The Role of Performance and Anticipatory Anxiety in Short-term Memory Recall

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Abstract

With the diagnosis of anxiety disorders on the rise in the United States, it has become increasingly important to understand the physiological consequences of anxiety on everyday tasks. We hope to understand the relationship between anxiety and working memory, and whether different types of anxiety produce varied physiological results. Fifteen participants were randomly placed in three groups (anticipatory, performance, and control). Each group was exposed to a stress stimulus and subjected to a series of memory tests involving word and picture recall. Heart rate (via ECG), galvanic skin response, and respiration rates were recorded to quantify anxiety levels. For word recall memory tasks, no statistically significant differences were found between the anxiety groups with respect to the mean number of correct responses as well as percent changes from baseline physiological measurements compared to the control. However, picture recall results showed significant differences between groups, with the performance group selecting the largest number of correct responses, on average.

Introduction

Anxiety is a normal, uncontrolled response to everyday stressors (Crowe *et al.*, 2007). Whether it be a child on their first day of school, a college student preparing for a final exam, or an adult meeting with their boss, everyone experiences dread, worry, or uneasiness resulting from a wide range of stimuli. The question remains, what kind of effects does anxiety have on an individual's performance?

Over the past several decades, researchers have sought to explain the effects of anxiety on cognitive function (Vendetti *et al.*, 2012). They commonly divide anxiety into two types: trait anxiety and state anxiety. Trait anxiety refers to an individual's inherent susceptibility to stress, while state anxiety involves stress based on an external situation (Walkenhorst & Crowe, 2009).

Evidence from multiple sources concludes that high levels of state anxiety are associated with inferior performance on cognitive function tasks, including those related to short-term memory (STM) (Crowe *et al.*, 2007). STM refers to the capacity of the brain to retain limited information for a small period of time (Aben *et al.*, 2012). In contrast, long term memory can store a greater amount of information for a potentially unlimited time period.

Additionally, it is important to recognize that working memory refers to the processes and structures used to manipulate and store information on a short-term scale (Arnsten, 2009). The mechanisms behind working memory have been extensively explored in Arnsten's Neuroscience Review (2009). It is proposed that the prefrontal cortex (PFC) is most sensitive to loss of cognitive ability due to stress exposure. PFC working memory capabilities depend on an extensive neuronal network. There is a demonstrated increase in glucocorticoid and catecholamine release in response to stress. Such an increase, especially in levels of dopamine and norepinephrine, activates excess cyclic adenosine monophophate (cAMP) and protein kinase C (PKC) signaling, ultimately suppressing PFC firing and impairing its cognitive roles (Arnsten, 2009).

To investigate the effects of acute stress on cognitive function, researchers in one study gave participants analogy problems in which they judged the validity of a C:D relationship based on a given A:B association. They also administered a stress stimulus to examine the effectiveness of complex reasoning processes in the presence of mild stressors. They found that stress-induced participants performed poorly on all analogy problems (Vendetti *et al.*, 2012). Similarly, Ishizuka, Hillier, and Beversdorf (2007), found that dipping participants' hands in cold water (a known stressor) impaired memory. However, there are conflicting studies that find opposing results regarding the correlation between memory and anxiety (Eysneck & Calvo, 1992). Walkenhorst and Crowe (2007) found that worry strengthened performance on visual memory tasks.

While previous research has widely examined the effects of anxiety on working memory through the processing of complex cognitive tasks (Vendetti *et al.*, 2012), few reported investigations focus specifically on short-term memory recall and visual recognition. Moreover, no study has isolated the effects of different forms of anxiety. For the purposes of this experiment and to accommodate for the variety of stressors that are encountered, two forms of anxiety will be induced. We define anticipatory anxiety as preparatory cognitive activity that is directed towards potential threats in the future. These threats can be mental, social, physical, or emotional in nature. . In addition, we define performance anxiety as anxiety stemming from concerns in regard to the production of desired results. The aim of the current research is to evaluate the impact of anticipatory and performance anxiety, on short-term memory free recall and image recognition tasks, by measuring changes in galvanic skin response, respiration rate, and heart rate. To account for variability in resting heart and respiration rates, we interpret any increase from baseline heart rate as a physiological response to stress. Any increase from baseline in the conductance of the skin, as measured by galvanic skin response, is also interpreted as a stress response. The sympathetic nervous system increases skin conductance when stimulated; presumably, this system produces negligible skin conductance within a resting individual.

We hypothesized that subjects with induced performance anxiety would perform better than the control group on both types of memory tests, while the subjects influenced by anticipatory anxiety would perform worse than the control group. Ultimately, the results from these experiments might give some indication of whether different forms of anxiety could improve or hinder academic performance.

Methods

Ethical Approval

All procedures were performed in accordance with protocols approved by the University of Wisconsin Madison and set to the regulations established by the Journal for Advanced Student Research (JASS). Each study participant was made aware of any possible risks and written consent was obtained for each experimental group. This study conforms to the standards set by the latest revisions of the *Declaration of Helsinki as required for human subjects.*

Group Assignment

Study participants were randomized into three groups: negative control, anticipatory anxiety, and performance anxiety. Each group consisted of 5 subjects for a total of 15 study participants (n=15). Subjects were between the ages of 18-30, and there was no selectivity for male or female subjects.

Experimental Procedure

Before measurements began, each participant was asked to sign the consent form and was given instructions on our experimental procedure. While seated in a quiet room at a testing station, GSR, ECG, and a respiration transducer were attached to the subjects to monitor a baseline response for one minute. Time, GSR, heart rate (ECG), and respiration rate were recorded throughout the entirety of the test. Subjects were then given directions based on which test group they were placed into.

Negative Control Group:

Subjects were first instructed to put on headphones for noise isolation. The subjects were then guided via PowerPoint instructions through the memory tests described below. No further instructions were verbally given.

Anticipatory Anxiety Group:

Subjects were first instructed to put on headphones. Subjects were then guided via typed instructions on the PowerPoint accompanying the two memory tests described below. Within these instructions, participants were told that they would hear a sudden, loud noise at any point during the experiment. The noise was described to subjects as 80 dB, which is below the pain threshold, but very loud. According to the Federal Interagency Committee On Noise (1992) 80 dB is classified as annoyingly loud and can cause damage with eight hours of exposure. To remind the subject of the impending noise, a question ("Have you heard a noise yet?") was included after each test. No actual sound was ever played.

Performance Anxiety:

Subjects were first instructed to put on headphones. Subjects were then guided via typed instructions on the PowerPoint accompanying the two memory tests described below. Within these instructions, test subjects were told that they would hear a sudden loud 80 dB noise, as described previously, if their performance on the memory test fell below a set standard. In addition, the subjects of this group were told that an observer was monitoring their responses. To remind the subject of the impending noise, a question ("Have you heard a noise yet?") was included after each memory test. No actual noise was ever played, regardless of performance.

After the completion of testing for each group, subjects were asked to fill out a follow up questionnaire, which addressed whether they thought the sound would occur and their levels of anxiety surrounding the potential sound. Control participants, as they were not informed of an impending sound, were administered a questionnaire regarding their anxiety levels during the experiment.

Memory Testing

Two types of memory tests were used in this study: word recall and picture recognition.

Word recall test:

Before any testing, a practice trial with three words was shown to verify that the subjects understood all the instructions and were familiar with the format of the test. Subjects were then presented with an instruction screen that they were verbally instructed to read carefully. Instructions regarding the impending 80 dB sound were included on this screen for the anticipatory and performance anxiety groups. When everything was clear, participants were asked to click to proceed to the three word recall tests. Three sets of twelve 3-syllable words were presented on the screen. Each set of twelve words began with a “get ready” screen to insure that the subject was looking at the screen. Flashing one by one on PowerPoint slides, words (taken from MRC Psycholinguistic Database set to Familiarity 500-max, Concreteness 500-max, Imagability 500-max) were presented for two seconds each. Immediately after each set of twelve words, the subjects were instructed to recall as many words as possible in any order, write them down on an answer sheet, and record the time of completion. In addition, participants in the anticipatory and performance anxiety groups were asked if they had or had not heard the noise yet. They were then instructed to proceed to the next set of words.

Picture recognition test:

The above-mentioned “get ready” screen also had an image underneath the text. The screen appeared for two seconds, the same duration as the recall words. The subject was not given any specific instruction to remember the image. After all of the word recall tasks were finished, the subjects were then presented with on-screen instructions to select the images they previously saw from a group of four similar images. The image arrays appeared in the following order: the image that preceded word recall test one, test two and test three. The subjects were asked to circle the corresponding number of the selected image on their answer sheet.

Physiological Response to Anxiety

Three tests were used to measure levels of anxiety: galvanic skin response (GSR), heart rate via electrocardiography (ECG) and respiration rate. By analyzing changes in physiological response using these three measurements we were able to determine a state of anxiety. Studies have shown that an increase in GSR response indicates a stressful or tense experience compared to a relaxed state with a success rate of 90.97% (Villarejo *et al*., 2012). Furthermore, studies have found there is a high degree of correlation between anxiety and an elevated heart rate (Gaburro *et al*., 2011). In addition, increases in respiration and blood oxygen levels have been associated with many states of anxiety (Mchugh *et al*., 2010; Millikan, 1942).

Each physiological measurement was calibrated according to BIOPAC Student Lab Program protocols, and a baseline measurement was established for one minute before any memory testing was performed. BIOPAC MP36 Student Lab Program software was used as the interface for recording measurements.

Galvanic Skin Response (GSR):

The BIOPAC systems GSR test was used based on manufacture's protocol to measure skin electrical conductivity. Averages were calculated over specific time periods stated below.

Electrocardiography (ECG):

The BIOPAC systems ECG SS1LS system was used based on manufacture's protocol to measure heart rate. Time differences between electrical beats were calculated providing an average heart rate over specific time periods stated below.

Respiration Transducer:

The BIOPAC systems respiration transducer was used based on the manufacture's protocol to measure respiration rate. Time differences between inhalations and exhalations were calculated providing an average respiration rate over specific time periods stated below.

Statistical Analysis

To record the heart rate and respirations during baseline and three word recall tests, three measures of each parameter were randomly selected, recorded, and averaged within each time group (baseline, test 1, test 2, test 3). Mean GSR measurements were recorded during each of the time groups as well. These averages, recorded for every subject, were used in all subsequent statistical analyses.

The extent to which an anticipatory anxiety state was induced was measured by averaging heart rate, GSR, and respiration rate data for each participant across the three sets of word recall memory tests and then subsequently averaged across the experimental subgroup. Percent change from the average baseline reading within the same experimental group was then calculated.

Galvanic skin response, heart rate, respiration rate, number of correctly recalled words and correctly identified pictures were analyzed for variance. Comparisons were made between all three experimental groups. Statistical analysis was performed in Excel using Single-Factor ANOVA (statistical significance set by alpha = 0.1) to determine if any physiological or memory related variances due to induced anxiety were significant.

Results

Induction of Anticipatory Anxiety:

Results showed that mean heart rate percent change in the anticipatory group was markedly increased compared to the mean heart rate change across the same time period in the control group (Fig. 1). Mean change in respiratory rate was also increased in the anticipatory anxiety group compared to the control population (Fig. 2). Conversely, percent change in GSR was moderately lower in the anticipatory anxiety group with respect to the control (Fig. 3). However, Single-Factor ANOVA (alpha = 0.1) showed that there was no statistical significance to these variations.

Induction of Performance Anxiety:

Performance anxiety was quantified in the same manner as anticipatory anxiety. Percent change in heart rate illustrated that, on average, subjects in the performance anxiety group deviated from baseline to a greater extent than the control group (Fig. 1). Similarly, percent change in respiration was slightly increased when observed in comparison to percent change in the control group (Fig. 2). Comparable to what was observed in the anticipatory anxiety group, percent change in GSR was lower in the performance anxiety group than the control (Fig. 3). Single-Factor ANOVA (alpha =0.1) analysis of these results illustrated that, similar to the results obtained from the anticipatory group, there were no statistical differences between any of the physiological variables.

Physiological Trends Between Memory Tests:

Physiological trends observed in the control group are depicted in Figure 4. On average, subjects showed a positive change from baseline in all three physiological variables during memory test one. However, as subjects proceeded to test two and three, participants showed diminished increases in GSR, and decreased heart rate. Respiration rates did not provide us with clear trends as respiration rate decreased during memory test two but subsequently increased during test three. None of the above trends were statistically significant.

Physiological data for the performance anxiety group is displayed in Figure 5. During all three memory tests subjects on average showed elevated change from baseline for heart rate and GSR. Analogous to the control group, respiration rates were elevated from baseline in tests one and three but reduced during test two. None of the above trends were statistically significant.

Anticipatory anxiety group data for physiological responses is displayed in Figure 6. GSR remained elevated from baseline during all three tests. However, the magnitude of the percent change tended to diminish from test one to three. Heart rate also showed diminishing magnitude of percent change, test one and two were elevated from baseline while in test three participants, on average, had a lower heart rate than baseline. Respiration rate was elevated during the three word recall tests and was relatively constant across all three. None of the above trends were statistically significant.

When all participants were combined, single factor ANOVA showed no significant differences in the physiological measurements of anxiety (GSR, heart rate, respiration rate) between the three word recall tests. However, a clear trend showing a general decrease in physiological measurements as the tests progressed in time was observed (Fig. 7).

Word Recall Memory Test:

Mean number of correct responses across experimental group were calculated for each word recall test and presented in Figure 8. Statistical analysis (Single-Factor ANOVA, alpha = 0.1) of the individual word recall tests illustrated that there was no significant difference between the control, anticipatory and performance groups in this test. P values for memory test 1, 2, and 3 were 0.81, 0.99, and 0.25, respectively.

Picture Recognition Memory Test:

Mean correct responses were averaged within each experimental group and displayed in Figure 9. Results showed that on average, participants in the performance anxiety group performed better than the control or the anticipatory anxiety group in selecting the previously viewed image from the two-by-two test array. Single-Factor ANOVA (alpha = 0.1) showed there was statistical significance between the experimental groups (P value of 0.063).

Word Recollection Between Memory Tests:

For the anticipatory, performance, and control groups, there were no statistical differences between memory test 1, 2, and 3, showing that participants were not improving or declining in performance as the recall tests proceeded. P-values were 0.94, 0.26, and 0.47 for memory tests 1, 2, and 3, respectively (Fig. 8).

<u>**Discussion**</u>

Overall, the success of our experiment was dependent on the assumption that anxiety will be induced by our methods. However, based on our physiological determinants of anxiety, which included galvanic skin response, heart rate, and respiratory rate, there is no statistically significant variation from baseline readings to indicate an induced state of anxiety (Fig. 1-3). On the other hand, the observed trends for heart and respiratory rates are consistent with our assumption that noise expectation induces anxiety, as indicated by an increase in physiological measurements from baseline in the anticipatory and performance groups. Surprisingly, the galvanic skin response showed an opposite trend, being highest in the control group. Trends in

GSR and heart rate for all experimental groups were shown to decrease test by test, as subjects progressed through the experiment (Fig. 4-6), potentially indicating a lack of continuous anxiety.

Furthermore, our hypothesis assumed that our physiological determinants for an induced state of anxiety would demonstrate a strong positive correlation; however, experimental evidence contradicts this. Linear regression analyses of the three measured physiological factors plotted against one another showed weak or even negative correlation (Fig. 10). Therefore, we might have not only failed to induce sufficient anxiety, but also chose physiological measures of anxiety that were too weak or unrelated.

In addition, in a post-test survey, the participants reported overall low levels of anxiety regardless of their experimental group placement. When asked to rate their level of anxiety from the hypothetical noise on a scale from 1-5 (with 5 being the most anxious), the performance group rated an average of 3.5, while anticipatory group rated their anxiety at 2.75. These values are not telling enough to conclude that anxiety was actually induced. Also, the participants of our study were almost all UW-Madison Physiology students conducting their own experiments throughout the testing period. For this reason, they may have felt less anxious about entering a research environment and performing tests than a subject unfamiliar with experimental procedure. In many studies that investigate memory and academic performance, standardized tests are administered to subjects instead of simple memory tests (Wu, 2). The higher level of intensity and analysis involved with standardized tests seem to be more effective in promoting anxiety.

Technical issues were also a persistent factor in data collection. It became clear after testing few participants that the GSR detector was sensitive to even the slightest movements of the fingers. Such sporadic movements resulted in peaks in the graph that may not have been attributed to skin conductance. The accuracy of the heart rate measurements, as quantified by an ECG, was also called into question. For one participant, the ECG data was unusable due to potential electrode detachment during the experiment. Finally, the data for respiration rate was highly skewed, associated with talking, coughing, and substantial upper body movement. As students with little experience working with these technical instruments, there was high potential for human error. Placement of ECG electrodes as well as tightness of the respiration monitor and the GSR finger electrodes was variable among participants due to a lack of previous exposure to these tools.

Experimental results were also restrained by a diminished sample size (n=15). Time restrictions and unforeseen experimental problems slowed the process of data collection. It is plausible that an increased sample size could have lead to significant results in favor or against our hypothesis. The diminished sample size resulted in outliers drastically skewing the physiological, word recall, and picture recall data. Future work in this type of research would require the sample size to be doubled at minimum.

These shortcomings likely influenced the results of the word recall tests, as the difference in the amount of recollected words between the control, anticipatory and performance groups was statistically insignificant throughout the entire duration of the experiment (Fig. 8). Also, there was no statistically significant trend in word recollection performance for any of the experimental groups across the three word recall tests; thus, subjects did not improve or learn through the duration of the test, eliminating this possibility as a potential confound.

There was a statistically significant difference in performance on the visual recollection task in the performance anxiety experimental group compared to the control or anticipatory anxiety groups (Fig. 9). This is consistent with our hypothesis that participants would perform better when their performance on the test determined if they heard the anxiety-inducing noise or not. Conceptually, it is reasonable to assume that participants in this experimental group would have been more aware of all the stimuli they were presented with. At no point during the memory tests were the participants explicitly told that the word recall test would be the only memory test. It is plausible that those in the performance group were more likely to recognize the pictures as a secondary test and mentally process the visual image to a greater extent, thus holding it in their short-term memory.

Future studies, based on a higher subject samples, could determine whether the increased respiration and heart rate trends, observed in the performance and anticipatory anxiety groups, are in fact significant. The apparent opposite trend, observed in GSR measurements could also be clarified by making sure the subjects remain as still as possible regardless of experimental group. Finally, enhanced visual recollection observed in the performance anxiety group should be thoroughly explored in order to test whether it was the visual component or some other confound, such as longer memory retention or lack of explicit instructions that was enhanced by performance anxiety. In conclusion, this study provided some evidence to support a positive correlation between anxiety and memory, particularly with performance anxiety and picture recognition. However, the exact correlation between induced performance anxiety and anticipatory anxiety in relation to memory remains unclear. Further investigation is required to find more conclusive evidence to support their relationships. This study and future research in this area could provide insight into academic performance and help determine how anxiety affects students.

Figures:

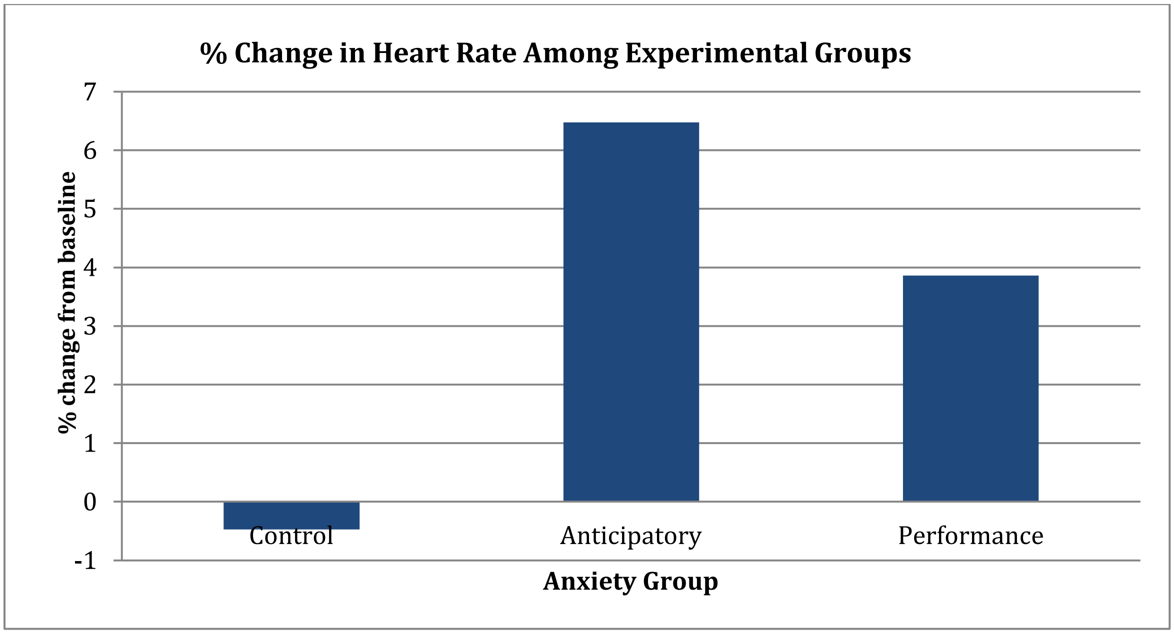

Figure 1: Based on single factor ANOVA with p-value: 0.509, the variability of heart rate is statistically insignificant between the three experimental groups at alpha = 0.1. However, anticipatory and performance group heart rates tend to be higher than in the control group, consistent with our hypothesis.

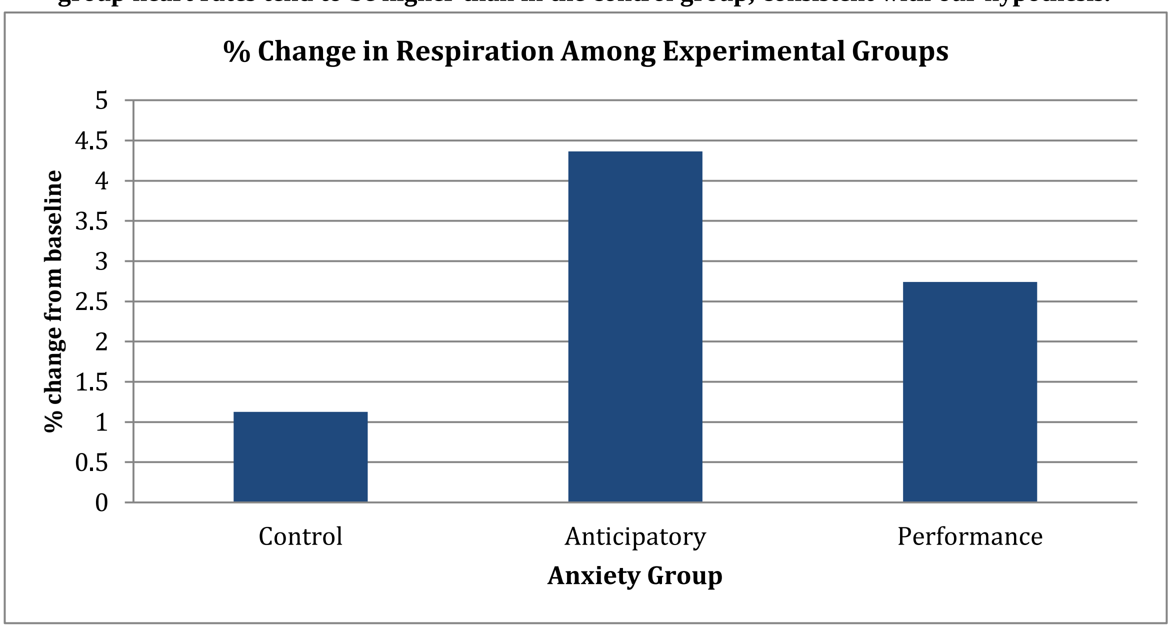

Figure 2: Based on single factor ANOVA with p-value: 0.698, the variability of respiration is statistically insignificant between the three experimental groups at alpha = 0.1. However, anticipatory and performance group respiration rates tend to be higher than in the control group, consistent with our hypothesis.

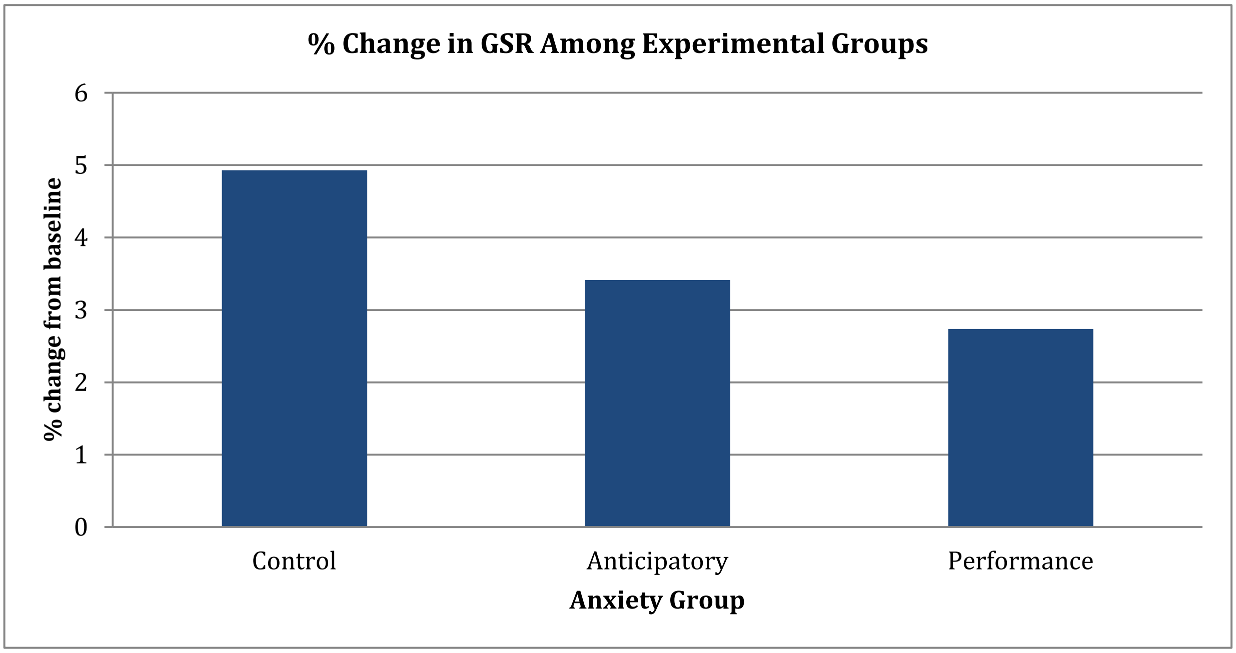

Figure 3: Based on single factor ANOVA with p-value: 0.934, the variability in galvanic skin response is statistically insignificant between the three experimental groups at alpha = 0.1. Contrary to our hypothesis, GSR in the control group tends to be higher than in either anticipatory or performance groups.

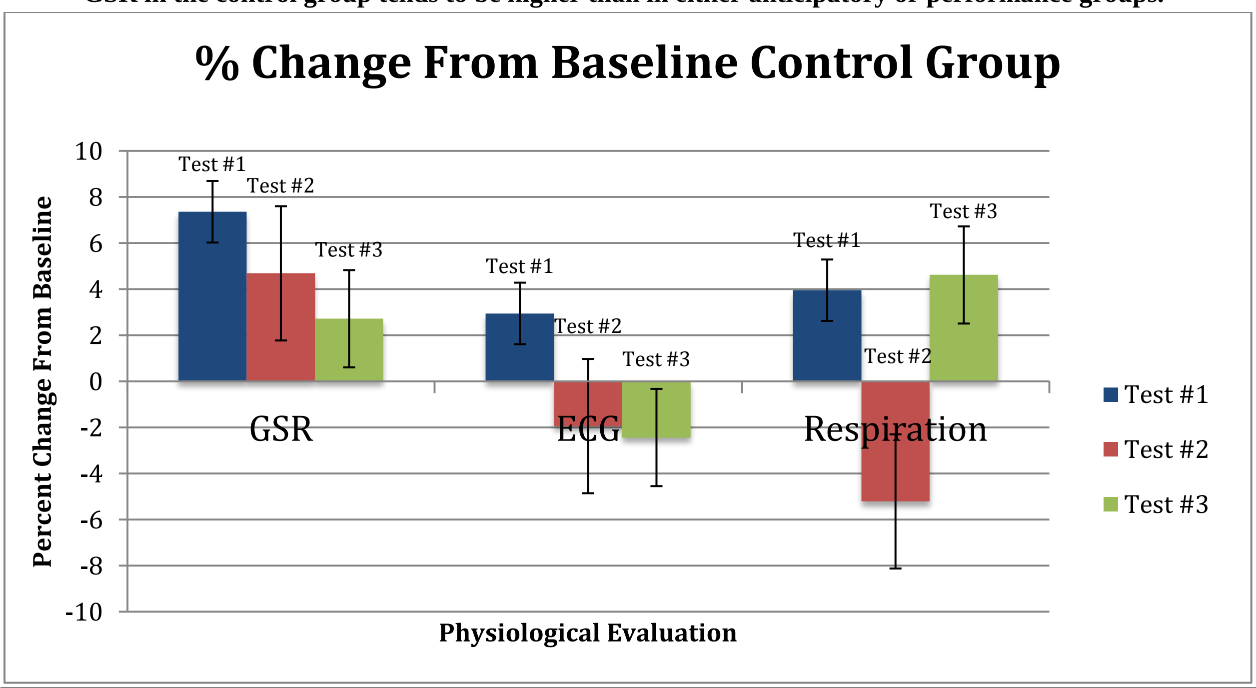

Figure 4: While not statistically significant, GSR as well as heart rate (ECG) tended to decrease throughout the testing duration, while respiration did not show a particular trend in the control experimental group.

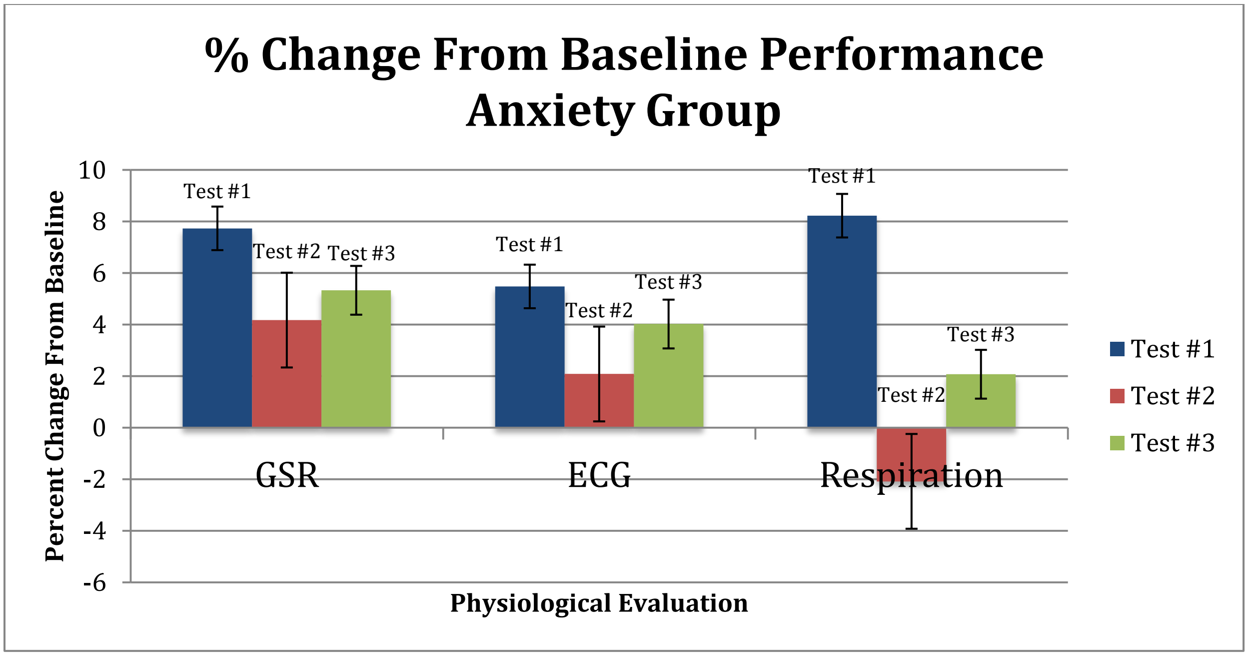

Figure 5: While not statistically significant, GSR as well as heart rate (ECG) tended to decrease throughout the testing duration, while respiration did not show a particular trend in the performance anxiety experimental group.

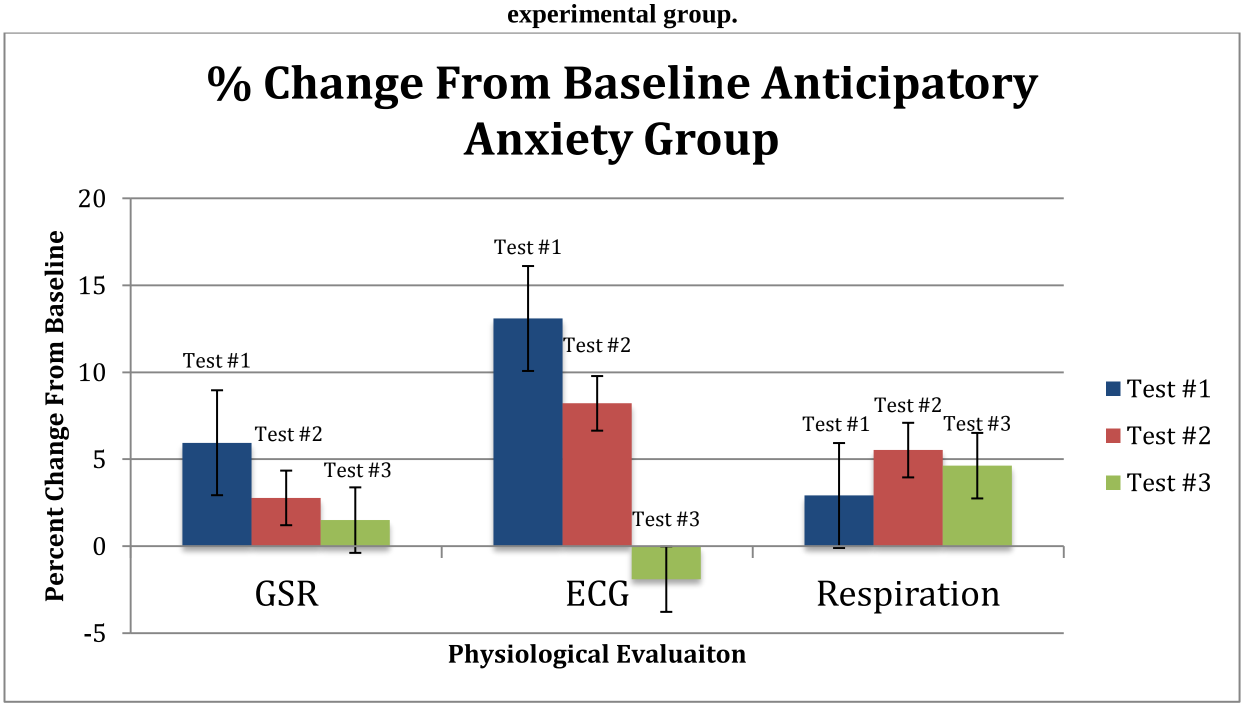

Figure 6: While not statistically significant, GSR as well as heart rate (ECG) tended to decrease throughout the testing duration, while respiration did not show a particular trend in the anticipatory anxiety experimental group.

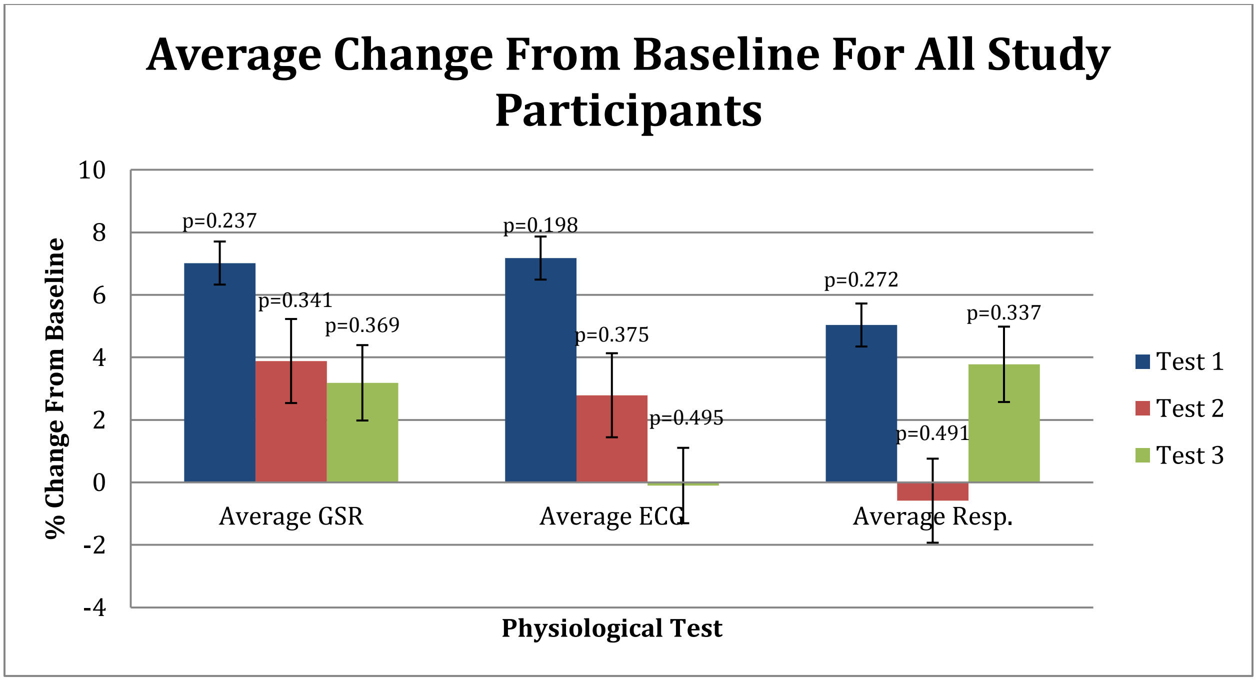

Figure 7: Percent change from baseline of physiological measurements of the participants in all three study groups during the three tests. P-values indicate the significance of change from baseline of each measurement at alpha = 0.1.

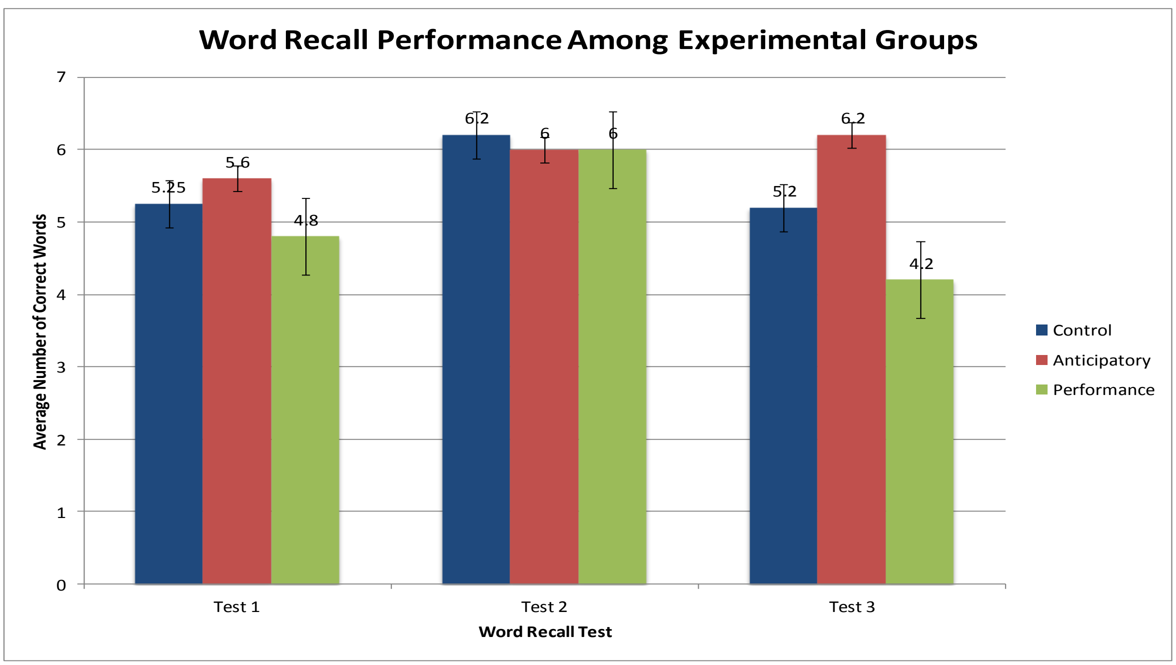

Figure 8: Based on a single factor ANOVAs at significance alpha = 0.1, the difference in the amount of recalled words between the control, anticipatory and performance groups was statistically insignificant throughout the entire duration of the test (Test 1 p-value: 0.94, Test 2 p-value: 0.26, Test 3 p-value: 0.47). Additionally, there was no statistically significant trend for any of the experimental groups in the word recollection performance between Test 1,2, and 3.

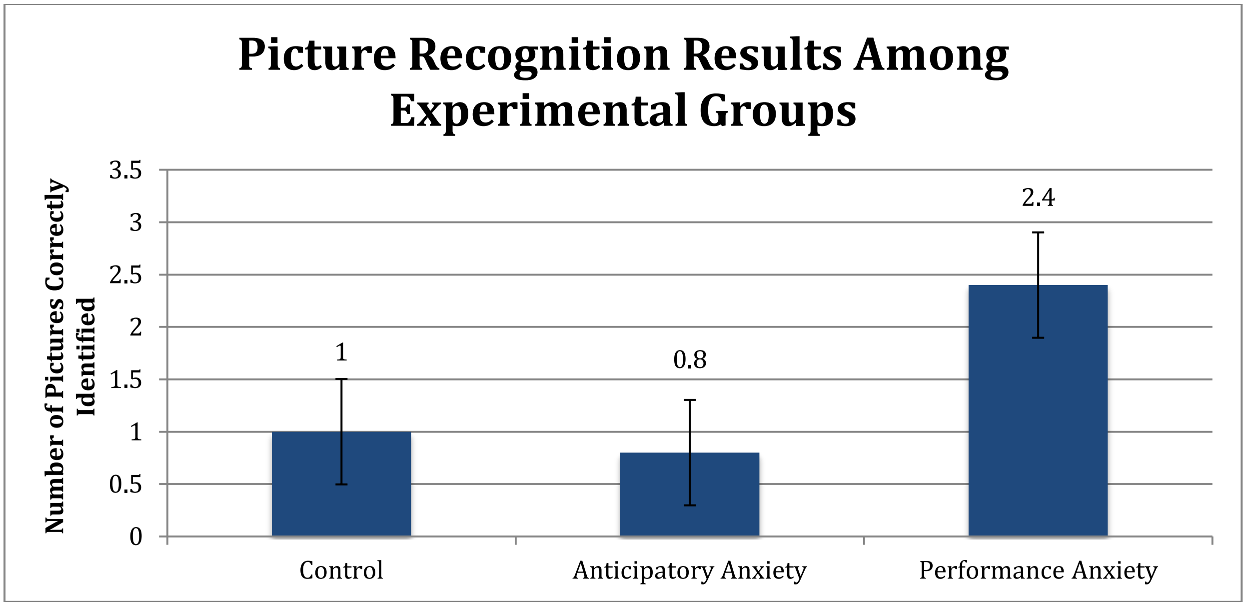

Figure 9: Based on a single factor ANOVA at significance alpha = 0.1, there was a statistically significant difference in performance on the visual recollection task in the performance anxiety experimental group compared to the control or anticipatory anxiety groups (p-value: 0.063). This is concurrent with our hypothesis that performance anxiety would help recollection.

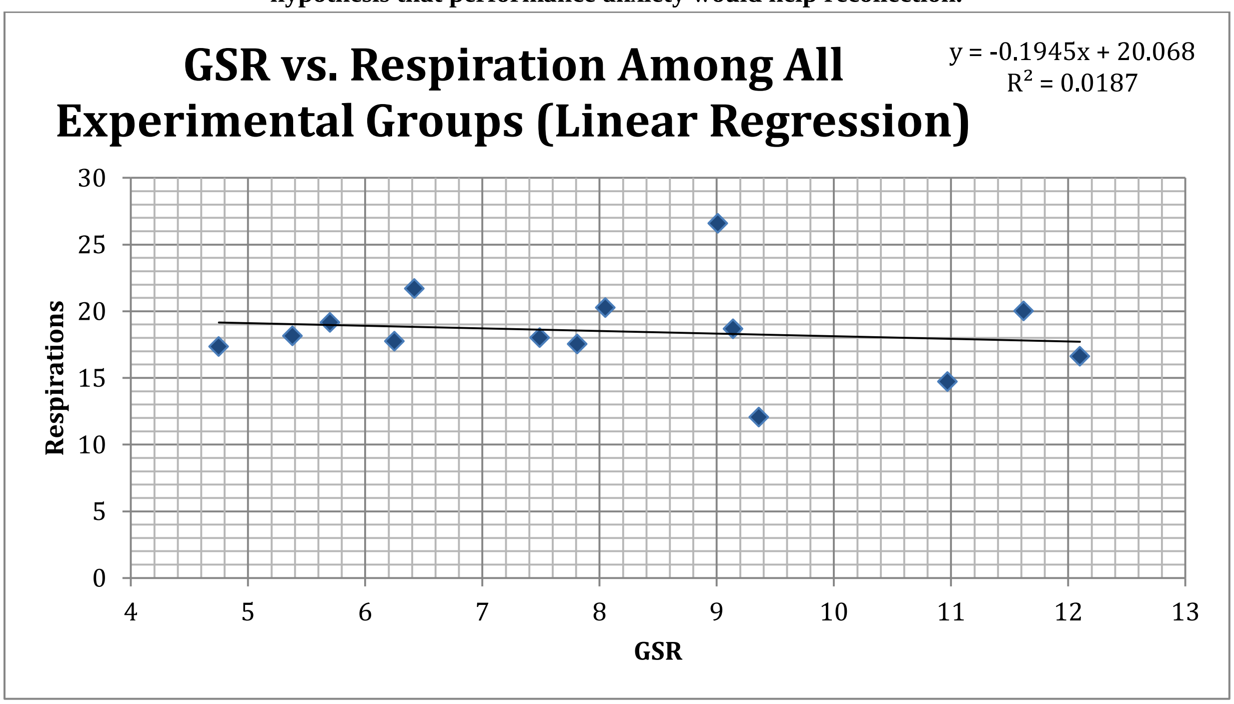

Figure 10: A linear regression comparing galvanic skin response to respiration amount. Since the $R^2 = 0.0187$, and the correlation has a negative trend, we can conclude that GSR and respiration rate are not strongly positively correlated, contrary to the expectation in our hypothesis. Linear regression analysis of GSR vs. heart rate and respirations vs. heart rate showed a similar lack of correlation.

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