant performed a reaction time test for a total of three trials. The test was performed immediately after relaxation or stimulation. The time was recorded for each trial.
- Data was analyzed based on mean averages of heart rate and reaction time and mean EEG peak amplitude.
- Paired t-tests were computed using Stats Analysis Data Package (Microsoft Excel, 2007) showed heart rate and EEG averages respectively as $P=0.0417$ and $P=0.00006093$, which indicated a statistically significant difference between control and experimental groups.
- No significant relationship between relaxation state and timed response was found ($P=0.4784$).

- We propose further studies be undertaken to further assess the relationship between relaxation and response time using different test modalities within an allotted time frame or involving more complex cognitive functions.

ABSTRACT

Due to the damaging psychological and physiological effects of prolonged stress, researchers have put forth significant effort in determining methods to reduce excessive levels of stress and promote relaxation. This study attempted to take this previous research and determine if a more relaxed person can indeed function better—as measured by a reaction time test—than someone who is not allowed to relax. Male and female college students were randomly split into a control and experimental group in which the control group conversed with researchers for three minutes and then performed a computerized reaction time test, while the experiment group was required to relax for the three minute time period and then perform the reaction time test. Relaxation was measured using EEG and heart rate data. Reaction time was compared between the control and experimental groups, and significance was evaluated. Heart rate measurements showed a significant decrease in beats per minute between the two groups, and EEG alpha wave amplitude likewise showed a significant difference between control and experimental subjects. However, it was determined that there was no significant difference in reaction times between the control and experimental groups. The brevity of the relaxation/conversation times as well as the simplicity of the reaction time test that was used could explain this. A test that measures accuracy under a time limit rather than a reaction time test might be a more rigorous measurement of improvement due to stress reduction.

INTRODUCTION

Unwarranted levels of stress and anxiety result in detrimental consequences on the quality of life for an individual. These negative effects are expressed in physical health, learning ability and retention, interpersonal relationships, and behavior. Some individuals partake in self-destructive coping mechanisms such as smoking or drinking alcohol in order to alleviate these effects of stress and anxiety (Dehghan-nayeri et al., 2011). To prevent these unhealthy behaviors, relaxation techniques are used as an alternative. Methods for relaxation can range from various breathing patterns to pleasant visual imagery exercises. These methods are also widely used to treat a variety of health problems including headaches, anxiety, and insomnia (Jacobs et al., 2004). Not only do relaxation techniques reduce bad habits and treat some common health problems, but they have also been proven to be effective for relieving stress and anxiety (Dehghan-nayeri et al., 2011).

Studies have attempted to make correlations with physiological and behavioral responses to stress and relaxation in order to improve performance abilities. However, there have been startling disparities, further serving as an impetus for implementation of our experiment. In 1964, the "reactive" hypothesis was supported by Desiderato, which states that reaction time is shorter *only* under stressful conditions. (Desiderato, 1964). In support of this hypothesis, more recent studies have revealed that corticotrophin releasing factor (CRF) is interrelated with stress responses. A study by Ohmura et al. suggested that CRF is partially responsible for increasing moderate amounts of stress that may enhance attention performance, which was assessed by serial reaction time tests in rats (Ohmura et al., 2009). However, results from various studies have contradicted the claims of Desiderato. A reduction in reaction time was seen within studies that *reduced* environmental stress (Eason et al., 1986, Banderet & Lieberman, 1989). Another study on yoga-based relaxation techniques in relation to attention speed and information processing showed a significant increase in scores on a six-letter cancellation task as compared to controls (Sarang & Telles, 2007).

Further information was revealed in the results of a study by P. Subramanya and S. Telles in which performance both increased and decreased while assessing three psychomotor tasks consisting of meditation, supine rest, and a control. The supine rest group showed an increase in performance on tasks involving strict motor speed but not on a digit substitution task, which relies more heavily on cognitive function. This suggests differing effects of relaxation based on task type (Subramanya and Telles, 2009).

In response to these conflicting results between stress-induced performance enhancements versus relaxation-induced performance enhancements, we chose to investigate the effects of relaxation on reaction time. Reaction time can potentially be applied to related studies interested in cognitive attention and focus. In addition, reaction time was seen as an appropriate method of assessment for physiological effects on performance and has been utilized in several of the studies previously mentioned. Further rationale for selecting this assessment was derived from a study by M. Miyashita, in which reaction time was assessed in relation to muscular relaxation. Results suggested there was not a significant difference between muscular reaction and muscular contraction (Miyashita et al, 1972). In accordance with these results, reaction time cannot be assumed to be non-correlated with neuromuscular flexion or extension responses, indicating a less biased assessment.

As a way of evaluating a state of relaxation, brain waves give a representation of neurological activity. Alpha waves in relaxed states give rise to asynchronous waves when performing mental tasks due to increased thalamocortical activity. The Sarang and Telles study has shown that meditation correlates with an increase in theta and alpha power represented with appropriate waves. (Sarang and Telles, 2007). Relaxation as characterized by the EEG ideally shows a decrease in alpha wave activity as measured in microvolts (μV), an approximately 60% reduction ranging from 12-18 μV in comparison to a control group. The amplitude changes of these waves are appropriate measurements for the assessment of a relaxed state.

Heart rate is largely under control of the autonomic nervous system, and thus we find it an appropriate measure of stress and relaxation (Task Force of European Society of Cardiology et al., 1996). Parameters for heart rate were assessed based on research published in the *Journal of College Teaching and Learning*, which shows a positive correlation between stress and heart rate. Reduction in stress via relaxing activities—yoga, humor, or reading for 30 minutes once a week for three weeks—reliably decreased heart rate by an average of 2-4 beats/min in students from a pre-study heart rate of 70-77 beats/min (Rizzolo et al., 2009).

The ultimate goal of this study is to assess if relaxation decreases response time. As evidenced by previous research, EEG and heart rate devices are appropriate measurements in determining if a person is in a relaxed state, especially considering the strong correlation between EEG alpha wave activity and relaxation. Physiological relaxation in an experimental group is hypothesized to result in a decreased reaction time when performing a visual-motor discrimination task as compared to a control group that was not allowed to relax.

Results on reaction time in relation to stress will be widely applicable, as well as informative, for various tasks to improve general quality of life. Many forms of employment are a source of stress, which can lead to accidents in the work place. Results of our study may be applicable as to whether relaxation techniques are effective in improving reaction time and avoiding such accidents. For example, operating a motor vehicle is an everyday task in which reaction time is imperative. Additional studies could be undertaken to assess relaxation in relation to car accidents. An inverse relationship between relaxation and reaction time would have interesting implications on how insurance companies classify safe drivers and process claims.

MATERIALS AND METHODS

Subjects/Trials and Ethical Approval

In this experiment a total of twenty-five male and female human participants were randomly selected with ages ranging from 18-29 (average age 21) to participate in a study on effects of relaxation on visual-motor reaction time using a computerized color discrimination task. All subjects were presented with the basic experimental concept and asked to sign a form of consent. Test subjects were randomly divided into a control or experimental group, of which they were unaware. Each set of experimental data was collected in ten minutes or less. We attempted to eliminate test-retest bias by averaging task runs.

Heart Rate Recordings

Heart rate was recorded using a Nonin pulse oximeter/carbon dioxide detector, model 8000K2. The initial heart rate was recorded followed by recordings at three consecutive one-minute intervals, at the one minute, two minute, and three minute mark of the experiment. These values were later averaged for each participant in both the control and experimental groups.

Electroencephalogram (EEG) Recordings

Brain activity was recorded by an EEG in microvolts (µV) using Biopac Student Lab Version 3.0.4 for Windows PC. EEG alpha waves were initially assessed for average recording in 20-60 µV range (resting, yet alert stage). At the beginning of each set of data collection, the subject was asked to remain still with eyes closed for a ten second calibration.

For both the control group and experimental group, frequency (Hz) along with minimum and maximum voltages (μV) were recorded and cross-referenced with standard values to characterize data as normal. Alpha waves from the third time interval (two to three minutes) were saved and selected for data analysis.

For the experimental group, alpha waves from the third time interval were assessed for a median value in the 2-10 μV range, to ensure frequency (approx 0.008 Hz) was consistent with other data sets. Minimum and maximum values were recorded to ensure there were no outliers from their respective ranges (minimum approximately -5 and maximum +5 μV). EEG readings were used to confirm a relaxed state as shown by a percent change in the alpha waves from the control group by 60%.

Reaction Time Test

A computerized color discrimination task was used as a measurement of reaction time. The online Internet reaction time test used in this study was provided by Top End Sports at http://topendsports.com/testing/reaction-timer.htm. We chose this task based on its measurement reliability, which appropriately reflects response time by dually assessing visual processing and motor output response. The background test color was chosen as lime green for maximum visual discrimination and was kept consistent between both groups. The subjects selected “start” when they were ready. When the color lime green appeared on the monitor screen, the subject selected “stop” as soon as possible. The task was performed three times. For each trial, the reaction time was recorded and then averaged for result analysis.

Control Group

The control group was monitored in a well-lit environment in a seated position with the opportunity for conversation for three minutes. Dialogue questions were kept consistent to initiate conversation and had subjective, directed responses from then on. EEG recordings were taken during the three minutes of conversation, and heart rate was recorded initially and at each minute mark. This selection of data was used as a control comparison for experimental group percent change. The subject was then asked to complete three trials of a reaction time test; the three recorded times were then averaged. No physiological recordings were taken during the reaction time test.

Experimental Group

The experimental group was instructed to relax with normal breathing in supine position for a period of three minutes in a dimly lit room. The EEG and heart rate measurements were taken during this time with heart rate being recorded in the same manner as the control group. Alpha waves from the last minute of recording time were assessed for a median value in the 2-10 μV range, to ensure frequency (approx .008 Hz) was consistent with other data sets. Minimum and maximum values were recorded to ensure there were no outliers from their respective ranges (minimum approximately -5 μV and maximum +5 μV). The subject was then asked to perform the same reaction time task as the control group for three trials, and the average reaction time was recorded for result analysis. No physiological recordings were taken during the reaction time test.

Statistical Analysis

Statistical analysis was performed using Microsoft Excel Data Analysis Package. The mean heart rate was calculated using values from the 2-3 minute interval for both the control and the experimental group. The data for the EEG maximum and minimum values was tabulated based upon the analysis of the selected EEG interval of the second and third minute. The standard deviations were taken into consideration for both the control group and the experimental group by entering the standard deviation values into the "descriptive statistics" test and comparing those values to ensure maximum values were within a reasonable range. The mean alpha wave value was calculated for both the control and the experimental group. The mean values for reaction time were also calculated for the control and experimental group. Significance was evaluated by using the "t-test two sample assuming equal variances" test.

RESULTS

Heart Rate Recordings

The average heart rate value for the second and third minute recording in the control group was approximately 74 beats per minute (bpm). The average heart rate value for the second and third minute recording in the experimental group was approximately 67 bpm. The P-value of these two averages is 0.0417, which shows these values are statistically significant. The standard deviations of the control group and experimental group were 10.25 and 9.921 respectively.

Electroencephalogram (EEG) Recordings

The average maximum amplitude for alpha waves for the second and third minute recording in the control group was 29.87 µV. The average value for the second and third minute recording in the experimental group was approximately 3.307 µV. The P-value of these two averages is 6.093×10^{-5}, which shows these values are statistically significant. The standard deviations of the control group and experimental group maximum peak values were respectively 20.61 µV and 2.649 µV. The calculated percent change between experimental group values from the mean of the control group was greater than 65 percent for two of the 13 subjects, while the percent change for the remainder of the subjects was greater than 80 percent (Table 1). Screenshots of data are shown in Figure 1.

Reaction Time Test

The average reaction time for the control group and the experimental group were 0.4997 seconds and 0.4971 seconds. The P-value of this data was 0.4784, which indicates there is no statistically significant difference between the control and experimental reaction time values. Results from the three assessments and their significance are summarized in Table 2.

DISCUSSION

Numerous problems were encountered with this project that may have led to inaccurate or deceptive results of how relaxation affected our specific reaction task. One problem that persisted during our project involved the technical aspects and use of the EEG program and equipment. Difficulty establishing and maintaining connections between the leads on the participant and computer equipment ultimately altered readings or resulted in a complete failure to receive readings. We implemented a plan to double-check our setup before starting the experiment to ensure proper connectivity.

Throughout the data collection process, other student researchers continuously interrupted our study by entering the room and creating noise, which thereby altered the relaxed state of our experimental participants. Alpha wave amplitude values that were more similar to the control group coincided with observation notes indicating distractions within the room at the time of the experiment. To combat the effects of intrusions, a sign requesting others to not enter the room during testing was constructed and proved beneficial to reducing this issue. Due to small sample size, we could not afford to exclude subject data completely due to these extenuating circumstances. Instead, intervals of interruption were meticulously noted and those periods were excised from the analysis.

We also maintain concerns on the subject of accuracy due to the lack of experience with electrical physiological recordings and measurements. We had expected that the EEG computer program would have been more conducive to analyzing; however, it took considerable amounts of time to navigate through the program to figure out how to measure maximum, minimum, and frequencies of brain waves. Previous studies had access to experienced technicians whereas experimenters in this study required time and additional use of the equipment to become skillful and proficient in data collection and analysis.

In addition to the aforementioned technical aspects, lack of significance may also be largely attributed to experimental design and the task chosen. Duration of our EEG testing was considerably shorter than previous studies in the field, which recorded experimental and control groups for periods ranging from 30 minutes to 2 hours. We chose a three-minute experimental period due to time constraints and to eliminate boredom in the participants, but this may have negatively affected our results.

The online computerized response task may not have been sophisticated enough to monitor or record a significant difference between a control and relaxed group. In the reaction task used here, time was assessed as the variable. It is speculated this set-up resulted in recorded values of time that limit variation inherently due to brevity of the task and the nature of small values prone to error in analysis. A task that might have been better able to capture a discrepancy in reaction time that favored one group over the other would test accuracy rather than time. As an example, a letter cancelation task would have allowed us to test for accuracy rather than time, which may have led to different results.

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AUTHOR CONTRIBUTIONS

In this study, Lindsey Dailey, Nora Krause, Malissa Roberts, Katelyn Schuster, Chinou Vang, were the contributing authors in the following aspects: design of the experiment, analysis and interpretation of the data, and drafting and revising this article for publication.

ACKNOWLEDGMENTS

The members of this study would gratefully like to acknowledge the following:

The University of Wisconsin-Madison Department of Physiology for use of laboratory facilities and equipment, the faculty member Dr. Andrew Lokuta for guidance, and the support of peer advising staff and volunteers for the duration of experimentation and statistical analysis. This study was funded under the tuition contribution, grants, and federal funding provided to the University of Wisconsin-Madison for research and greater learning educational experiences.

TABLES AND FIGURES

Table 1. Difference between Control and Experimental EEG Maximum Alpha Wave Value as a Percentage Change.

Experimental Maximum Alpha Value (μV)	Percent Change from Control Average
0.32	0.99
1.02	0.96
0.91	0.96
1.52	0.94
1.92	0.92
2.23	0.91
2.51	0.9
3.49	0.86
3.41	0.86
4.13	0.84
4.38	0.83
8.39	0.67*

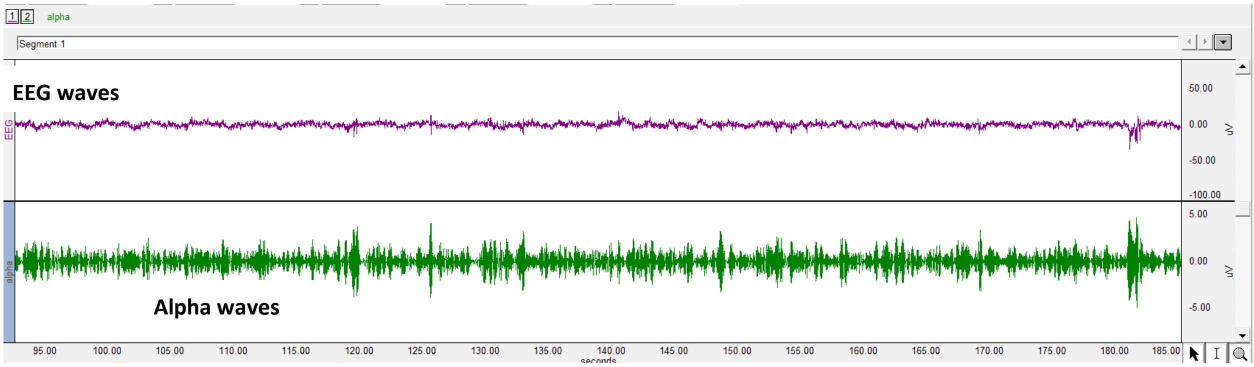
Percent change from each individual experimental maximum alpha value was calculated from mean control alpha value for n=13. Asterisks indicate values less than 80 percent change.

Table 2. Assessments and Significance

Assessments	p-value	Significance
Heart Rate	0.0417	<0.05
EEG Alpha Amplitude	0.00006093	<0.001
Reaction Time	0.4784	>0.05

P-value tests were formulated from Stats Analysis package for n= 12 for control group and n=13 for experimental group.

a)



b)

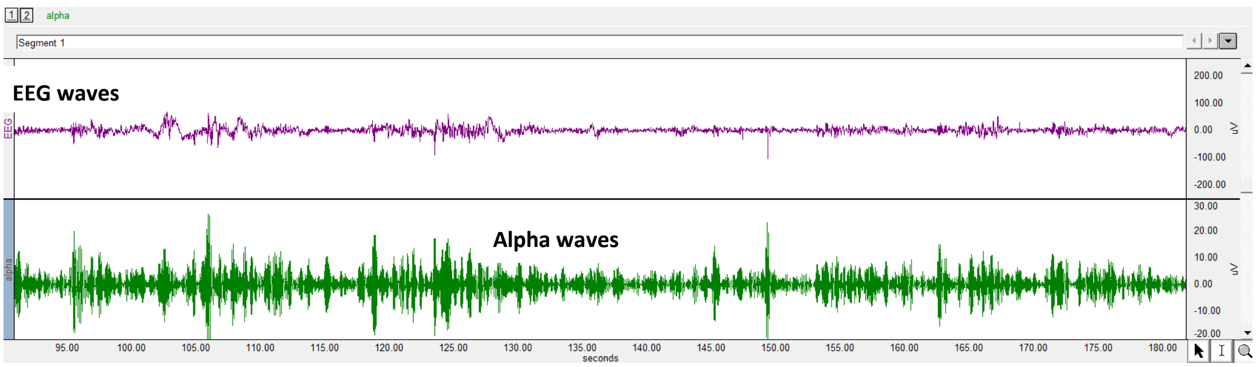


Figure 1. Alpha wave patterns generated by Windows PC Biopac Student Lab Version 3.0.4 for two different subjects. Typical values for EEG waves are between 20-100 µV (Kandel, et al., 1991). Experimental alpha wave data (a) shows a lower voltage peak than control data (b). Note the different scales in each recording.