The Effect of Emotion on Cognitive Flexibility Using the Stroop Test While Monitoring Heart Rate, Respiration Rate, and Electrodermal Activity Levels

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ABSTRACT

The purpose of this experiment was to examine the changes in cognitive flexibility that arose from physiological changes in the body caused by emotion. In 30 subjects, either happiness or fear was induced in the subject while their heart rate, respiration rate, and electrodermal activity were measured. Cognitive flexibility was tested using the Stroop test by measuring reaction time. We hypothesized that fear would lead to faster reaction times while happiness would lead to slower reaction times. T-tests showed a significant decrease in reaction time for incongruent and congruent fear Stroop tests ($p=0.00287$ and $p=0.00166$ respectively) and also for congruent happy Stroop tests ($p=0.00566$). This supports our hypothesis that fear leads to a faster reaction time and better cognitive flexibility, however happiness also showed increased cognitive flexibility. Overall it seemed that fear was a stronger emotion, inducing a greater physiological and cognitive change. While improved reaction times may be a sign of increased cognitive flexibility, this does not necessarily imply that accuracy or best judgment is used while in a fear state. There is definitely a tie between emotion and cognitive ability which should be further explored in other contexts.

INTRODUCTION

As one of the oldest areas of research, humans have found an intrinsic interest in our capability of emotions and why they are relevant to the roles of our lives. Emotions can be volatile, unpredictable, and indistinguishable from their physiological effects making it difficult to study yet is what captivates the interest (Alive Publishing Group). Emotions and their impact on physiological effects poses many interesting questions for scientists to study. One study acquired information that varying emotions had mappable sensations throughout the body (Nummenmaa, et. al. 2013). Another study demonstrated that the autonomic nervous system had measurable changes in response to different emotions (Ekman, et. al. 1983). One must simply think back to a time on their way to see a significant other as the heart races and excitement builds or recall the lethargy that sadness caused one to feel from the devastating loss of a loved one. The point of interest is to explore what affects emotions have on the body, and how our physiological state in turn impacts our behavior. As it is evident emotions do cause physiological effects, we further seek how the cognitive abilities of an individual are affected concurrently by physiological changes induced from an emotion.

The purpose of this study is to determine how an individual's cognitive flexibility, metal ability to switch between two different thoughts, is affected by an emotional stimulus and the resulting physiological changes promoted by that emotion. To do this, the participants will watch YouTube videos that induce a specific emotion: fear or happiness. While watching the video clips the participants will be monitored via electrocardiogram (ECG), Galvanic Skin Response (GSR), and a respirator transducer. We chose these three forms of measurement because heart rate, sweat, and respiration activity are indicative physiological responses that are affected by emotion. That is, when a participant experiences a fear or happy emotion from the video clip, we expect these measurements to change in comparison to their baseline levels. An ECG measures the electrical conduction system of the heart over a period of time. The GSR is used to measure the skin's ability to conduct electricity. This will show us how a person's perspiration changes in response to emotion. The respirator transducer will allow us to monitor the participant's breathing (BioPac). With all of these different measurement devices, we will be able to measure how emotion can affect heart rate, sweating, and respiration patterns.

We expect these physiological changes in the body to in turn affect the participant's performance on the Stroop test. The Stroop test measures one's mental capacitance to switch between conceptually different thoughts through cognitive processing. It also tests the capability to think about multiple concepts simultaneously, known as cognitive flexibility, and processing speed. It is used as a tool in the evaluation of executive functions. By testing the subjects before and after the viewing, we can use the before test as a control for non-aroused cognitive abilities and compare these scores with the ones from after viewing the videos.

To perform this experiment, we will first hook up each participant to all three devices- the ECG, GSR, and respirator transducer and establish a baseline activity for each of these measurements. We will begin recording measurements throughout the duration of the experiment. Next, participants will take the Stroop test online before watching the emotional YouTube video in order to establish a baseline score for the test. Immediately after, they will watch a YouTube video based on their assigned emotion category (happiness or fear). Following completion of the video, the participant will then retake the Stroop test. The goal is to see if an emotional response to the video has an effect on the Stroop test score (cognitive function), as well as any physiological changes depicted by the ECG, GSR, and respirator transducer.

The physiological changes induced by the emotional stimuli will affect cognitive flexibility, one's ability to distinguish between multiple thoughts on one subject. We chose two emotions that express more degrees of emotion within a positive-negative categorization, fear expressing broad negative feelings and happiness expressing more variable positive feelings. Fear is an emotion that can be taught, for example a bad experience almost drowning may develop a fear towards water or from a movie clip that one can relate to their own life. Fear is also found to be confused with anxiety which is only felt when the danger is not physically present at that point, the thought of water vs. being physically by a pool, and time leading to similar side emotions such as paranoia. Happiness is the goal most healthy individuals strive for and mainly found in people with high satisfaction within their lives. Happiness can be linked to health, life expectancy, spirituality, etc. but can be limited by genetics. Therefore, these emotions can be expressed to different degrees based on different individuals. Although, we assume the cognitive flexibility will be similarly affected based on similar emotional induced-physiological changes that occur limiting the skew of data. We predict that emotional stimulus of fear will impact these physiological responses by causing an increase in heart rate, electrodermal activity, and respiratory rate. Fear puts the body in a stressed state similar to anxiety or panic therefore symptoms will be similar. As a result, the subject will have a faster Stroop test score due to an increased reaction time and increase in cognitive flexibility (Zhou, et al. 2011). In contrast, we predict the happiness stimulus to cause a decrease in heart rate, some electrodermal activity, and a relatively stable respiratory rate. Happiness can lead to a more relaxed and content state and as a result, we expect the Stroop test score to be slower (Phillips 2002). The idea that the body is more relaxed concludes the subject will have a slower reaction time.

MATERIALS

- BIOPAC © Systems, Inc.; Goleta, California
    - A/D Box #MP36
    - Software: Biopac © Student Lab 4.0 Program
- BIOPAC © Devices via Biopac Student Lab 4.0 Program
    - Galvanic Skin Resistance (GSR) - measurements for electrodermal activity (skins ability to conduct electricity; BSL EDA Finger Electrode Xdcr, part #: SS3LA
    - Electrocardiography (ECG) - measurements for heart rate; BSL Shlded Electrode Assembly, part #: SS2L
    - Respiratory Belt Transducer - measurements for respiration and breathing habits;

BSL Respiratory Effort Xdcr, part # SS5L

- Two Stroop test programs; first: http://ezyang.com/stroop/, second: http://cognitivefun.net/test/2
- Headphones; Audio-Technica monitor headphones ATH-M50
- PC Computers; Computer #1 for Emotional Stimulus/Stroop Test; Computer #2 for Biopac recordings of the Physiology 435 Lab Room (Medical Science Center 2395)
- Videos; “More NFL - A Bad Lip Reading of the NFL” and “paranormal activity 3 scary scene”
- Excel Spread Sheet for recordings per volunteer

METHODS

Students at UW-Madison who are enrolled in Physiology 435 were asked to volunteer for this study. Participants were given a consent form to sign prior to participation. We had thirty test subjects total for the experiment.

In order to observe the physiological changes induced by the viewing of an emotional video, participants’ heart rate, respiratory rate and electrodermal activity were measured via the Biopac© Student Lab 4.0 Software. A base rate was procured before the video was shown. The individual was administered a Stroop test before viewing the video in order to gauge baseline cognitive flexibility. Once control measurements had been recorded, the participant was shown a video selected to induce one of two emotions (happiness or fear). The physiological measurements were recorded throughout the viewing. Post-viewing, the participant retook a Stroop test to observe any changes in cognitive flexibility due to the emotion induced by the video. Figure 1 in the appendix demonstrates our methodology.

An electrocardiogram (ECG) was used to measure the heart rate of the subject. An ECG is a simple, painless test that records electrical signals as they pass through the heart by recording and testing the heart's electrical activity. Every heartbeat sends a signal from the top of the heart to the bottom that causes contractions via action potentials. These calcium-dependent contractions induce a contractile force to pump blood from the heart to pulmonary and systemic systems of the body in a rhythmic pattern. ECG results show the rate at which a heart is pumping, timing of heartbeats, as well as steadiness or irregularity of heartbeats. A Galvanic Skin Response (GSR) was used to measure the electrodermal activity of the subject. A GSR is a simple, painless test that detects emotional arousal through electrical skin conductance from changes in salt and water in the sweat gland ducts. A GSR works by application of a minimal electrical current sent through small conducting plates typically attached to fingers or toes via electrode cuffs. A Respiratory Belt Transducer was used to measure the activity of respiration of subjects throughout the test. A Respiratory Belt Transducer contains an electrical device that measures linear changes in length. Changes in thoracic or abdominal circumference indicate the depth of inhalation and expiration to assist in determining breathing rates.

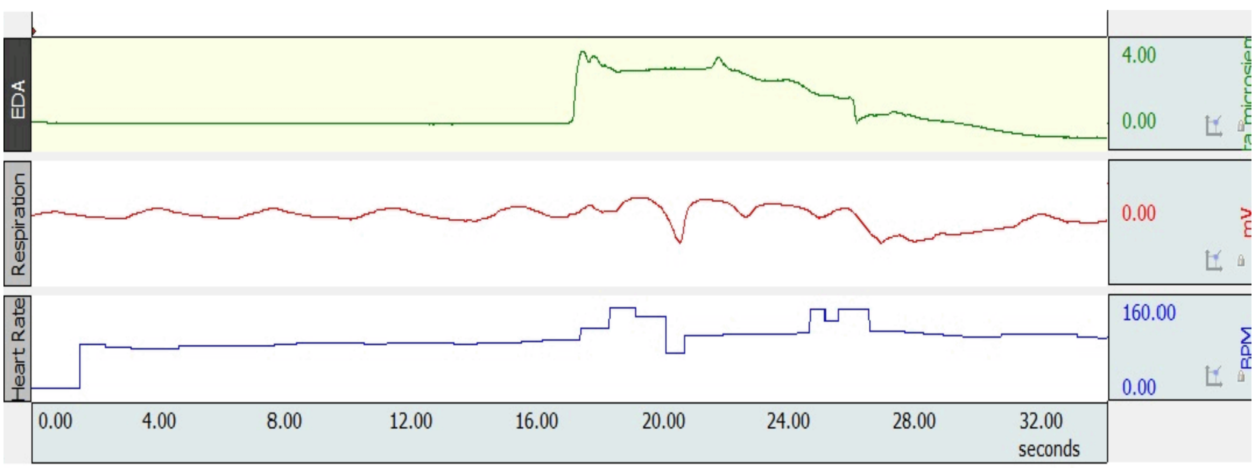


Figure 2. Screenshot of recordings showing positive control events.
The positive control demonstrates a change made to respiration, which in fact changed the GSR and ECG readings proportionally, purposely from resting rate to rapid breathing and tension back to resting.

In order to measure the cognitive flexibility, a Stroop test was performed. A Stroop test works by measuring the reaction rate and correctness of an individual selecting the color of a word rather than the word itself, a persons' ability to distinguish between color variation from word recognition (Stroop, 1935). There are twenty four trials, with a mix of them being congruent and incongruent. A congruent test is defined when the color of the word and the word itself are the same color. An incongruent test is defined when the color of the word and word itself do not match. Scores were measured by the reaction times for both congruent and incongruent tests. Typically, a person is expected to score better on congruent tests because there are little to no interference effects. Interference effects arise when two conflicting functions, word reading and color naming, are put against each other. The subject is asked to name the color which conflicts with a person's natural tendency to read the word itself. (Comalli, et al. 1962). Two different Stroop tests were used, one for the initial test and one for the post-video test. The initial test is found at http://ezyang.com/stroop/ and the second test is at http://cognitivefun.net/test/2. Both websites give the reaction times for congruent and incongruent trials. Two separate Stroop tests were administered in an attempt to minimize the learning curve, which is the idea that subjects would gain skill or efficiency from their experience and production time to improve results (Aquilano p.1). To minimize this we chose two different web sites and Stroop tests so the subject having taken the test before on that same website that they would reduce the chance of performing better the second time. We wish to see if the changes in reaction times are a response to the emotional video, not because they have learned or memorized from the first time they took the test.

First, the participant was hooked up to the devices. For the ECG, electrodes were applied on right forearm (white) and left (red) and right (black) calves. A respirator belt was placed beneath armpits and around the chest for the respiratory rate. The GSR was measured by putting electrodes with gel in the electrode cavity on two fingers of the non-dominant hand. The participant was seated in a relaxed position and put on headphones. We began initial recordings and administered the first Stroop test. The participant then watched the video that was selected for them. They are not told which emotion was assigned to them. The videos we used were: "More NFL - A Bad Lip Reading of the NFL" (happy-inducing) and "Paranormal Activity 3 scary scene" (fear-inducing). After watching the video, the participant was asked if they felt that they were emotionally affected by the video using a Likert scale, giving their emotional response a rank from 1 to 5, lower number indicated lower emotional stimulation and vise versa. We then had them retake the Stroop test.

The reaction times for both pre- and post-Stroop test were recorded, as well as the mean beats per minute, the minimum and maximum respiratory rate and the mean galvanic response. After all of the data was collected, comparisons of heart rate, respiratory activity, Stroop test scores, and electrodermal activity between pre-emotional stimuli and post-emotional stimuli were performed. The percent change between the baseline and the post-stimulation Stroop test reaction times was calculated in order to compare within the individual. We conducted a T-test to determine whether there was a significant difference between the Stroop test results before and after the viewing of an emotion inducing video.

RESULTS

The Stroop test reaction times and percent changes for happiness and fear can be seen in Table 1 and Table 2 respectively. A positive percent change means that the reaction time was slower than the baseline and a negative percent change means that the reaction time was faster than the baseline. For happy congruent Stroop test scores, there was 1 positive percent change and 14 negative percent changes. The average positive percent change was 0.524%. The average negative percent change was -15.719%. For happy incongruent Stroop test scores there were 6 positive and 9 negative percent changes. The average positive percent change was 8.441%, and the average negative percent change was -7.837%. The overall average for happy congruent Stroop test scores was -14.636% and the overall average for happy incongruent Stroop test scores was -1.326%.

There were 2 positive and 13 negative percent changes for fear congruent Stroop test scores. The average positive percent change was 1.173%. The average negative percent change was -28.248%. For fear-incongruent Stroop test scores, there was 1 positive percent change and 14 negative percent changes. The average positive percent change for fear-incongruent scores was 1.557% and the average negative percent change was -15.616%. For the fear congruent Stroop test scores, overall the average was -24.325% and the incongruent overall average was -14.381%.

We performed a two-tail paired t-test between the before and after scores of the Stroop test for each emotion (incongruent and congruent for each). For the happiness-induced subjects, the p-value for incongruent Stroop test scores was 0.60076, and the p-value for congruent Stroop test scores was 0.00566. The fear p-value for incongruent Stroop test scores was 0.00287, and the p-value for congruent Stroop test scores was 0.00166. Using p=0.05, this tells us that there was a significant change for the congruent test scores for happy-induced subjects as well as a significant change for both the congruent and incongruent test scores for the fear-induced subjects.

The mean measured heart rate, respiratory rate, and electrodermal activity for all subjects during the first Stroop test, during the video and during the second Stroop test can be seen in the tables below respectively. For each physiological measurement per emotion the best individual results are included as well.

Figure 3A. Average Mean BPM for Fear Subjects for Each Step in Study

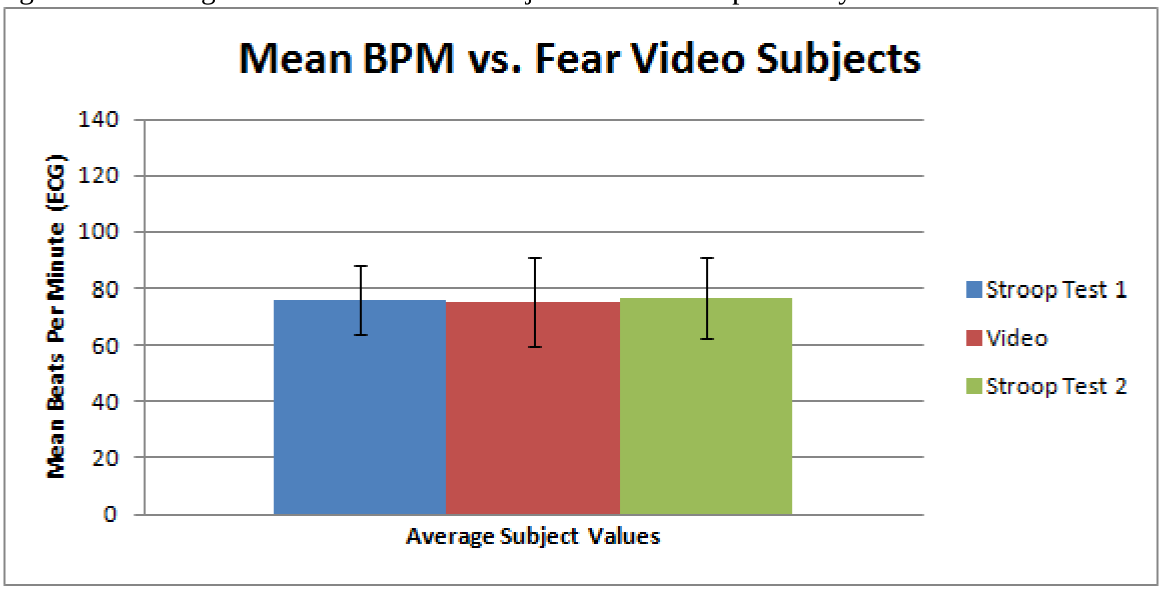
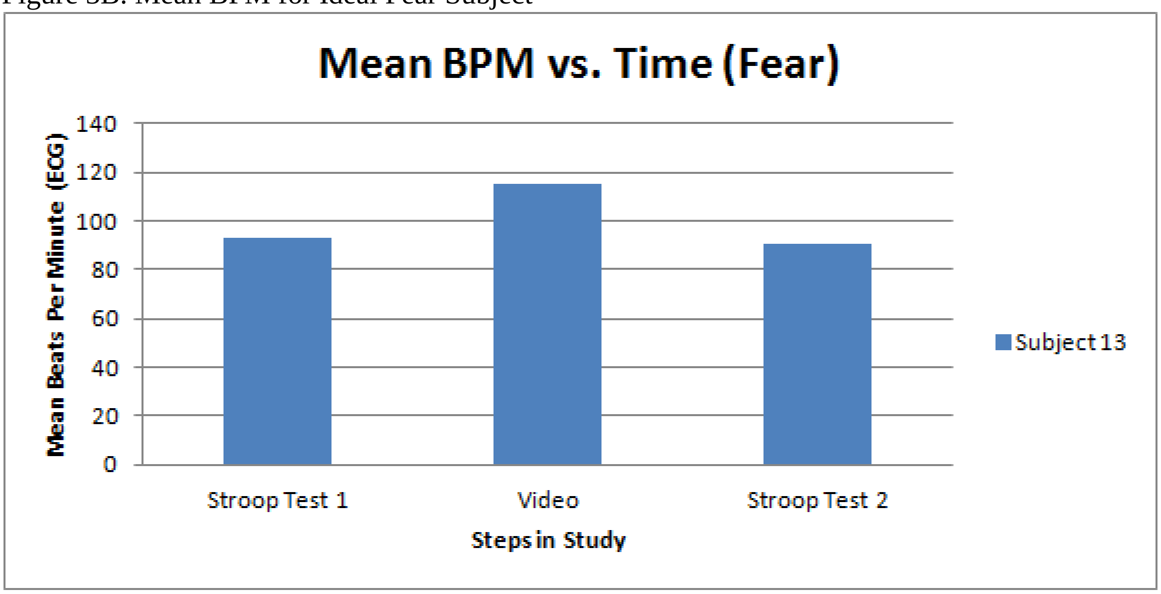


Figure 3B. Mean BPM for Ideal Fear Subject



In Figure 3A, the mean BPM for all fear subjects during the first Stroop test was 76.1 bpm (SD=12.0), during the video was 75.5 bpm (SD=15.5), and during the second Stroop test was 76.8 bpm (SD=14.0). The mean BPM results for the ideal fear subject, as seen in Figure 3B, during the first Stroop test was 93.1 bpm, during the video was 114.9 bpm, and during the second Stroop test was 91.0 bpm. Subject 13 illustrates the increase in heart rate while watching the fear-inducing video.

Figure 4A. Average Mean BPM for Happy Subjects for Each Step in Study

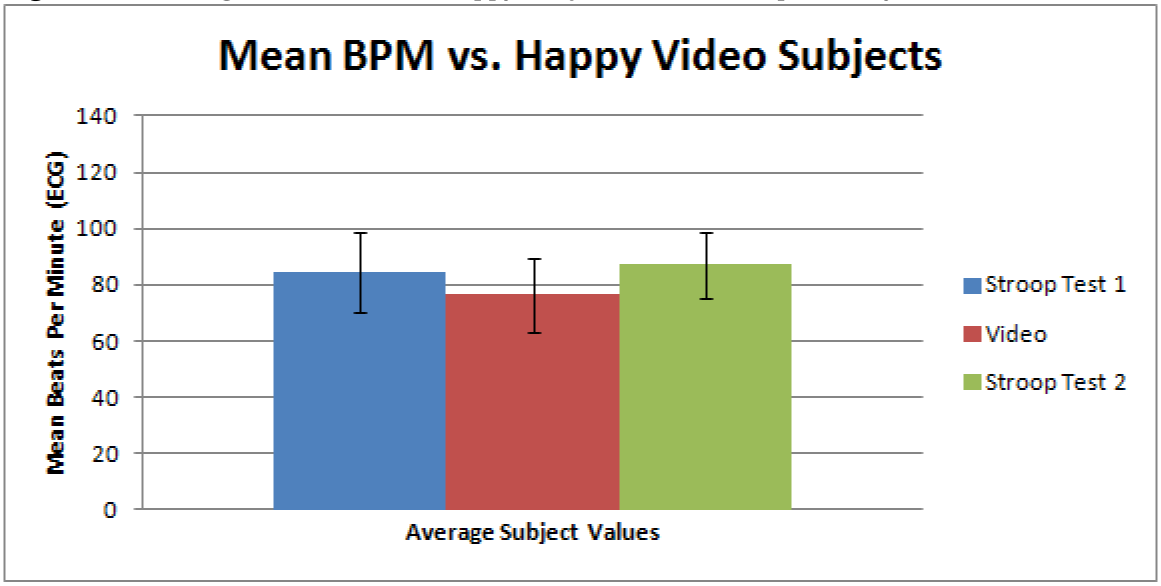
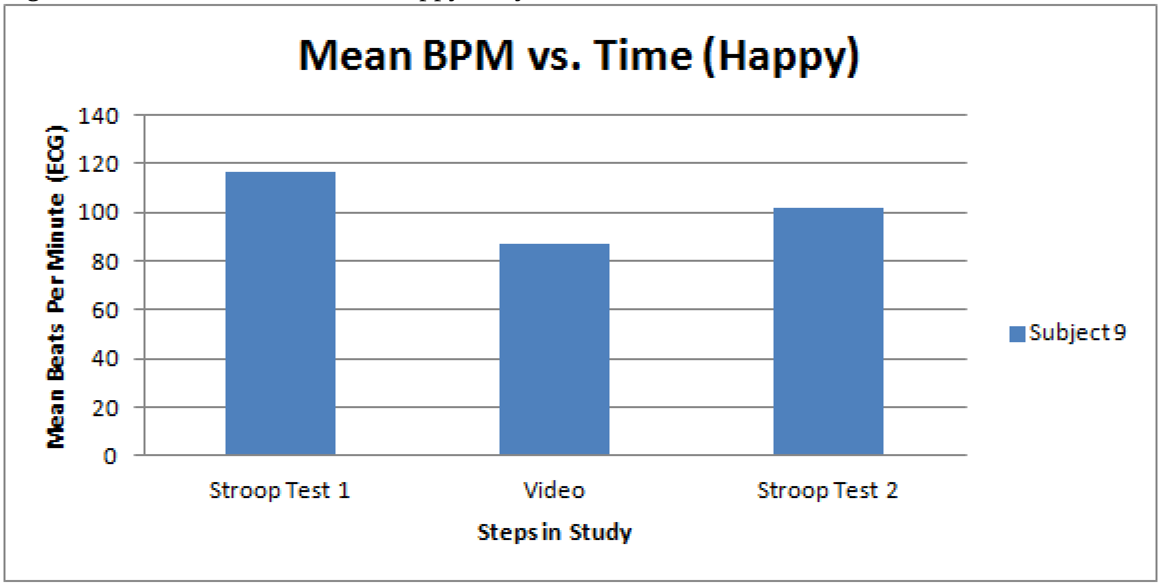


Figure 4B. Mean BPM for Ideal Happy Subject



In Figure 4A, the mean BPM for all happy subjects during the first Stroop test was 84.4 bpm (SD=14.3), during the video was 76.3 bpm (SD=13.1), and during the second Stroop test was 87.0 bpm (SD=11.8). Figure 4B demonstrates the ideal happy subject's results, with the mean BPM during the first Stroop test being 116.2 bpm, during the video being 87.4 bpm, and during the second Stroop test being 102.0 bpm. Subject 9 shows the change in heart rate as a result of watching the happy video.

Figure 5A. Average Mean Respiration Signal for Fear Subjects for Each Step in Study

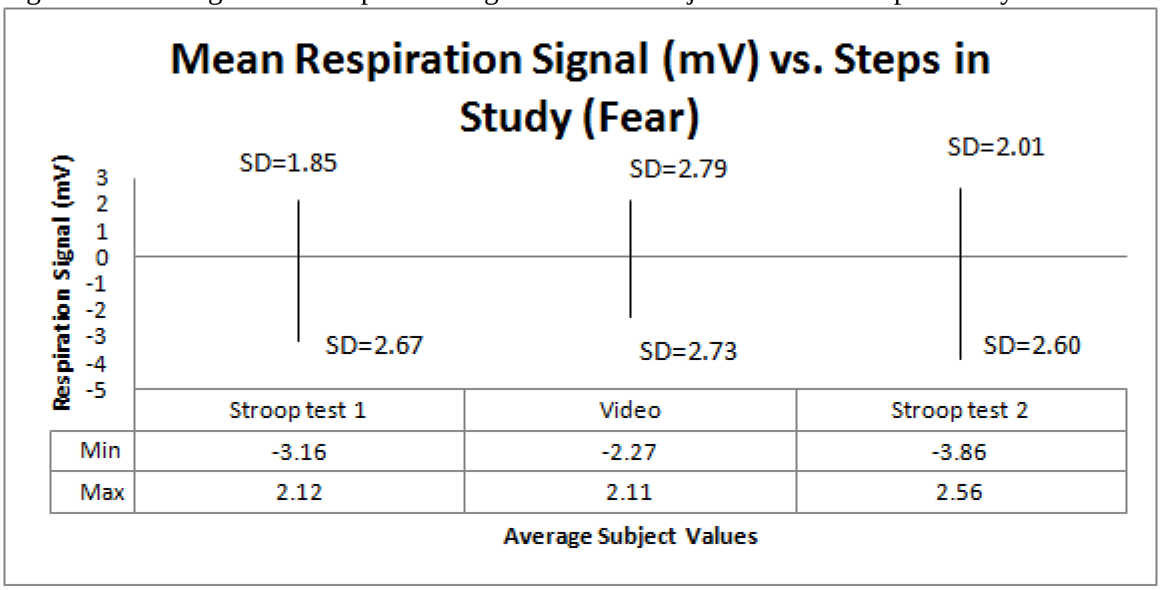
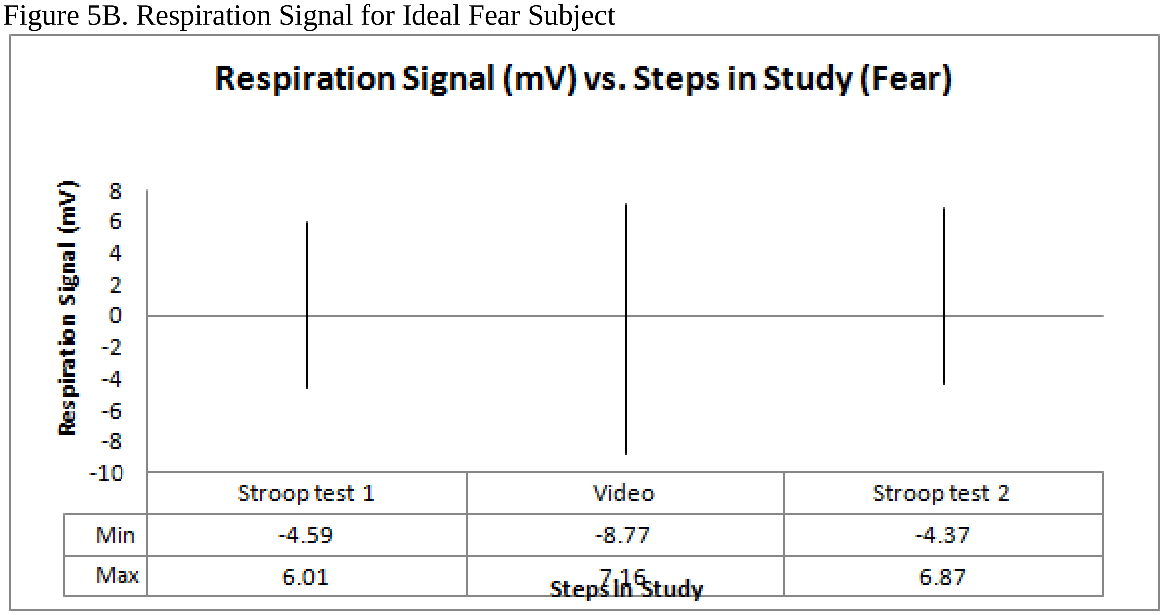


Figure 5B. Respiration Signal for Ideal Fear Subject



In Figure 5A, the mean delta for all fear subjects between the min and max respiration signal during the first Stroop test was 5.28 mV (SD=4.3), during the video was 4.38 mV (SD=5.4), and during the second Stroop test was 6.41 mV (SD=4.2). In Figure 5B, the mean respiration signal for the ideal fear subject during the first Stroop test was 10.60 mV, during the video was 15.93 mV, and during the second Stroop test was 11.24 mV. For the specific individual results graph the ranges of depth of respiration indicate that there was an increase during the video as a result of fear.

Figure 6A. Average Mean Respiration Signal for Happy Subjects for Each Step in Study

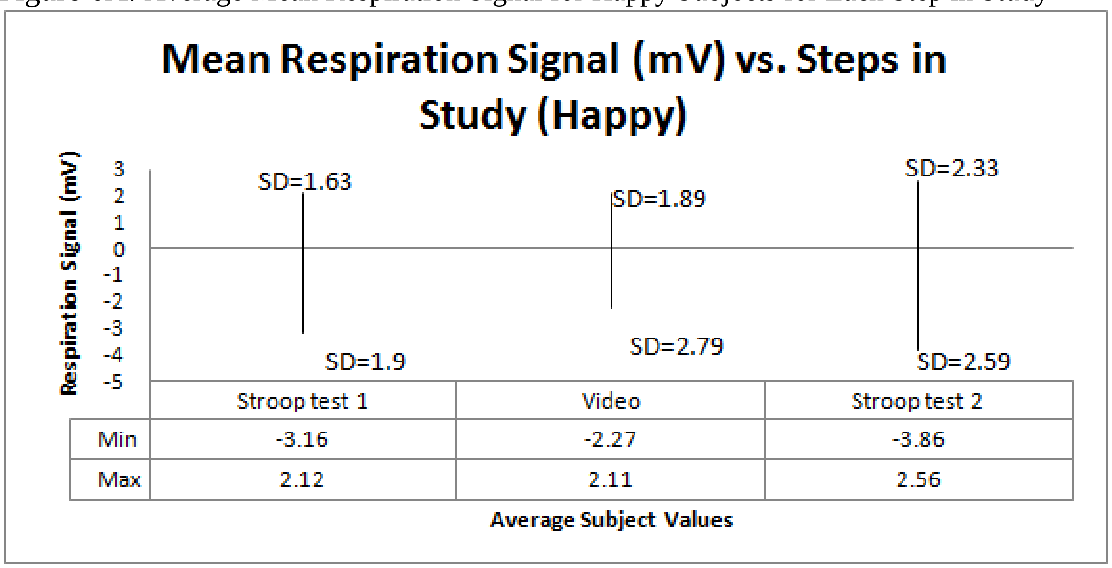
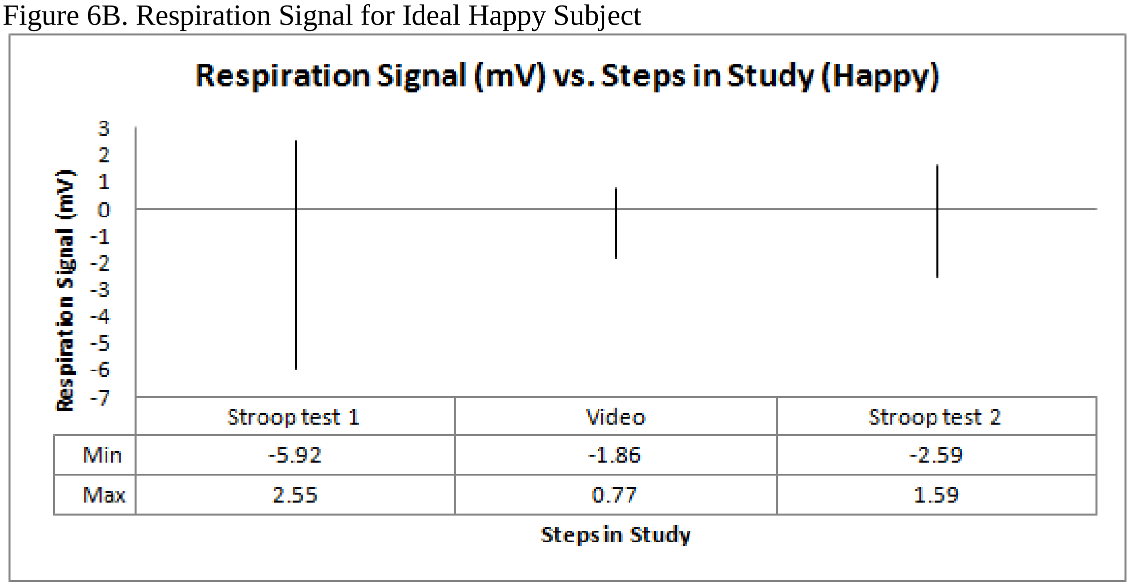


Figure 6B. Respiration Signal for Ideal Happy Subject



In Figure 6A, the mean respiration signal for all happy subjects during the first Stroop test was 6.03 mV (SD= 2.20 mV), during the video was 6.29 mV (SD= 4.30 mV), and during the second Stroop test was 6.75 mV (SD= 4.60 mV). In Figure 6B, the mean respiration signal for the ideal happy subject during the first Stroop test was 8.47 mV, during the video was 2.63 mV, and during the second Stroop test was 4.18 mV. For the specific individual results graph the lines depict the range of depth of breath. The smaller range during the video is indicative that the subject was in a relaxed state.

Figure 7A. Average Mean Electrodermal Activity (Sweat) for Fear Subjects for Each Step in Study

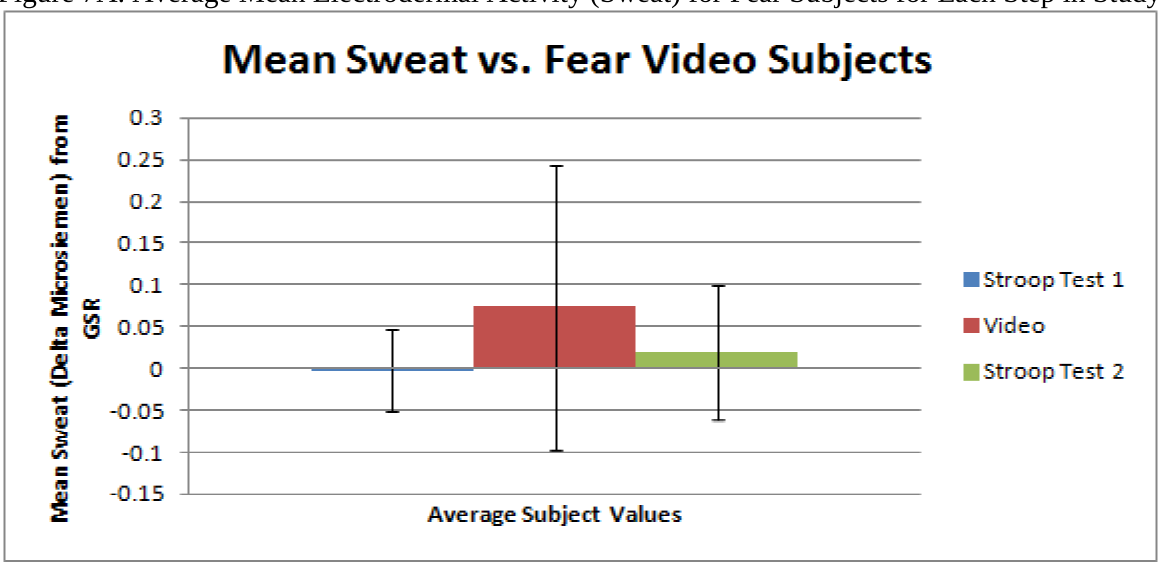
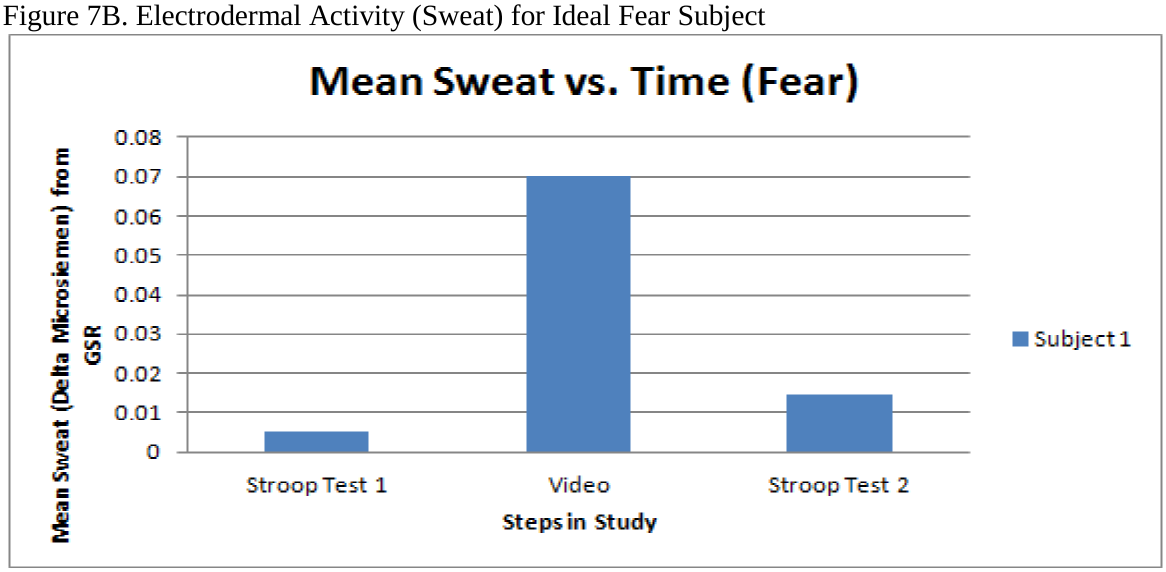


Figure 7B. Electrodermal Activity (Sweat) for Ideal Fear Subject



In Figure 7A, the mean electrodermal activity for all fear subjects during the first Stroop test was 0.002 µS (SD= 0.050 µS), during the video was 0.074 µS (SD= 0.160 µS), and during the second Stroop test was 0.019 µS (SD= 0.080 µS). In Figure 7B, the mean electrodermal activity for the ideal fear subject during the first Stroop test was 0.005 µS, during the video was 0.069 µS, and during the second Stroop test was 0.015 µS. Subject 1 shows the significant spike in amount of sweat produced while watching the fear-inducing video.

Figure 8A. Average Mean Electrodermal Activity (Sweat) for Happy Subjects for Each Step in Study

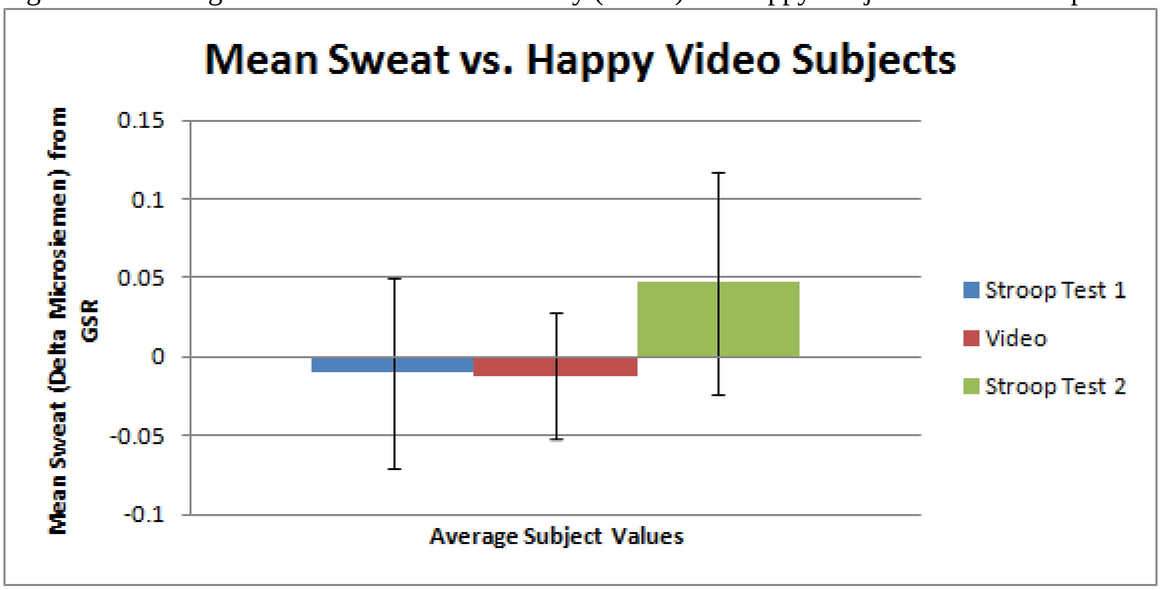
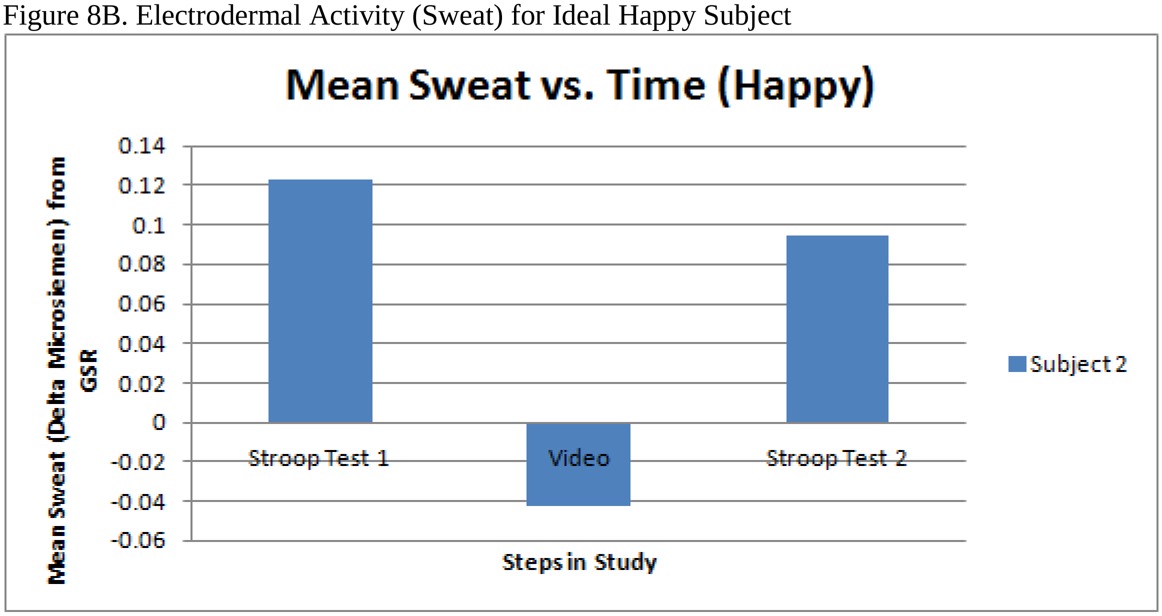


Figure 8B. Electrodermal Activity (Sweat) for Ideal Happy Subject



In Figure 8A, the mean electrodermal activity for all happy subjects during the first Stroop test was -0.010 µS (SD= 0.06 µS), during the video was -0.012 µS (SD= 0.040 µS), and during the second Stroop test was 0.047 µS (SD= 0.070 µS). In Figure 8B, the mean electrodermal activity for the ideal happy subject during the first Stroop test was 0.123 µS, during the video was -0.042 µS, and during the second Stroop test was 0.095 µS. The graph for Subject 2 indicates the change in electrodermal activity production as a result of watching the video. The negative value indicates that less electrodermal activity was produced while watching the video, which can be associated with a calm state.

The mean Likert scale result for happy was 4.033, and the mean result for fear was 2.833. The individual Likert scale reported values can be seen in Table 3 in the appendix.

Below are bar graphs depicting the change in reaction time for the Stroop tests before and after the fear and happy video, respectively. One graph showing the congruent and another showing the incongruent results for each emotion.

Figure 9A. Average Congruent Stroop Test Reaction Time for Fear

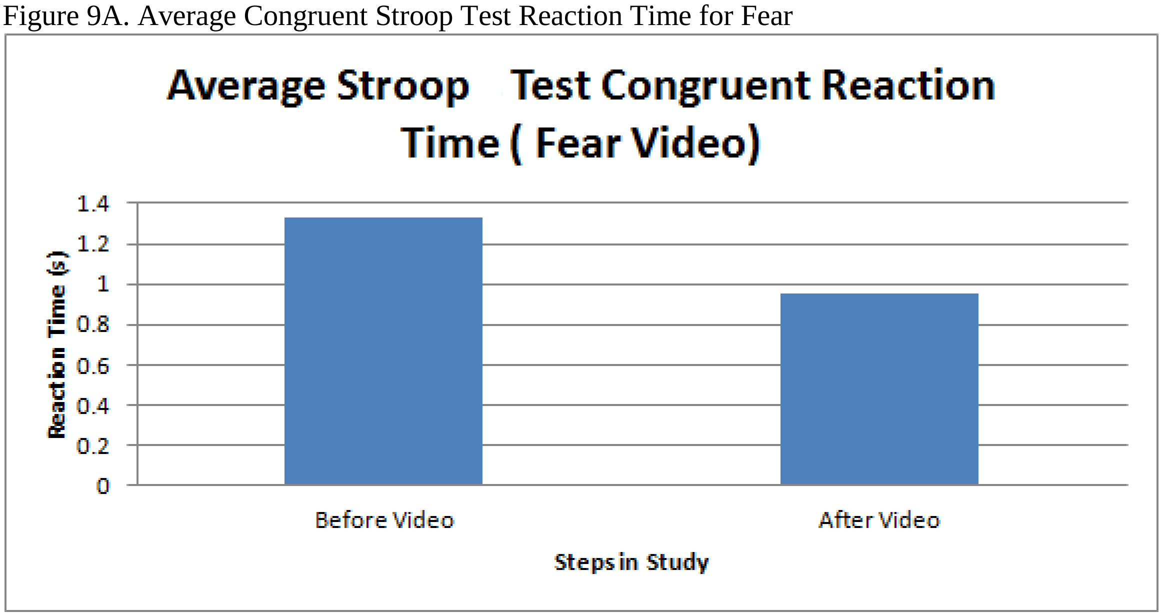
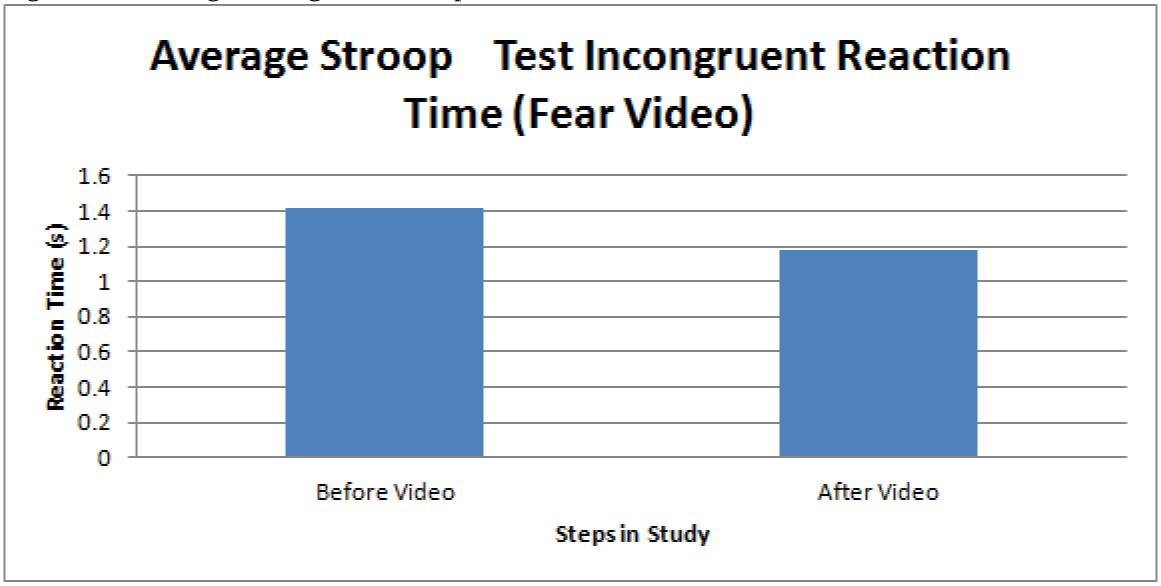


Figure 9B. Average Incongruent Stroop Test Reaction Time for Fear



In Figure 9A, the average congruent reaction time before the video was 1.33 seconds (SD= 0.42 s). The average congruent reaction time after the video was 0.95 seconds (SD= 0.15 s). This gave an average decrease in reaction time of 0.91 seconds. In Figure 9B, the average incongruent reaction time before the video was 1.41 seconds (SD= 0.33 s). The average incongruent reaction time after the video was 1.17 seconds (SD= 0.18 s). This gave an average decrease in reaction time of 0.24 seconds.

Figure 10A. Average Congruent Stroop Test Reaction Time for Happy

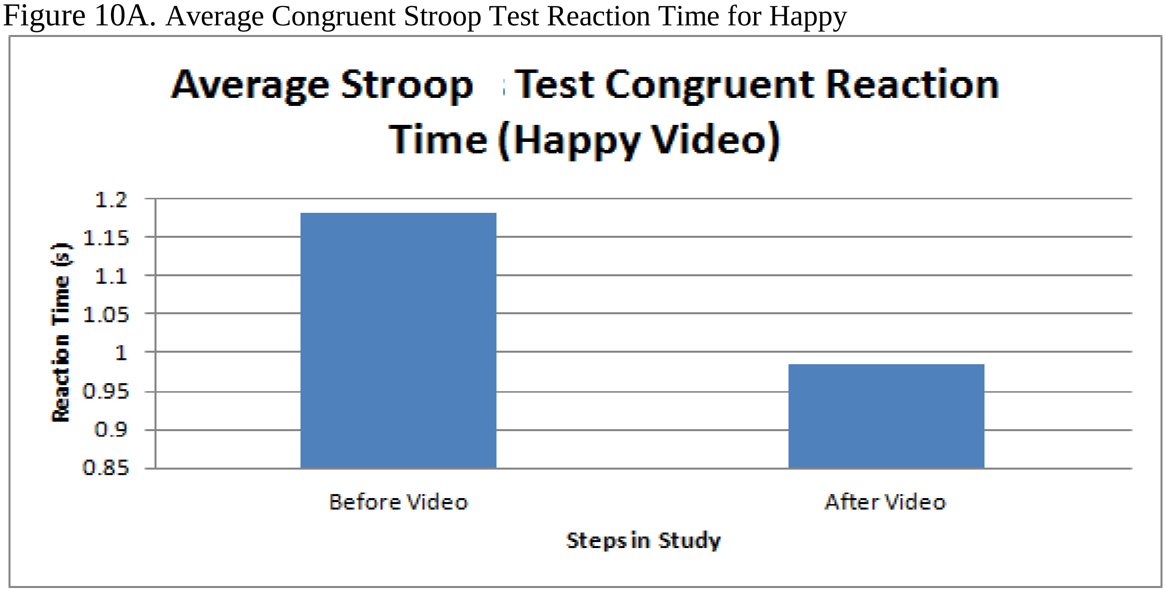
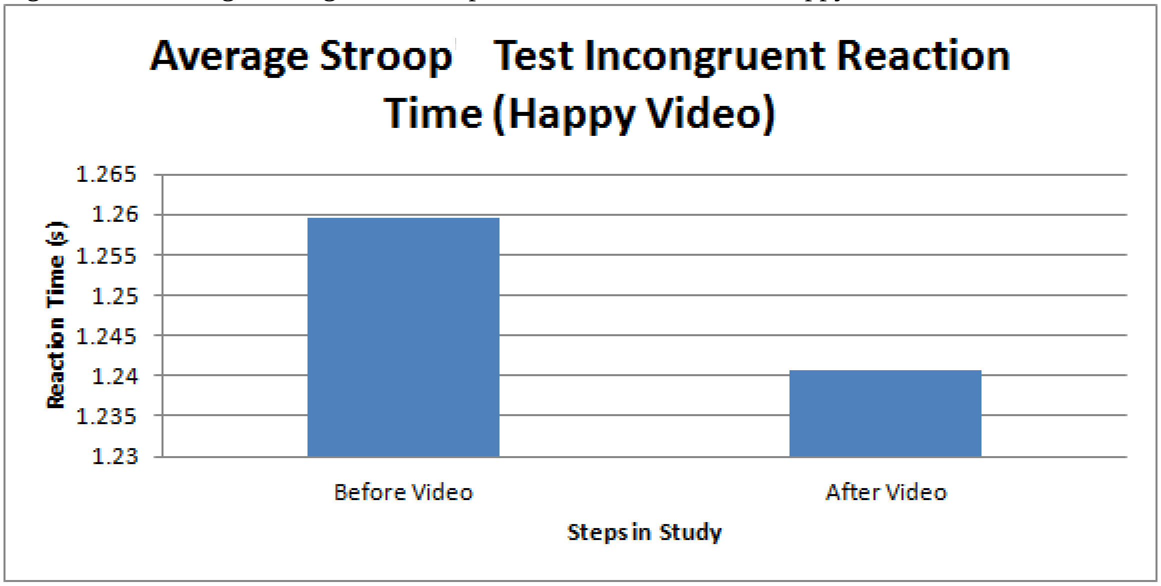


Figure 10B. Average Incongruent Stroop Test Reaction Time for Happy



In Figure 10A, the average congruent reaction time before the video was 1.18 seconds (SD= 0.32 s). The average congruent reaction time after the video was 0.99 seconds (SD= 0.15 s). This gave an average decrease in reaction time of 0.19 seconds. In Figure 10B, the average incongruent reaction time before the video was 1.26 seconds (SD= 0.20 s). The average incongruent reaction time after the video was 1.24 seconds (SD= 0.23 s). This gave an average decrease in reaction time of 0.02 seconds.

DISCUSSION

We obtained significant p-values for three of the four t tests of Stroop test scores. The only non-significant p-value was for the happy incongruent Stroop test scores. When comparing the happy and fear t-test p-values, fear had a more significant change in reaction times. This can also be seen in the percent changes calculated for the reaction times. Fear consistently led to faster reaction times in the Stroop test taken after watching the video. This supports our hypothesis that fear leads to faster reaction times. We originally thought that fear would cause an increase in cognitive flexibility, demonstrated by a faster reaction time. Our participants did in fact show an increase in reaction time and ergo cognitive flexibility but this does not necessarily mean an increase in accuracy also occurred. Thinking faster could lead to a higher error rate; future experiments can explore this relationship. This means that fear can help in certain situations, such as in fight-or-flight, but may not be advantageous in other situations, such as taking an exam.

On the other hand, happiness was only significant for the congruent Stroop test. In fact, happiness seemed to lower the reaction times to a degree, which does not support our hypothesis. The relaxed body state that accompanies a feeling of happiness could lead to a sense of clarity that would lead to faster reaction times. This opposes our original assumption that a relaxed state would lead to a generally slower reaction time. As a result of our findings, happiness should be further explored to better understand the influence the emotion has on the human body and mind.

The difference between significance can also be seen between congruent and incongruent Stroop tests, regardless of associated emotion. Both congruent Stroop tests were significant at a much lower p-value than their incongruent counterparts. In fact, the incongruent happy Stroop test was not even close to being significantly altered by the video. The lack of significant reaction time changes for the incongruent tests as opposed to the congruent tests can be attributed to the fact that the brain can process congruent name/color pairings easier than incongruent name/color pairings (Dalrymple-Alford 1966). Because the incongruent tests required more cognitive flexibility, this could explain why the incongruent reaction times showed markedly less change after watching the video as compared to the congruent reaction times.

As previously mentioned, the learning curve from repeating the Stroop test was minimized by using two slightly different Stroop tests. However, the learning curve was likely not fully negated. This could partially reflect the faster times seen in the second Stroop test, however it should not explain this significant of a change in reaction time.

When looking at the change in reaction time, our results show that fear is definitely a stronger influence on physiological changes as well as on cognitive flexibility. In congruent and incongruent fear tests, on average the reaction time decreased by -24.325% and -14.381%. In comparison, congruent and incongruent happy tests had an average reaction time decrease of -14.636% and -1.326%. This leads us to believe that fear leads to a stronger reaction in the subjects than happiness. If an individual truly is in a fearful situation it is a great advantage that the cognitive functions operate faster and allow a person to react more quickly. Further studies testing other parameters could be performed to support this claim. This is all related to the fight-or-flight response which is governed by the sympathetic nervous system (Jansen et al, 1995).

Our results also showed that there was a temporal effect of emotion. During the viewing of the video, a majority of the physiological measurements had a large change, either positive or negative from the baseline. In the measurements recorded after the viewing and during the second Stroop test the physiological measurements returned closer to baseline. This tells us that the emotions induced by the video were not lingering. This brings up an interesting observation of the immediate versus lasting effects of emotion and how our body responds to any emotional disruptions in our physiology. Additionally, even though a few of the participants had seen a similar video to the one we showed them for the happy category, they still claimed the video elicited a happy emotion from them and the physiological measurements confirmed this as well.

It is also important to comment on the generation of our participants. Since everyone we sampled was in the 18-23 year old age range, our data is not indicative of how older generation participants might respond to the videos. With the younger age group, it is possible that people can remain emotionally detached from the videos because this generation has grown up with the advent of video technology. Thus, older generation participants who are not so accustomed to videos may be subject to a greater emotional and physiological impact than younger individuals.

Our hypothesis for heart rate was supported by both the happy and fear groups. For happiness, the beats per minute (BPM) generally declined during the video. For fear, the BPM generally increased during the video. This supports our claim that different emotions cause different physiological effects on the heart. The heart rate data for all participants is shown in Tables 4 and 5 as well as Figure 3A and Figure 4A, while the graphs for the ideal subject data points are represented in Figure 3B and Figure 4B, correlating to the fear and happy groups. This makes sense because one would expect a happy video to have a calming effect on an individual, while a scary video would be expected to cause nervousness, anxiety, and excitement that would increase heart rate. Additionally, it is important to note that the heart rate increased for most individuals (for both happy and fear) after the video ended and during the second Stroop test. This can likely be attributed to the stress under taking a timed speed-related test, such as the Stroop test, makes an individual more alert and anxious, causing an elevated heart rate via autonomic nervous system (Taelman 1366).

Our hypothesis for the maximum and minimum depth of respiration was somewhat supported by both the happy and fear groups on an individual basis, although the overall data was not conclusive. It was expected that the happy video would cause one to have a shallower depth of breath, due to the calming effect of the video, while it was expected for the scary video to cause a deeper maximum breath due to fear. While the overall data as shown in Tables 4 and 5 as well as Figure 5A and Figure 6A did not show a convincing trend, the ideal subject results for the fear and happy groups in Figure 5B and Figure 6B are indicative of the ideal results we hypothesized. As shown for the happy participant in Figure 6B, the depth of breath is at a minimum during the video and this can likely be attributed to the calming effect the video elicits. On the other hand, the fear participant in Figure 5B shows an increased depth of breath during the video which can likely be attributed to anxious and nervous feelings the participant experienced.

Our hypothesis for electrodermal activity (EDA) was supported by both the happy and fear groups, however not as conclusively as the heart rate data. For happiness, the electrodermal activity levels generally declined during the video. For fear, the electrodermal activity levels generally increased during the video. This makes sense because one would expect a scary video to cause an individual to sweat more due to nervousness and excitement than a happy video which elicits a more calming effect. Similar to heart rate, sweat levels tended to increase after the video and during the second Stroop test, which can likely be attributed to the alertness and anxiousness experienced by an individual taking a test (Renaud et al, 1997). The EDA data for all participants is shown in Tables 4 and 5 as well as Figure 7A and Figure 8A, while the graphs for the ideal subject data points are represented in Figure 7B and Figure 8B, correlating to the fear and happy groups.

CONCLUSION

Overall through induction of emotions and measurement of cognitive abilities, the experiment supported our hypothesis that physiological changes had an effect on reaction time and therefore cognitive flexibility. Our fear subjects demonstrated physiological changes and reaction time improvements that supported our hypothesis. The results for happiness were more inconclusive. While the physiological changes were consistent with our predictions, the reaction times improved which did not support our hypothesis. A wide range of behaviors are affected by emotions, so future research can be done on emotions to see the implications that they have both physically and mentally since behavior is certainly related to emotion. This could possibly be a useful tool for psychologists dealing with the after effects of intense emotion such as Post-Traumatic Stress Disorder or forms of depression. If one can have a more thorough understanding of the physical side effects of emotions, the cognitive side effects can also be dealt with in a more knowledgeable manner. This is just one way that various sciences can overlap and assist one another in understanding the human condition.

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APPENDIX

Figure 1. Flowchart demonstrating our methodology.

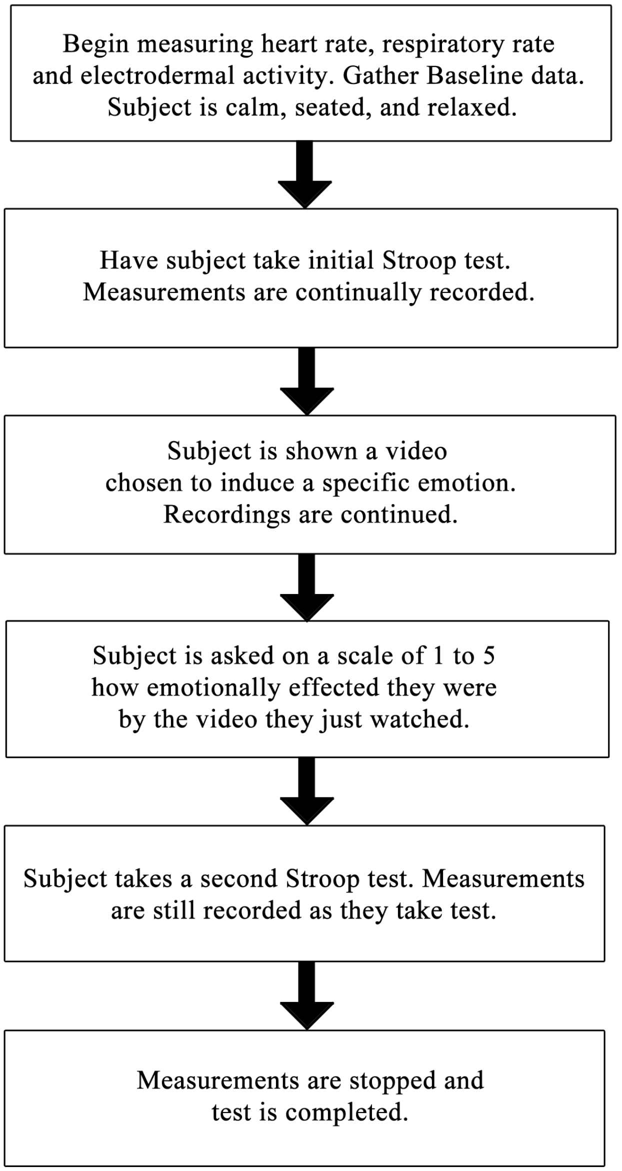

Table 1. Stroop Test Reaction Times and Percent Change Between Before and After Tests for Happy-Induced Subjects

Subject	Before Incongruent Baseline (s)	After Incongruent (s)	% Change Incongruent	Before Congruent Baseline (s)	After Congruent (s)	% Change Congruent
1	1.03	1.282	24.466	1.258	1.067	-15.183
2	1.272	1.268	-0.314	1.115	0.9266	-16.897
3	1.189	1.186	-0.252	1.106	0.946	-14.467
4	1.144	1.014	-11.363	0.9546	0.7177	-24.817
5	1.282	1.063	-17.082	1.317	0.9486	-27.973
6	1.261	1.317	4.440	1.145	1.151	0.524
7	1.18	1.057	-10.423	1.22	1.007	-17.459
8	1.216	1.249	2.714	1.003	0.987	-1.595
9	0.927	0.942	1.618	0.843	0.713	-15.421
10	1.457	1.272	-12.697	1.13	1.101	-2.566
11	1.249	1.055	-15.532	1.07	0.997	-6.822
12	1.496	1.456	-2.674	1.154	0.9303	-19.384
13	1.693	1.759	3.898	2.22	1.267	-42.928
14	1.451	1.647	13.508	1.26	1.166	-7.460
15	1.046	1.044	-0.191	0.9169	0.8519	-7.089
Mean	1.259	1.241		1.107	0.985	
SD	0.199	0.235		0.317	0.154	
# of (+)			6			1
# of (-)			9			14
Mean (+)			8.441			0.524
Mean (-)			-7.837			-15.719
Average of (+) and (-)			-1.326			-14.636

Table 2. Stroop Test Reaction Times and Percent Change Between Before and After for Fear-Induced Subjects

Subject	Before Incongruent Baseline (s)	After Incongruent (s)	% Change Incongruent	Before Congruent Baseline (s)	After Congruent (s)	% Change Congruent
16	1.226	1.221	-0.408	1.039	0.901	-13.282
17	1.31	1.158	-11.603	1.16	0.8765	-24.440
18	1.88	1.351	-28.138	1.292	1.127	-12.771
19	1.838	1.009	-45.103	1.241	0.8425	-32.111
20	1.05	0.946	-9.905	1.047	0.816	-22.063
21	1.749	1.563	-10.635	1.745	1.138	-34.785
22	1.156	1.174	1.557	0.8485	0.8644	1.874
23	1.598	1.188	-25.657	1.273	1.279	0.471
24	1.13	1.107	-2.035	1.1	0.98	-10.909
25	1.9367	1.338	-30.913	2.3306	1.084	-53.488
26	1.479	1.355	-8.384	2.011	0.9425	-53.132
27	1.536	1.146	-25.390	1.614	0.8696	-46.121
28	0.9586	0.9349	-2.472	0.899	0.7418	-17.486
29	0.9746	0.9516	-2.360	0.9757	0.8025	-17.751
30	1.374	1.178	-14.265	1.341	0.9537	-28.881
Mean	1.416	1.174		1.327	0.947	
SD	0.334	0.176		0.424	0.149	
# of (+)			1			2
# of (-)			14			13
Mean (+)			1.557			1.173
Mean (-)			-15.616			-28.248
Average of (+) and (-)			-14.381			-24.325

Table 3. Likert Scale Reported Values

Subject	Happy	Subject	Fear
1	3	16	3.5
2	5	17	1.5
3	4	18	3.5
4	1	19	2
5	4	20	3
6	4.5	21	3
7	5	22	3
8	4	23	3
9	4	24	2
10	5	25	2.5
11	4	26	1
12	5	27	4.5
13	4	28	4
14	5	29	4
15	3	30	2
Mean Response	4.033	**Mean Response**	2.833

Subjects were asked “On a scale of 1-5 how happy/fearful did the video make you feel?”

Table 4. Physiological Data of Happy-Induced Subjects.

Subject	Mean BPM Before	Mean BPM During	Mean BPM After	Resp. Delta Before	Resp. Delta During	Resp. Delta After	Mean EDA Before	Mean EDA During	Mean EDA After
1	65.2	56.29	64.363	9.2	5.91	15.859	-0.0082	-0.00494	0.0224
2	79.77	76.03	89.2	10.12	11.78	12.47	0.12321	-0.04239	0.09461
3	102.2	95.822	103.475	7.425	8.643	6.9801	-0.074	-0.0032	0.24741
4	90.599	76.193	92.67	7.719	9.0124	10.06	-0.05886	-0.0214	0.0095
5	93.043	80.415	91.905	2.87	1.78	6.304	-0.00612	0.004561	0.0633
6	91.341	73.344	94.027	8.042	4.948	8.6209	0.0226	-0.0273	0.0783
7	89.67	82.63	91.29	7.34	3.55	4.04	-0.0091	0.0109	0.02701
8	78.347	67.65	80.57	7.4985	13.86	10.84	-0.06776	-0.03042	0.04186
9	116.27	87.39	102	5.1	3.52	3.81	-0.13519	-0.01391	-0.00339
10	62.89	60.36	66.11	0.61	1.45	0.62	-0.00715	-0.05103	0.01427
11	82.83	75.38	85.74	8.47	2.63	4.18	0.02126	-0.03617	-0.01262
12	84.08	101.95	83.95	2.46	12.59	2.84	0.02622	0.12954	-0.02112
13	65.9	63.06	77.03	4.36	5.43	3.54	0.01026	-0.03449	0.03395
14	74.97	63.18	81.57	0.37	0.16	0.15	-0.01512	-0.05	0.09519
15	89.36	85.29	100.64	8.9	9.05	10.89	0.02654	-0.01227	0.01173
Mean	84.431	76.332	86.969	6.032	6.288	6.747			
SD	14.316	13.055	11.775	3.179	4.312	4.579			
# of (+)							6	3	12
# of (-)							9	12	3
Mean (+)							0.0383	0.0483	0.0616
Mean (-)							-0.0424	-0.0273	-0.0124

Table 5. Physiological Data of Fear-Induced Subjects.

Subject	**Mean BPM Before**	**Mean BPM During**	**Mean BPM After**	**Resp. Delta Before**	**Resp. Delta During**	**Resp. Delta After**	**Mean EDA Before**	**Mean EDA During**	**Mean EDA After**
16	67.8	70.55	51.93	4.56	2.2	4.76	0.00535	0.06991	0.01453
17	74.808	67.71	79.361	7.76	10.8	13.074	0.0141	0.00454	-0.0243
18	69.251	72.525	63.393	2.313	0.615	2.352	0.0192	0.0135	0.00186
19	95.923	86.964	103.596	14.18	5.421	9.986	-0.0299	0.0223	0.0694
20	80.624	80.806	82.068	3.364	4.77	5.803	0.01152	0.0979	0.0677
21	58.189	72.207	63.698	1.5945	-0.3501	2.494	-0.0328	0.1225	-0.0402
22	59.907	58.722	60.414	2.653	1.785	2.738	-0.00968	0.02498	-0.0095
23	86.38	75.2	84.44	1.15	0.56	0.92	0.07085	0.08577	0.0242
24	76.542	84.188	78.502	0.647	1.3801	1.4673	-0.10984	0.61124	-0.0878
25	82.66	69.72	89.09	1.34	3.74	11	0.09667	0.02652	0.0605
26	80.48	78.8	80.22	6.31	0.88	4.75	-0.03228	-0.02724	0.04557
27	87.99	90.15	88.7	10.6	15.93	11.24	-0.00982	-0.01983	-0.04094
28	93.11	114.94	90.96	11.36	15.6	12.12	-0.09058	0.10029	-0.07406
29	62.23	48.98	70.44	2.57	1.56	4.4	0.02081	0.02374	0.05358
30	66.28	60.42	64.85	8.81	0.76	9.11	0.04818	-0.04741	0.22574
Mean	76.145	75.459	76.777	5.281	4.377	6.414			
SD	11.957	15.507	13.990	4.301	5.392	4.236			
# of (+)							8	12	9
# of (-)							7	3	6
Mean (+)							0.0358	0.1003	0.0626
Mean (-)							-0.0449	-0.0315	-0.0461