The Effect of Distractors on Physiological Stress During a Test

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ABSTRACT

College exams are undoubtedly stressful, but when external distractions are present most students would say that it is even harder to concentrate. Distractions could lead to a physiological stress response and potentially a poorer performance. Previous studies suggest that noise can lead to increased stress hormone release as well as decreased performance of a task requiring concentration or thought. We wondered how common test-day distractions might affect an individual's physiological stress response. We hypothesized that taking tests in a distracting environment would lead to elevated stress when compared to an quiet environment. Twenty UW-Madison undergraduate students completed three basic knowledge tests: the first in silence, the second with background noises (i.e. whispering and paper rustling), and the third with a proctor standing over the participant's shoulder. We chose to measure heart rate, Electrodermal Activity (EDA), and respiratory amplitude. Paired t-tests showed that there was a significant difference in heart rate and EDA under stimuli while there was no significant difference in the respiratory amplitude. This all suggests that distractions during tests do cause measurable stress in test-takers, especially background noise.

INTRODUCTION

Every student has had the misfortune of taking an exam and experiencing some annoying and distracting sound or stimuli while trying to complete the test to the best of their abilities. Typically, this situation results in anger and frustration on the part of the test-taker. Most likely, the student would describe their condition at that point as stressed. But how exactly is that stressful annoyance impacting them physiologically?

Noise is a psychological concept that can be defined as sounds that are distracting, unpleasant, and unwanted by the listener (Kryter, 1970). Previous studies have illustrated a relationship between noise and stress. A review paper by Ragnar Rylander discussed how individual exposure to constant, disturbing, and undesired noises often leads to increased feelings of annoyance (Rylander 2006). As the length of exposure to these noises increases, individual stress and anxiety levels rise. A study by Isling and Gunther (1980) found that when individuals were exposed to noise during a high concentration demanding task, the individuals experienced an increase in the the levels of their stress hormones, such as cortisol.

Previous research has focused on the connection between the central nervous system, noise interpretation, and the stress response. These studies suggested that an environmental sound's capability to induce a physiological stress response, such as an increase in heart rate, is dependent upon how the specific sound is interpreted by the central nervous system, as reviewed by Rylander (2004). The central nervous system processes the intensity and frequency of a sound, compares them to past experiences, and then initiates a specific pathway dependent upon the subconscious association (Rylander 2004). The auditory pathways of the central nervous system include indirect pathways to the reticular activating system, which is the group of nuclei responsible for regulating arousal (Rylander 2004). The reticular activating system anatomically connects the limbic system to the neuroendocrine system and the autonomic nervous system. The neuroendocrine system releases corticosteroids, such as cortisol, which affect the development and control of physiological stress. In a stress inducing situation, the sympathetic nervous system is activated and increased levels of cortisol are released into the blood, creating a physiological stress response such as increased heart rate and blood pressure (Rylander 2004).

Additional studies have focused on the relationship between auditory distractions and cognitive performance. One study conducted focused on the effects of irrelevant background noise on the speech perception and cognitive performance of elementary school students. This study found that the students' task based performance was significantly impaired by the exposure to the irrelevant background noise (Klatte *et al*., 2007). The background noise was found to especially impair language processing and phonological storage. The researchers suggested that irrelevant background noise distracted the students' attention to task-irrelevant thoughts, therefore, directly impairing cognitive performance. This study illustrated the potential negative effects that irrelevant background noise can have on the cognitive performance and focus of students. A study by Banbury *et al.* (1998) explored the connection between cognitive performance and typical noise heard in an office setting. Their data suggested that both talking and general background noise, such as rustling papers, computers, tapping, etc, disrupts memory and, consequently, performance on both written and numerical tasks. There have also been studies that have suggested a correlation between performance and stress. A study completed in 2008 analyzed a group of pianists and how their levels of stress were elevated during a performance in comparison to a practice session (Yoshie *et al.*, 2008). This study measured heart rate and sweat rate in order to illustrate that a physiological stress response occurred. These results indicate that increased heart rate and sweat rate are markers of physiological stress.

Based upon this background information, we decided to investigate the effects of common classroom distractions on the physiological stress levels of individuals while taking an exam. Every college student has complained about some distracting stimuli that they have experienced while taking an exam. Distractions such as tapping of a pencil or rustling of papers are sounds that students hear on a daily basis. We were interested in seeing if these common distractions become magnified and cause a physiological stress response during a test-taking situation. We decided to focus on one auditory distraction and one non auditory distraction to see if there was any variation dependent upon whether the stimulus was a sound or not. The two distractions we used were hovering over the test taker and exposing the test taker to a soundtrack of a collection of everyday noises heard in the classroom. We hypothesized that the exposure to both the auditory and non-auditory distractions during a timed exam would act as stress inducers and activate the sympathetic nervous system therefore increasing the respiratory amplitude, heart rate, and electrodermal activity from the baseline.

METHODS AND MATERIALS

The 20 participants had their heart rate, electrodermal activity (EDA), and respiration rate measured during the study with the Nonin Pulse Oximeter/Carbon Dioxide Detector (Model 9843), BIOPAC® BSL EDA Finger Electrode Xdcr SS3LA, and BIOPAC® BSL Respiratory Effort Xdcr SS5LB, respectively. The Biopac Student Lab System: BSL 4 software, the Biopac Student Manual, Microsoft Excel, and Windows 7 were all used for data collection and analysis.

Design and Procedure

All test subjects had an initial baseline (heart rate, electrodermal activity (EDA), and respiratory amplitude) recorded for ninety seconds. They were then told they were to complete 3 tests modeled after the Wonderlic test for potential professional football players. All three tests contained different questions of equal difficulty. The tests consisted of 20 questions to be completed in 4 minutes. To create an environment that simulates a real and intense test-like situation, subjects were given more questions than they would be able to comfortably answer in the allotted four minute test period. In addition, subjects were told that the test was designed for high school students to be able to finish, effectively inducing stress since the test was difficult to finish in that time.

To show physiological stress we used three different measurements: respiratory amplitude, heart rate and electrodermal activity (EDA). The respiratory transducer was used to test for changes in the pattern of breath amplitude. In addition, EDA was used to test for changes in skin conductance. Data for both respiratory amplitude and EDA were recorded using the Biopac computer program (See Figure 2). Heart rate was measured using a digital pulse-oximeter and heart rate was recorded every thirty seconds.

After collecting a basline, each subject was exposed to a different auditory stimulus while taking each test: first silence (Test One), then a YouTube video that contained whispering, paper crinkling, and tapping (https://www.youtube.com/watch?v=wjS4j1zkc80, section from 8:30-12:30) (Test Two), and finally, an experimenter standing over the shoulder of the participant watching them take the test (Test Three). An outline of the general procedure is depicted in Figure 1.

Experimental Groups/Participants

All 20 participants were college students at University of Wisconsin-Madison enrolled in Physiology 435. Each participant signed a written consent form prior to participation. Each participant took all three tests under each experimental condition.

Control Groups

For the purpose of ensuring fully functional equipment and for preliminary exploration of the stress responses, a member of the research team had their heart rate, EDA, and respiration rate measured while being exposed to all three testing conditions. A stress response was elicited from the team member; this confirmed the thinking that the testing procedure would yield results for analysis and gave us a positive control. For a negative control, the subjects took one of the three tests in a silent environment in which no stimuli were administered. This was the first testing condition for each participant.

Measures of Stress

EDA: Electrodermal activity measures the electrical conductance of the skin in terms of sweat response as a function of time. Skin conductance is dependent upon the amount of sweat-induced moisture in the skin. The sympathetic nervous system activates the secretion of sweat glands. As a result, skin conductance is an indicator of physiological stress. Electrodermal activity was measured on the non-dominant index and middle finger during an initial baseline and throughout all three tests.

Respiratory transducer: The respiratory transducer SS5L was used to measure respiratory amplitude. The transducer measures changes in the thoracic circumference in millivolts during respiration. The average respiratory amplitude was calculated for each of the three test periods. This value was compared to the average respiratory amplitude calculated during the baseline period. Any statistically significant deviation away from the baseline average was recorded as a positive sign of stress.

Heart Rate: The digital pulse oximeter was used to measure the heart rate of the participants. The clip was placed on the ring finger on the non dominant hand. A baseline heart rate was recorded for each participant and compared to the average heart rate (beats/min) calculated for each of the three test periods. An increase in heart rate was recorded as a positive indicator of stress.

RESULTS

Physiological Data

Paired t-tests were performed for all three physiological measurements in order to compare the deviation from baseline between the negative control, Test One, and each of the two stimuli groups, Test Two and Test Three (df=19). Another paired t-test demonstrated a statistically significant difference for change in EDA between Test One and Test Two ($p=0.0004677$) and Test One and Test Three ($p=0.001136$) (See Table 1 and Figure 3). Additional paired t-tests showed that changes in heart rate between Test One and Test Two ($p=0.004959$) and Test One and Test Three ($p=0.003818$) were also statistically significant on an individual level (See Table 1 and Figure 4). The paired t-test for respiratory amplitude indicated that there was no statistically significant difference in the change in amplitude between Test One and Test Two ($p=0.2039$) or between Test One and Test Three ($p=0.7832$) (See Table 1 and

Figure 5). The paired t-test for respiratory rate also indicated that there was no statistically significant difference in the change in respiratory rate between Test One and Test Two (p=0.293) or between Test One and Test Three (p=0.7821) (See Figure 5 and Table 1). We constructed bar graphs to display the average deviation from baseline for all four physiological measures in the three tests.

Performance Data

We used paired t-tests to analyze the statistical significance of the number of questions completed and the percent of questions correct for each for the three different tests. The data showed that the difference in percent of questions correct was not statistically significant between any of the tests (See Table 2 and Figure 7). More paired t-tests were used to analyze the difference in number of questions completed between the tests. The t-tests indicated that participants answered a statistically significant fewer number of questions for Test Two than either of the other tests. On the other hand, no statistically significant difference existed between the number of questions answered in Test One and Test Three (See Table 2 and Figure 8). We constructed estimated probability density plots to indicate the probability that percent correct and number of questions answered lie within a certain range of values. The overlap of the curves seen in Figures 7 and 8 indicates that, as a whole, the participants' variance in performance between the certain tests was small. In Figure 8, the shifted curve indicates that most people answer fewer questions for Test Two than Tests One and Three.

DISCUSSION

Our data supports our hypothesis that exposure to both auditory and non-auditory stimuli while taking an exam would elicit a physiological stress response. The paired t-tests comparing the change in average heart rate away from baseline measured during Test Two and Test Three to the change in average heart rate away from baseline measured during test one both yielded p-values less than 0.05 indicating statistical significance. The same data trends were recorded with change in EDA away from baseline. Exposure to both the auditory and non-auditory stimuli caused a statistically significant increase in both heart rate and EDA. We compared the change in average heart rate and EDA away from baseline from Test Two and Test Three to Test One, which allowed us to rule out the possibility that the physiological stress response was caused by the act of taking an exam rather than the stimuli. Since the difference in the change from baseline for both average heart rate and EDA between Test One and Test Two/Test Three was statistically significant, we can conclude that exposure to both the auditory and non-auditory stimuli successfully induced a physiological stress response.

The paired t-tests comparing the change in respiratory amplitude from baseline measured during test two and test three to the change in respiratory amplitude from baseline measured in test one yielded p-values greater than 0.05. This indicates that the change in respiratory amplitude and respiratory rate observed in Test Two and Test Three was not significantly different from the change observed under negative control conditions during Test One. As a result, we cannot conclude that exposure to either the auditory or non-auditory stimuli caused a physiological stress response via respiratory amplitude. This may have been due to human error when measuring respiratory amplitude and rate. The elastic band used for measuring respiratory amplitude was difficult to place over test subjects' bulky clothing, possibly resulting in inaccurate data. As a result, it is likely that our data for change in respiratory amplitude was not accurate or reliable.

Regarding the test performance data, we saw no statistically significant difference in the percent of correctly answered questions over the number of completed. This would support our assumption that all three tests were equally difficult. Additionally, participants answered statistically significant less number of questions for Test Two than either of the other tests. This suggests that the participants were more distracted by the conditions of Test Two (crinkling paper, whispering, and tapping). This was the only variation observed between the effects of the auditory stimuli and the non-auditory stimuli. Additional experiments would need to be conducted in order to draw conclusions about the varying effects of auditory versus non-auditory stimuli. Cohen (1978) argues that an individual's attention can be impaired when their processing capacity is overloaded by the combined demands of the noise, the stressor, and the ongoing task. Further research needs to be done in order for conclusions to be drawn about the specific effects of an auditory stimulus on attention.

In the future, it would be interesting to measure varying degrees of stress with a greater number of students. That is, more test subjects should be used in order to normalize the extremes in data seen. This rendered some data insignificant in order to get a more accurate representation of the difference between stimuli and their corresponding stress responses. It would also be worthwhile to study the stress variables on a scaling factor, as in, testing a certain auditory stimulus at different volumes, in order to see the specific point at which a distraction causes a significant amount of stress.

While relevant to the daily lives of college students, it is important to consider the factors that went into the test taking environment that we created. In a real environment, tests are rarely taken by yourself in a small room with multiple people standing around you. That in itself can increase stress even if the people are situated behind the test taker and they are not visible during the test. It's also rare that school exams take place while the student is hindered by various pieces of data-collecting equipment. However, though these things surely contribute to create stress that is not normal to a test taking environment, real exams generally involve grades, which have the ability to cause a range of stress levels depending on the person and their preparation.

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TABLES

Table 1:
Paired *t*-test Results for physiological data

Physiological Measurements	Comparison	p-value (df = 19)	Confidence Interval
Heart Rate	Test One vs Test Two	0.004959	0.4935572 to 2.3988428
	Test One vs Test Three	0.003818	0.7300948 to 3.2752052
Electrodermal Activity	Test One vs Test Two	0.0004677	-1.3224318 to -0.4450262
	Test One vs Test Three	0.001136	-1.4337875 to -0.4200805
Respiratory Amplitude	Test One vs Test Two	0.2039	-1.9644813 to 0.4479103
	Test One vs Test Three	0.7832	-0.5317717 to 0.6954377
Respiratory Rate	Test One vs Test Two	0.293	-0.4613309 to 1.4479359
	Test One vs Test Three	0.7821	-0.3364666 to 0.4406396

Table 2:
Paired *t*-test Results for Performance Data

	Comparison	p-value (df = 19)	Confidence Interval
% Correct/ Completed	Test One vs Test Two	0.5263	-0.07117129 to 0.03761520
	Test One vs Test Three	0.3827	-0.08342830 to 0.03350118
	Test Two vs Test Three	0.7374	-0.05852817 to 0.04215714
Number Completed	Test One vs Test Two	1.64e-06	3.188586 to 6.011414
	Test One vs Test Three	0.6979	-1.293276 to 1.893276
	Test Two vs Test Three	1.969e-07	-5.43731 to -3.16269

FIGURES AND LEGENDS

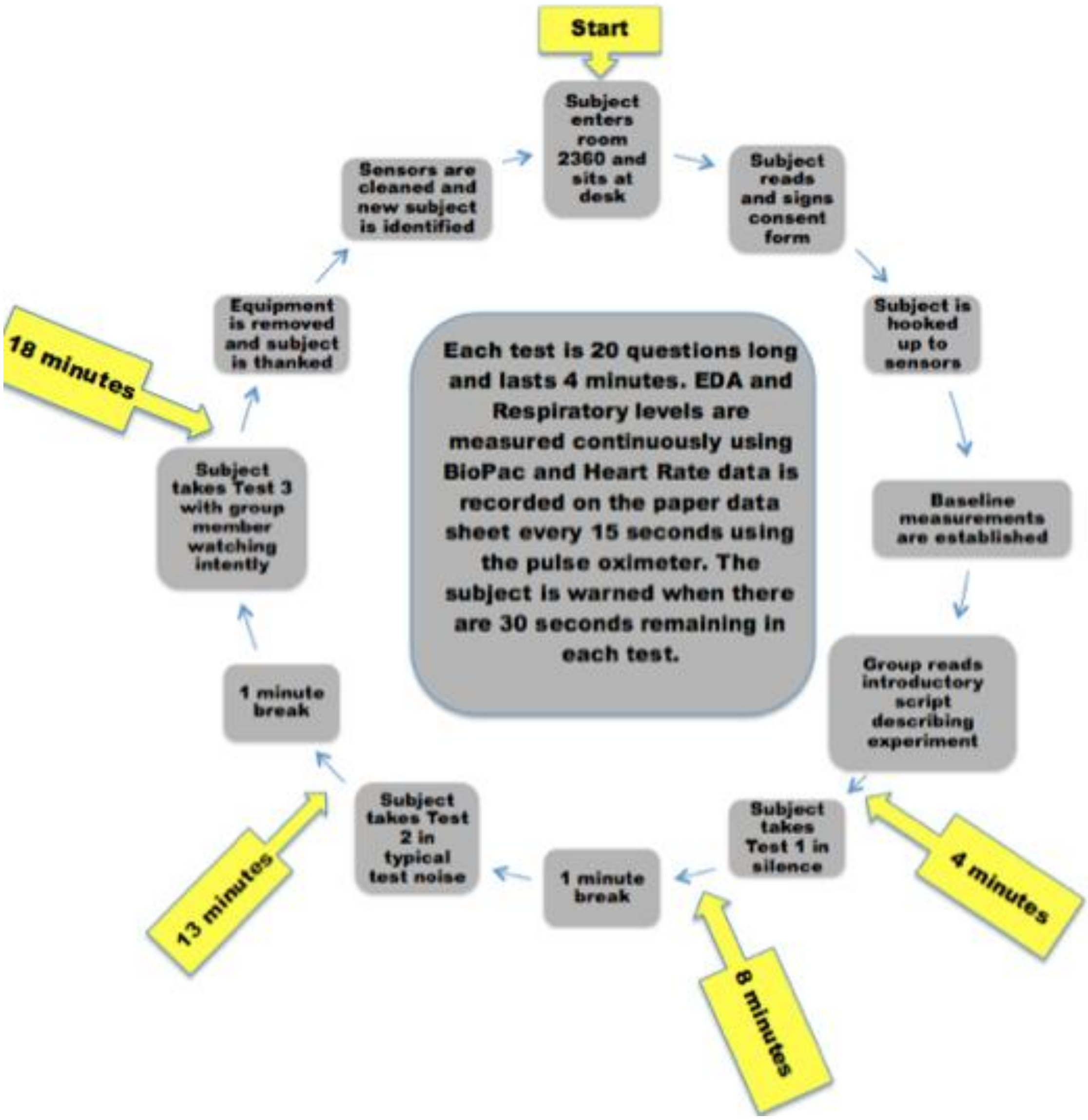

Figure 1: Timeline of the experimental procedure. The procedure remained the same for all subjects.

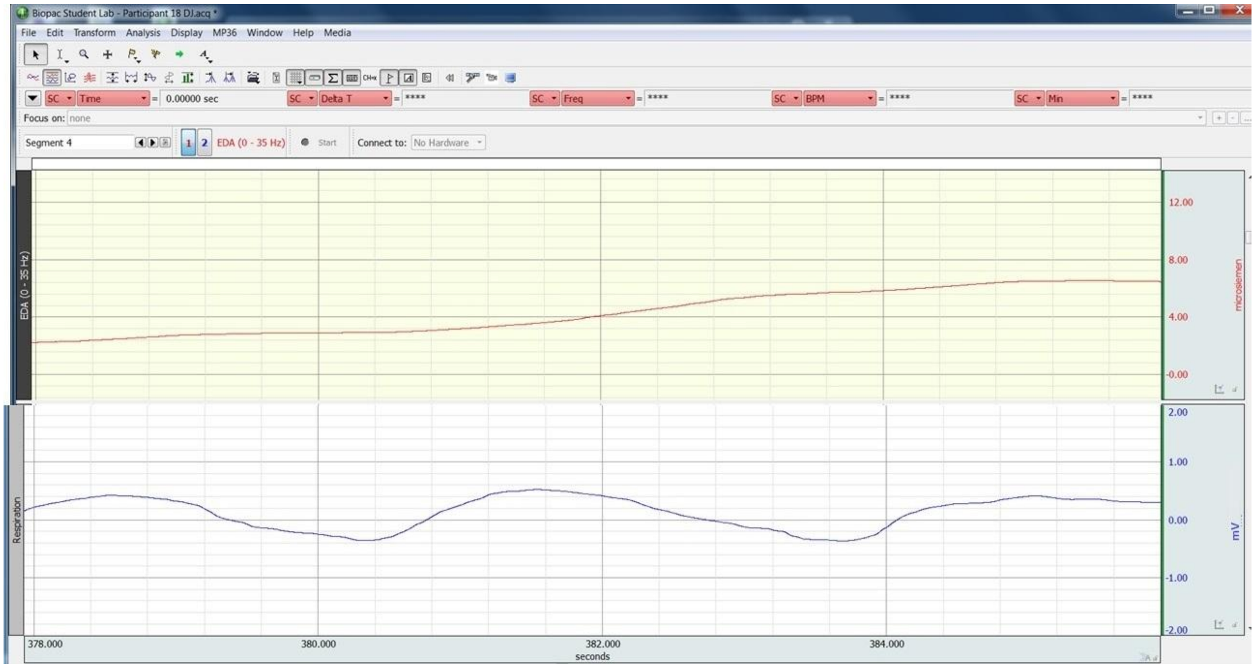

Figure 2: This is an example of raw data from Biopac Student Laboratory System. Using tools in Biopac we were able to calculate average values for EDA and respiratory amplitude for each portion of the experiment for every participant.

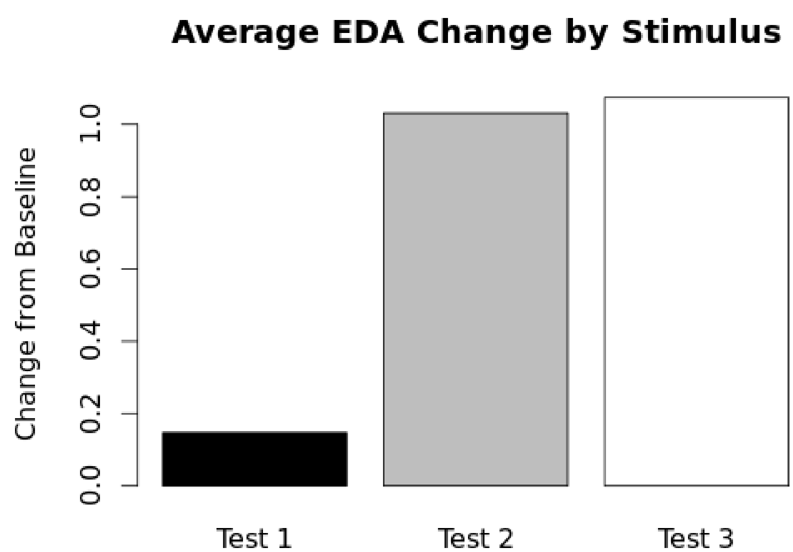

Figure 3: Electrodermal activity (EDA) change from baseline, measured in MicroSiemens. The black bar represents Test 1, the grey bar represents Test 2, and the white bar represents Test 3.

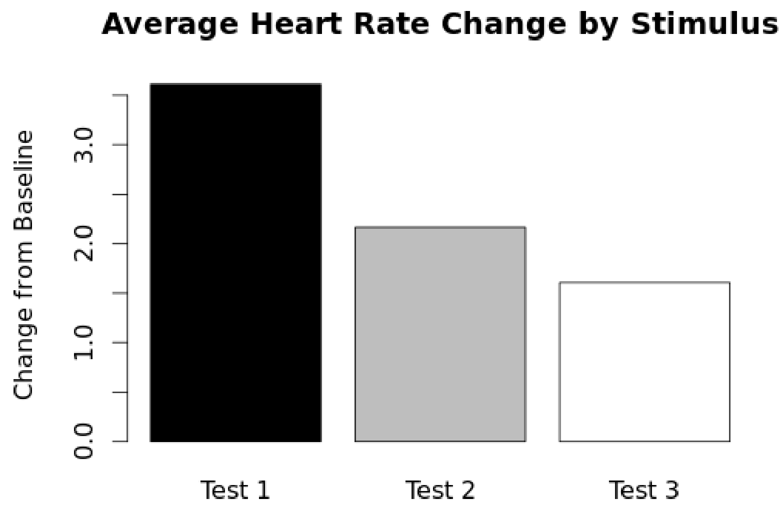

Figure 4: Heart rate change from baseline, measured in beats per minute (BPM). The black bar represents Test 1, the grey bar represents Test 2, and the white bar represents Test 3.

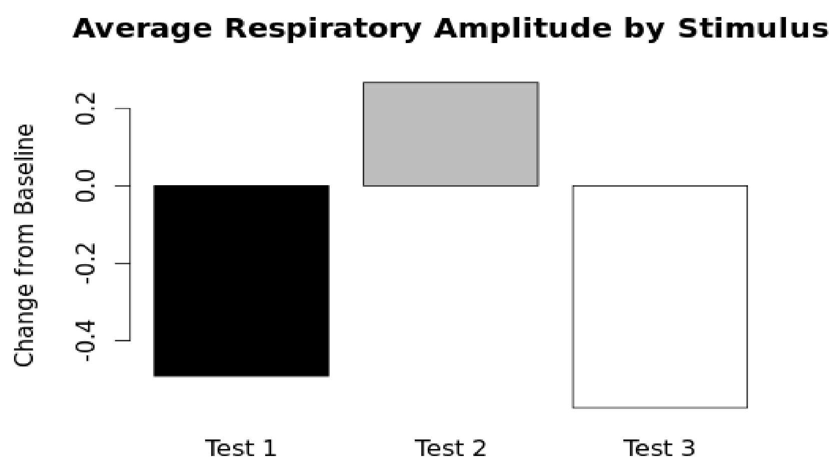

Figure 5: Respiratory amplitude change from baseline, measured in milliVolts. The black bar represents Test 1, the grey bar represents Test 2, and the white bar represents Test 3.

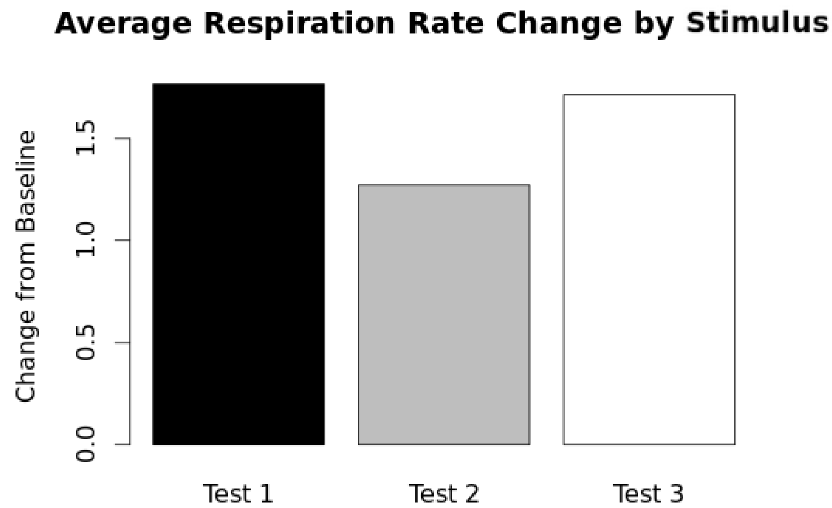

Figure 6: Respiratory Rate change from baseline, measured in breaths per minute. The black bar represents Test 1, the grey bar represents Test 2, and the white bar represents Test 3.

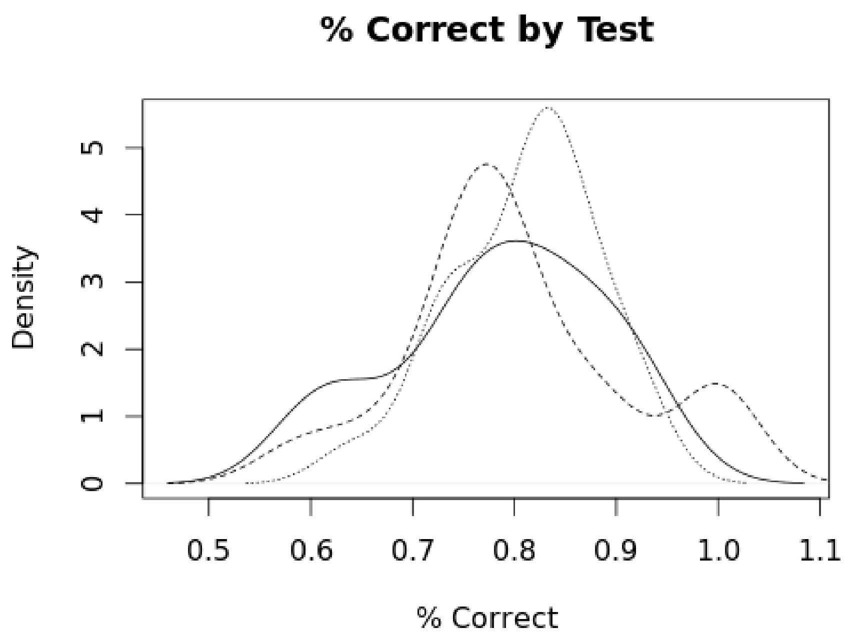

Figure 7: Percent of questions correct divided by questions completed for the three tests. The solid line represents Test 1, the dashed line represents Test 2, and the dotted line represents Test 3.

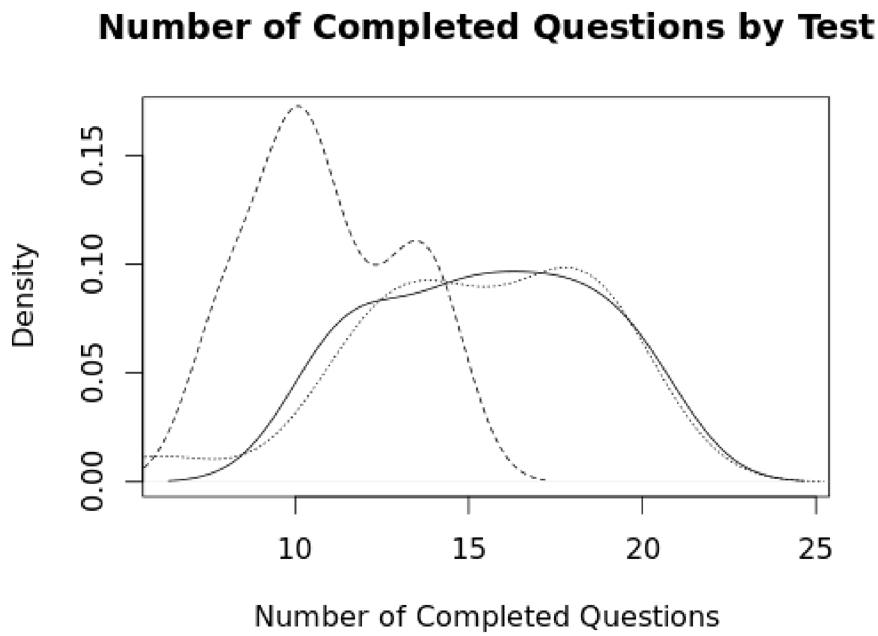

Figure 8: The number of questions completed per test. The solid line represents Test 1, the dashed line represents Test 2, and the dotted line represents Test 3.