Analysis of autonomic response to stressful and calming visual and auditory stimuli

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Date of Submission: May 8, 2015
Word Count: 4488

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Key Words: anxiety, audio, auditory, blood pressure, environment, fear, heart rate, meditation, relaxation, senses, sight, skin conductance, sound, stress, trigger, visual

Abstract:

Stress is a recognizable physical sensation that results from a stimulus associated with anxiety or fear in which the body has regulatory mechanisms for control in order to alter the stimulation of sympathetic innervation and therefore alter the body's behavior during a stress-inducing incident. The human body's method of monitoring acute stress is through the hypothalamic-pituitary adrenal axis (HPA-axis), which assists in regulation of the autonomic responses that result from acute stress including, but not limited to, immediate changes in blood pressure (BP), heart rate (HR), and skin conductance response (SCR). The purpose of this study was to determine how stressful and calming auditory and visual stimuli affect the body's acute autonomic response. It was hypothesized that calming stimuli would result in decreased BP, HR, and SCR, while stressful stimuli would result in an increase in these variable measurements. It was also hypothesized that visual exposure to stimuli would result in a larger autonomic response than auditory exposure for both calming and stressful stimuli. After analyzing HR, BP, and SCR in 11 subjects exposed to calming visual and auditory stimuli and 9 additional subjects exposed to stressful visual and auditory stimuli, it was determined that some, but not all, measures of autonomic response resulted in a statistically significant difference in baseline measurements and measurements gathered during exposure to stimuli. Measures of systolic blood pressure (sBP) and diastolic blood pressure (dBP) were found to have a significant change in calming visual stimuli and calming auditory stimuli respectively. SCR was found to have a significant change in baseline and autonomic response to stimuli in both calming auditory and visual stimuli. In addition, it was determined that some, but not all, measures of autonomic response resulted in a significant statistical difference in visual and auditory exposure to stimuli. A significant change in dBP and SCR appeared to demonstrate a more prominent autonomic response to visually presented stimuli and further investigation would determine if this observed trend could be established and reproduced.

Introduction:

Many aspects of daily life, including academics, relationships, general planning, or even a recreational horror film, result in unpleasant feelings of anxiety or fear that produce what is commonly known as stress. Moderating stress is a familiar challenge to many, and the human body can become fatigued or ailed in response to stress, especially over time. The HPA-axis assists in the regulation of stress (Vale, 2006). In response to a physical or environmental trigger of stress, the hypothalamus produces corticotropin-releasing hormone (CRH), which binds to CRH receptors in the anterior pituitary (AP) and promotes the release of adrenocorticotropic hormone (ACTH). ACTH targets the adrenal cortex of the adrenal gland in order to stimulate the synthesis of cortisol (Vale, 2006). Cortisol levels increase in response to physical or environmental triggers of stress and are regulated via a negative feedback loop to the hypothalamus and pituitary where both CRH and ACTH production are inhibited, resulting in a decrease in cortisol and therefore a decreased physical sensation of stress (Vale, 2006).

Stress has been shown to have a vast negative impact on health and is a prominent concern in the United States, as it routinely affects close to 50 percent of adults (Stress Management Health Center, 2014). According to the American Heart Association, acute health effects of stress include body-ache, stomachache, tight muscles, and clenched jaw (*American Heart Association*, 2014). Prolonged heightened levels of cortisol due to stress can lead to a wide range of more severe health concerns. Chronic stress is associated with an increased risk of heart disease, HBP, diabetes, depression, anxiety, decreased immune function, weight gain, memory impairment, sleep problems, and dysfunctions of excretory, digestive, and reproductive systems (*National Institute of Mental Health*, 2014; Mayo Clinic Staff, 2014). It has been determined that emotional disorders are prevalent in over 50 percent of the population in response to untreated chronic stress, and between 75 and 90 percent of doctor appointments are stress-related (Stress Management Health Center, 2014). Due to the significance of stress-related health ailments, it is important to study what triggers, both positive and negative, have the greatest impact on the autonomic response to stress.

In related studies of physiological stress, subjects were shown pleasant (physiologically similar to calming), unpleasant (physiologically similar to stressful), and neutral images. One study determined that unpleasant images evoke a stronger physiological response than pleasant or neutral images, which could be due to negativity bias (Ito et. al., 1998). In another study, HR declined in every treatment while SCR increased significantly with exposure to unpleasant pre-target images regardless of whether the target image was unpleasant or pleasant (Fujimura et. al., 2013). Results of a third related study also determined that HR decreased and SCR increased with exposure to unpleasant images a well as pleasant images, while neutral images did not illustrate a significant change in either physiological variable (Bianchin et. al., 2011).

Additionally, a study by Croy et. al. suggests that visual stimuli may induce a stronger autonomic response than auditory, olfactory, or tactile stimuli. 'Disgust' was evoked using four sensory stimuli; three stimuli were different and one additional stimulus was used as a control. Each stimulus was presented using visual, auditory, tactile, and olfactory channels and physiological changes such as HR, SCR, and sBP were measured. Results showed that visually disgusting stimuli were significantly more effective at producing an autonomic response than olfactory and tactile stimuli. However, minimal evidence of autonomic response was observed for auditory disgust. Researchers determined that the sensory channel in which disgust is evoked is significant and that a generally similar emotive response occurs in all sensory channels with exception to audition, but autonomic responses vary in strength and rate of decay, with visual disgust eliciting the greatest response (Croy et. al., 2013).

Physiological stress can be detected and monitored in many different ways. One determination of physiological stress is that of heart rate (HR) (*American Heart Association*, 2014). HR can function as an indication of cardiovascular activity level or amount of oxygen intake and is measured in beats per minute (BPM) (*American Heart Association*, 2014). A normal range of resting HR is considered to be between 60 and 100 BPM, with the age-predicted maximum HR being equal to 220 BPM–age. This means that the average maximum HR is dependent on age and generally decreases with increased age (*American Heart Association*, 2014). A chronically elevated resting HR over a prolonged period of time is indicative of overexertion and could result in permanent damage to the heart and lungs (*American Heart Association*, 2014). Further research on the physiological effects of acute stress could benefit the understanding of chronic stress and its perceived risks.

A second measurement of interest is blood pressure (BP) measured in millimeters of Mercury (mmHg). In males, a BP of 120/80 is considered normal (110/70 for females), and a value of 140/90 is used as a threshold for diagnosis of high BP (HBP), or hypertension. Hypertension results in an increased risk of vascular weakness, vascular scarring, blood clots, and arterial build-up of plaque. Systolic blood pressure (sBP) is usually slightly more important for monitoring, as it is indicative of a significantly increased risk of cardiovascular disease (*American Heart Association*, 2014). Over time, untreated HBP is known to increase risk of both life-altering dysfunctions and life-threatening illnesses (*American Heart Association*, 2014).

Sympathetic skin conductance response (SCR) measured in microSiemens is another measurement that can be used to evaluate physiological stress response. SCR is also known as electrodermal activity (EDA) or Galvanic Skin Response (GSR) and is a measure of arousal in the peripheral autonomic nervous system (ANS) (*MIT Media Lab*, 2014). It is established due to the "fight or flight" response used to prepare for management of a perceived threat (*Psych Lab*, 2014). In response to physiological arousal, due to emotional response to stimuli, the skin temporarily acts as an improved conductor of electricity (*MIT Media Lab*, 2014), allowing for SCR to be measured quantitatively. The conductance between the two electrodes is quantified for comparison purposes (*MIT Media Lab*, 2014).

Analysis of SCR output, as well as BP and HR output, can contribute to the understanding of stress and the body's autonomic response that occurs as a reaction to an external stimulus. This knowledge will assist in determination of physiological trauma that occurs from prolonged stress and could lead to additional treatment options and prevention methods that can be incorporated into high-stress environment communities that currently lack mechanisms of improving stress-related conditions and their long-term adversary effects on overall health.

In order to benefit from understanding the immediate effects of stress on physiological function, it is imperative to clarify certain types of stimuli for comparison (stressful and calming) and methods of exposure of such stimuli (visual and auditory) that may increase or decrease the measured variables of autonomic response (BP, HR, and SCR) as an indication of stress level. Understanding the physiological changes that result from acute stress will help to develop improved strategies for coping with external stressful stimuli in everyday life and traumatic environments. The videos and tracks provide clips and sounds from possible day to day interactions that have the potential to evoke an acute stress response or calming response and could lead to increased or decreased chronic stress with prolonged exposure to such stimuli.

This research was conducted by inducing a physiological response in a participant via visual or auditory exposure to stimuli. The stimuli were differentiated as "calming" and "stressful" and the autonomic response of the subject was measured in terms of HR, BP, and SCR. By stimulating different sensory pathways, the differences in autonomic response due to different sensory exposure to stimuli can be observed. A determination of whether auditory or visual exposure to stimuli has a greater impact on autonomic response can be concluded from this study. In addition, the mean change in the autonomic variable measurements can be determined as either increased or decreased as a result of the visual and auditory exposure of stressful and calming stimuli.

It was hypothesized that auditory and visual calming stimuli would cause significant decreases in mean HR, BP, and SCR due to decreased sympathetic autonomic response. In contrast, auditory and visual stressful stimuli were hypothesized to result in significant increases in mean HR, BP, and SCR as a result of sympathetic stimulation. Additionally, it was hypothesized that visual stimuli would evoke a larger change in physiological response than auditory stimuli due to the previous determinations of Croy et. al.

Methods and Materials:

The population of this study consisted of a total of 20 male and female students ages 19 to 23 recruited from the University of Wisconsin-Madison Physiology 435 course enrollment. All subjects that participated signed a consent form. Subjects were randomly distributed into either Group 1 or Group 2. Group 1 consisted of 5 males and 4 females that heard stressful audio clips and viewed stressful visual clips. Group 2 consisted of 4 additional males and 7 additional females that heard calming audio clips and viewed calming visual clips. A summary of the demographic distribution can be seen in Table 1 below. Physiological changes of BP, SCR, and HR were recorded for each subject.

Calming audio clips contained sounds of ocean waves crashing on the beach, a crackling campfire, rain, and waterfalls. Stressful audio clips contained sirens, gunfire, growling bears, bees buzzing, hissing snakes, explosives, and radio static. The calming video contained images of ocean waves, beaches, campfires on the beach, scenic views, sunsets, and floating candles. The stressful video contained images of ambulances, gunshots, a blank static screen, bears, snakes, spiders, and a beehive. These objects were predetermined to be calming or stressful based on popular consensus.

The 10+ series automatic BP monitor, model BP791IT from Omron Healthcare, Inc. was cuffed to the left arm of the seated participant. Next, the BSL EDA Finger Electrode Xdcr, model SS3LA obtained from BIOPAC Systems, Inc. was plugged into channel 2 of the BIOPAC system. Gel 101 of the Isotonic Recording Electrode Gel, from BIOPAC Systems, Inc. was applied to the finger strap electrodes, which were then wrapped around the right index and middle fingers. Finally, the BSL Pulse Plethysmograph, model SS4LA from BIOPAC Systems Inc. was plugged into channel 1 of the BIOPAC system. It was then strapped to the left index finger of the subject.

Once all of the apparatuses were set up, a baseline value was determined and recorded for each of the three vital sign measurements. Baseline was defined as a measurement that remained relatively constant for two minutes while the subject was seated and neutrally resting. After baseline was established, the subject was blindfolded and the five-minute audio clip for the group that the subject was assigned was played. SCR and HR were continuously recorded throughout the duration of the clip. BP was recorded a total of three times, starting at the beginning of the clip and offering a reading at thirty-seconds, and subsequently at each two-minute interval following for the duration of the clip. After the clip was complete, all of the equipment was removed from the subject. The subject was then asked to stand up, walk around the room, and sit back down. All of the equipment was then reattached and the same procedure as above was repeated for the video clip.

Baseline was re-established. The participant was asked to wear noise-canceling headphones for the duration of the video. The five-minute video clip for the group that the subject was assigned was played. SCR and HR were continuously recorded throughout the duration of the clip. BP was recorded initially and at two-minute intervals until the termination of the clip as described above.

Finally, all of the equipment was disconnected from the subject and a post-experimental survey was completed. The post-experimental survey included relevant questions about the content pertaining to the calming or stressful stimuli. The subject was asked to evaluate each object or event from the video and audio clips on a scale of 1 (very happy) to 6 (very unhappy). This survey offered valuable information of the preferences and fears of each individual subject to confirm commonality of likes and dislikes between subjects and provide potential reason for outlying data. Upon completion of the survey, the subject was debriefed, and the equipment was cleaned and prepared for the next participant. The order of events each subject experienced is illustrated in timeline format in Figure 1.

The data was compiled and analyzed using R Statistical Software to conduct a series of paired t-tests in order to determine significance of comparisons. For each variable, sBP, dBP, HR, and SCR, tests of statistical significance comparing baseline to stimuli measurements for calming and stressful auditory and visual stimuli, as well as tests of statistical significance comparing auditory exposure to stimuli and visual exposure to stimuli for both calming and stressful stimuli independently were completed. This evaluation determined if a difference exists between mean baseline and mean stimuli measurements for each variable and if a difference exists between the mean change in visual and auditory exposure to stimuli for both calming and stressful stimuli. Analysis consisted of calculation of a t-value, determination of the degrees of freedom, and conclusion of a p-value. A p-value of less than 0.05 is considered statistically significant. This was determined for all combinations of measured variables and stimuli.

Using R Statistical Software, a confidence interval of 95 percent was established for each of the variables measured (SBP, DBP, HR, SCR). For each variable, significance was determined for a difference in mean baseline measurements and mean stimuli measurements for calming and stressful auditory and visual stimuli, as well as significance for a difference in mean change of the variable in auditory exposure and mean change of the variable in visual exposure to stimuli for both calming and stressful stimuli. A statistically significant difference in mean baseline and mean stimuli measurements as well as in mean change for each variable between auditory and visual exposure to stimuli was determined based on the spread of the confidence interval. A confidence interval that includes zero is considered insignificant, while a confidence interval that excludes zero is considered significant. The numeric sign of the confidence interval determines the favored result of the data. Specifically, a negative confidence interval spread concludes that the data presents a greater and significant change in data consisting of visual stimuli, while a positive confidence interval determines that the data illustrates a greater and significant change in data consisting of auditory stimuli.

For the comparisons in which significant p-values and confidence intervals were calculated, the difference in the mean baseline and mean stimuli measurements was observed in order to determine whether it indicated an increase or decrease in the variable measured due to the exposure to the stimuli. The difference in the change in means between auditory and visual stimuli was also observed in order to determine whether it illustrated that auditory or visual exposure to stimuli was more effective in inducing an autonomic response.

Results:

The mean values and corresponding standard deviations for all of the physiological measurements for each of the stimuli treatment groups and can be found in Table 2. The results from the paired t-tests of the sBP, dBP, HR, and SCR comparisons between baseline and stimuli measurements for each mode of stimulus treatment, as well as comparisons between calming audio and visual stimuli and stressful audio and visual stimuli were collected. In comparisons of baseline and stimuli measurements, there was no significant difference between the baseline measurements and the measurements collected during treatment with stimuli for the comparisons of calming auditory sBP, calming auditory HR, calming visual dBP, calming visual HR, or any of the stressful visual or auditory stimuli comparisons (neither sBP, dBP, HR, nor SCR). A significant difference was determined between the baseline measurements and stimuli measurements for calming auditory dBP ($p=0.009371$) and SCR ($p=0.0001187$), as well as calming visual sBP ($p=0.0195$) and SCR ($p=0.03351$). An organized summary of the p-values that were calculated to determine the significance for each comparison of baseline and stimuli measurements can be found in Table 3 of the appendix. Boxplots displaying each of the comparisons determined to indicate a significant difference between baseline and stimuli measurements can be found in Figures 2-5 of the appendix.

For the comparisons between auditory and visual stimuli, the p-values for SBP showed no significant difference between auditory and visual for calming or stressful stimuli. For dBP the p-values showed that there was a significant difference between auditory and visual for both calming ($p=0.01231$) and stressful stimuli ($p=0.03304$). For HR p-values showed no significant difference between auditory and visual for calming or stressful stimuli. However, the p-value for SCR showed there was a significant difference between stressful audio and visual stimuli ($p=0.01912$). The p-value of SCR for the difference between calming audio and visual showed that it was not significant, however it was approaching significance ($p=0.05117$). An organized summary of the p-values that were calculated to determine the significance for each comparison of auditory and visual exposure to stimuli can be found in Table 4 of the appendix. Boxplots depicting each of the comparisons determined to indicate a significant difference between auditory and visual exposure to stimuli can be found in Figures 6-9 of the appendix.

The 95 percent confidence intervals for each variable comparing baseline and stimuli measurements, as well as visual and auditory stimuli, were calculated and analyzed for significance. In the comparison between baseline and stimuli measurements, it was determined that the 95 percent confidence intervals showed no significant difference between the baseline measurements and the measurements collected during treatment with stimuli for the comparisons of calming auditory sBP, calming auditory HR, calming visual dBP, calming visual HR, or any of the stressful visual or auditory stimuli comparisons (neither sBP, dBP, HR, nor SCR). A significant difference was determined between the baseline measurements and stimuli measurements for calming auditory dBP (1.434170, 7.959769) and SCR (0.6381421, 1.3763663), as well as calming visual sBP (0.5882632, 5.3511307) and SCR (0.04695535, 0.93838492). A summary of the 95 percent confidence intervals determined for each comparison of baseline and stimuli measurements is displayed in Table 5.

For the comparisons between auditory and visual stimuli, it was determined that the 95 percent confidence intervals for SBP change and HR change for both calming and stressful stimuli showed no significant difference between auditory and visual exposure methods. The 95 percent confidence interval for DBP change showed significance and determined that visual exposure to stimuli was more effective in inducing an autonomic response than auditory exposure for both calming (-10.282626, -1.596162) and stressful (-5.2685469, -0.2870086) stimuli. The 95 percent confidence interval for SCR change determined a significant difference between auditory and visual exposure of stressful stimuli (-1.629277, -0.193051) in favor of visual exposure, while there was no significant difference between auditory and visual exposure of calming stimuli (-1.032350350, 0.003182245), although the results suggest that the data is approaching significance with a slightly larger evoked response in visual stimuli in comparison to auditory exposure to stimuli. A summary of the 95 percent confidence intervals determined for each comparison of auditory and visual exposure to stimuli is displayed in Table 6.

For each instance of a significant p-value and confidence interval, the difference in the mean baseline and mean stimuli measurement was quantified to determine whether the measured variable increased or decreased with the exposure of the stimulus. For calming auditory stimuli, the mean baseline dBP was 78.4 mmHg and the mean stimulus dBP was 73.7 mmHg, resulting in a difference of +4.7 mmHg or a 4.7 mmHg decrease in dBP due to calming auditory stimuli. Additionally, the mean baseline SCR was 4.5 microSiemens and the mean stimulus SCR was 3.6 microSiemens, resulting in a difference of +0.9 microSiemens or a 0.9 microSiemen decrease in SCR due to calming auditory stimuli. For calming visual stimuli, the mean baseline sBP was 114.4 mmHg and the mean stimulus sBP was 111.4 mmHg, resulting in a difference of +3.0 mmHg or a 3.0 mmHg decrease in sBP due to calming visual stimuli. Additionally, the mean baseline SCR was 4.5 microSiemens and the mean stimulus SCR was 4.1 microSiemens, resulting in a difference of +0.4 microSiemens or a 0.4 microSiemen decrease in SCR due to calming visual stimuli.

Discussion:

For this experiment it was hypothesized that both the calming visual and auditory stimuli would cause significant decreases in mean HR, BP, and SCR whereas stressful visual and auditory stimuli would cause significant increase. Additionally, it was hypothesized visual stimuli would evoke a larger response overall than that of auditory stimuli. The data showed that there were significant differences due to both visual and audio calming stimuli, but none due to stressful stimuli. The calming auditory stimulus caused a decrease from baseline in dBP and SCR, and the calming visual stimulus caused a decrease from baseline in sBP and SCR. This finding contradicts what was found in a previous study by Fujimura et al. where the unpleasant (physiologically similar to stressful) images induced a larger response than pleasant (physiologically similar to calming) images.

For each instance of a significant p-value and confidence interval, the quantified difference in the mean baseline and mean stimuli measurement determined the effect that the exposure of the stimulus had on the physiological measurements collected. It was determined that difference between the mean baseline physiological measurements and the mean stimulus measurements were significant for calming stimuli. In addition, it was determined that occurrences of significance were equally present in both calming auditory and visual stimuli. No significant changes were found in stressful auditory or visual stimuli.

Furthermore, it was hypothesized that the visual stimuli would have a larger impact than the auditory stimuli on the sympathetic autonomic response for both stressful and calming stimuli. The difference in the change in means between auditory and visual stimuli was quantified to determine which stimulus was more effective in inducing the response. It was determined that the changes in dBP (stressful and calming) and SCR (stressful only) during visual stimuli were larger than during auditory stimuli. The confidence intervals for HR and sBP showed no significant difference between visual and auditory stimuli (stressful and calming).

These findings support the first part of the hypothesis because the calming visual and auditory stimuli did cause significant decreases in mean BP and SCR. These values appear with asterisks (*) in Table 3 in the Appendix. The findings of the study did not support part of the hypothesis that stated that the visual stimuli would increase mean physiological responses. There was minimal evidence that the visual stimuli would evoke a larger change in physiological response than auditory stimuli. These findings suggests that physiologically, people are more sensitive to stimuli that are calming, and the corresponding physiological responses are lowered in short periods of time. It can be concluded that calm visual stimulation may be more effective in induction of autonomic response to stimuli than stimulation of the calm auditory pathway.

The overall findings contradicted previous studies that have been conducted, except for the findings of calming audio and visual stimuli as mentioned above. Unlike in Fujimura et. al., unpleasant (stressful) images created an insignificant change in response in SCR compared to pleasant (calming) stimuli. Similar to Croy et. al., our results showed that in some instances visual stimuli elicited a stronger response than auditory stimuli.

One of the assumptions made to obtain the data included the assumption that the calming and stressful stimuli were a good representation of stimuli that is calming and stressful, respectively. The human race is vastly different and it is not possible to predict a person's responses to different stimuli. In addition it was assumed that the vitals that chosen to measure would be reliable indicators of stress.

In the experiment there were several sources for human error. It was difficult to replicate the same testing environment for the trials of all of the subjects. The SCR data may not be accurate as it was easily influenced with slight movements of the subject's hand. Additionally, loud noises in the hallway could have influenced the trials especially if the subject was participating in calming visual stimuli. The source of error for the visual stimuli could be due to the size of the laptop screen on which the video was shown as well as its distance to the subject and the bright, white light in the room. This could have caused the subject to get distracted from the video.

There are several things that could be changed to improve this study. The light setting could be lowered when testing the visual stimuli in order to make the video the main focus for the subject. It could also be useful to complete the experiment within a cubicle where there are barriers to limit the participant's detection of peripheral activity that could be responsible for interfering with the subject's view of and focus on the video; peripheral activity includes unavoidable movement made by the researchers during the data collection and manipulation of equipment.

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Acknowledgements:

We would like to thank the University of Wisconsin-Madison for providing the necessary equipment and facilities utilized for the completion of this study. We would like to express much gratitude to Dr. Andrew Lokuta and the many helpful teaching assistants of Physiology 435. Additionally, the time offered by the volunteer participants of Physiology 435 who participated in our study was greatly appreciated.

Tables:

Table 1. Demographics Table.

	Audio and Visual stimuli	Number of Males	Number of Females
Group 1: Stressful	9 students	5	4
Group 2: Calming	11 students	4	7

This table illustrates the distribution of study participants into two treatment groups. Group 1 consisted of those exposed to stressful stimuli and group 2 consisted of participants exposed to calming stimuli.

Table 2. Mean and standard deviation of all measurements and treatment groups.

	baseline sBP	baseline dBP	baseline HR	baseline SC	stimulus sBP	stimulus dBP	stimulus HR	stimulus SC
ca	115.0(±13.1)	78.4(±9.3)	84.9(±17.7)	4.5(±1.9)	113.2(±13.3)	73.7(±7.4)	82.9(±16.8)	3.6(±1.9)
cv	114.4(±13.3)	73.5(±8.2)	84.9(±17.7)	4.5(±1.9)	111.4(±12.0)	74.8(±7.9)	81.2(±20.4)	4.1(±2.0)
sa	113.9(±9.6)	72.4(±6.6)	77.0(±13.7)	4.7(±1.5)	109.5(±7.5)	71.9(±6.1)	80.0(±17.8)	4.4(±1.8)
sv	109.6(±8.0)	70.8(±6.8)	77.0(±13.7)	4.7(±1.5)	107.9(±6.8)	73.0(±4.4)	74.2(±10.9)	5.3(±2.3)

This table displays the calculated means and standard deviations of the population for both the baseline measurements and the measurements collected during treatment of stimuli. Measurements include systolic blood pressure, diastolic blood pressure, heart rate, and skin conductance. ca: calming auditory; cv: calming visual; sa: stressful auditory; sv: stressful visual; sBP: systolic blood pressure; dBP: diastolic blood pressure; HR: heart rate; SC: skin conductance.

Table 3. P-values Determined for the Comparison of Baseline and Stimuli Measurements.

	CA	CV	SA	SV
sBP	0.4404	0.0195*	0.1127	0.2997
dBP	0.009371*	0.34	0.6374	0.1248
HR	0.7925	0.5064	0.3438	0.2373
SCR	0.0001187*	0.03351*	0.2706	0.2529

P-values were determined from a series of paired t-tests performed for each of the changes in the four listed variables (systolic blood pressure, diastolic blood pressure, heart rate, and skin conductance) for the comparison of baseline and stimuli measurements for calming auditory and visual stimuli and stressful auditory and visual stimuli. sBP: Systolic Blood Pressure; dBP: Diastolic Blood Pressure; HR: Heart Rate; SCR: Skin Conductance Response; CA: Calming Auditory; CV: Calming Visual; SA: Stressful Auditory; SV: Stressful Visual. *p-values of significance

Table 4. P-values Determined for the Comparison of Auditory and Visual Exposure of Stimuli.

	CA/CV	SA/SV
Systolic Blood Pressure Change	0.6518	0.3463
Diastolic Blood Pressure Change	0.01231*	0.03304*
Heart Rate Change	0.463	0.09459
Skin Conductance Change	0.05117	0.01912*

P-values were determined from a series of paired t-tests performed for each of the changes in the four listed variables (systolic blood pressure, diastolic blood pressure, heart rate, and skin conductance) for the comparison of auditory and visual methods of exposure for both calming and stressful stimuli. CA: Calming Auditory; CV: Calming Visual; SA: Stressful Auditory; SV: Stressful Visual. *p-values of significance

Table 5. Ninety-Five Percent Confidence Intervals Determined for the Comparison of Baseline and Stimuli Measurements.

	CA	CV	SA	SV
sBP	-3.116929, 6.632081	0.5882632, 5.3511307	-1.287518, 10.028259	-1.799450, 5.132783
dBP	1.434170, 7.959769	-4.005278, 1.520430	-1.922704, 2.959741	-5.2984366, 0.7799181
HR	-10.10940, 12.89986	-11.80456, 22.37674	-10.007908, 3.927852	-3.222797, 11.226575
SCR	0.6381421, 1.3763663	0.04695535, 0.93838492	-0.3279227, 1.0195116	-1.6236210, 0.4928821

Confidence intervals were determined with 95 percent certainty for each of the changes in the four variables listed (systolic blood pressure, diastolic blood pressure, heart rate, and skin conductance) for the comparison of baseline and stimuli measurements for calming auditory and visual stimuli and stressful auditory and visual stimuli. sBP: Systolic Blood Pressure; dBP: Diastolic Blood Pressure; HR: Heart Rate; SCR: Skin Conductance Response; CA: Calming Auditory; CV: Calming Visual; SA: Stressful Auditory; SV: Stressful Visual.

Table 6. Ninety-Five Percent Confidence Intervals Determined for the Comparison of Auditory and Visual Stimuli.

	CA/CV	SA/SV
Systolic Blood Pressure Change	-4.594073, 7.018315	-8.934506, 3.527098
Diastolic Blood Pressure Change	-10.282626, -1.596162	-5.2685469, -0.2870086
Heart Rate Change	-7.469163, 15.250890	-1.524048, 15.607882
Skin Conductance Change	-1.032350350, 0.003182245	-1.629277, -0.193051

Confidence intervals were determined with 95 percent certainty for each of the changes in the four variables listed (systolic blood pressure, diastolic blood pressure, heart rate, and skin conductance) for the comparison of auditory and visual methods of exposure for both calming and stressful stimuli. CA: Calming Auditory; CV: Calming Visual; SA: Stressful Auditory; SV: Stressful Visual.

Figures and Legends:

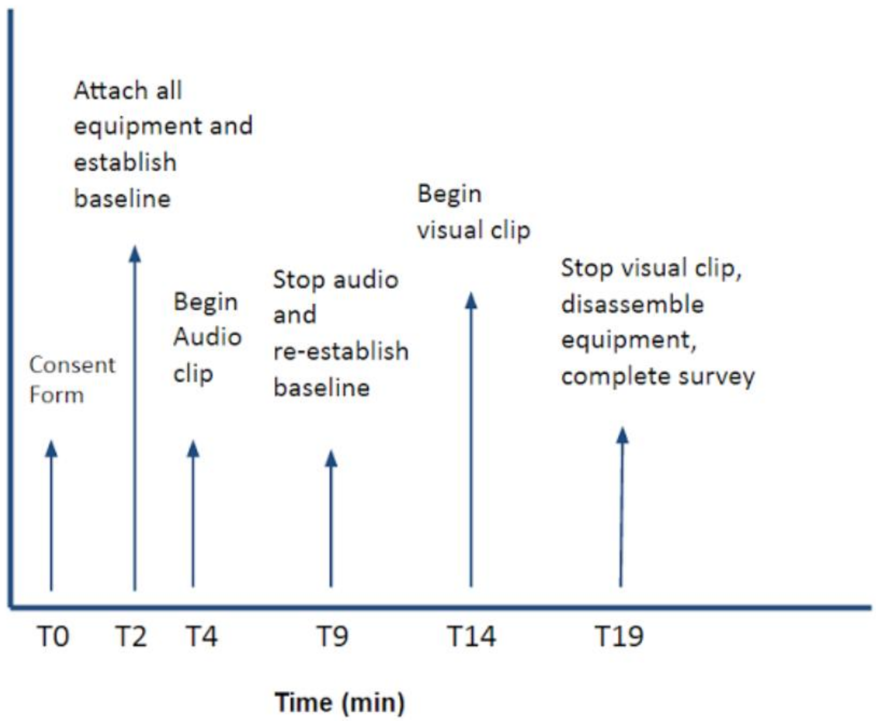

Figure 1. Methodological Timeline of Events. The figure above displays the general timeline of events experienced by each participant during the data collection process. The timeline begins with the introduction of the study and signing of the consent form and terminates with the disassembly of equipment and completion of a short survey of personal preferences.

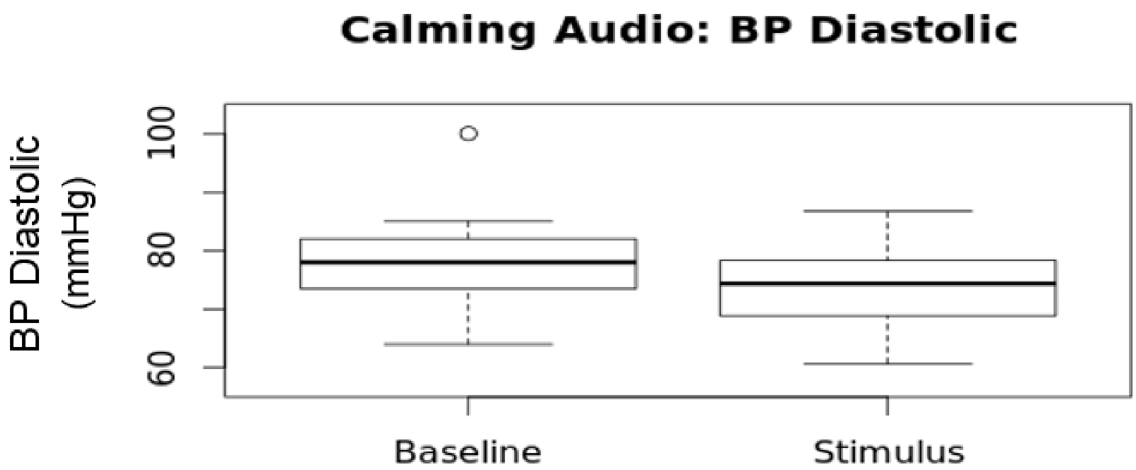

Figure 2. Comparison of baseline and stimulus diastolic blood pressure during calming auditory stimulus. The above boxplot depicts a significant difference in mean diastolic blood pressure at baseline and exposure to calming auditory stimulus. Mean of baseline = 78.4 mmHg; mean of stimulus = 73.7 mmHg; difference between means = +4.7 mmHg; p-value = 0.009371.

Interpretation of a Boxplot. The box illustration consists of three defining loci: the top line, the bolded middle line, and the bottom line. The bottom line indicates the 25^{th} percentile (Q1), while the top line is indicative of the 75^{th} percentile (Q3), and the bolded middle line is representative of the median. The distance between Q1 and Q3 is known as the interquartile range (IQR), which creates the box structure. Projecting from the box on either side are dashed lines that extend out to horizontal lines that are known as 'whiskers'. The bottom whisker represents Q1 - 1.5 x IQR, while the top whisker represents Q3 + 1.5 x IQR. Outliers are represented by floating, unfilled circles. All calculated mean values can be found in Table 2. Difference between means = mean of baseline - mean of stimulus.

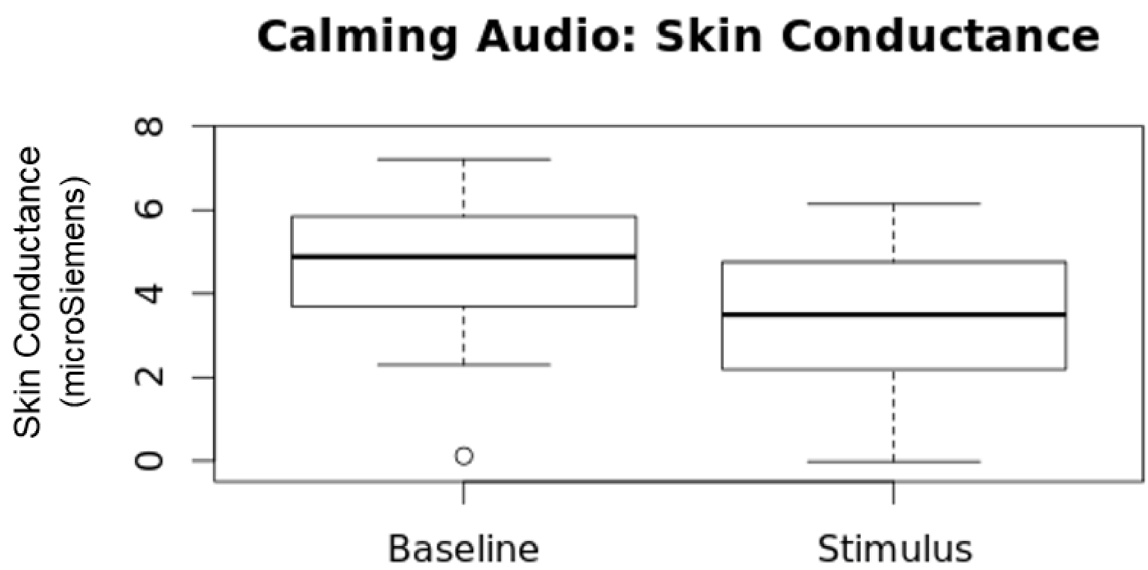

Figure 3. Comparison of baseline and stimulus skin conductance response during calming auditory stimulus. The above boxplot depicts a significant difference in mean skin conductance response at baseline and exposure to calming auditory stimulus. Mean of baseline = 4.5 microSiemens; mean of stimulus = 3.6 microSiemens; difference between means = +0.9 microSiemens; p-value = 0.0001187. Refer to Figure 2 for instructions on how to interpret a boxplot.

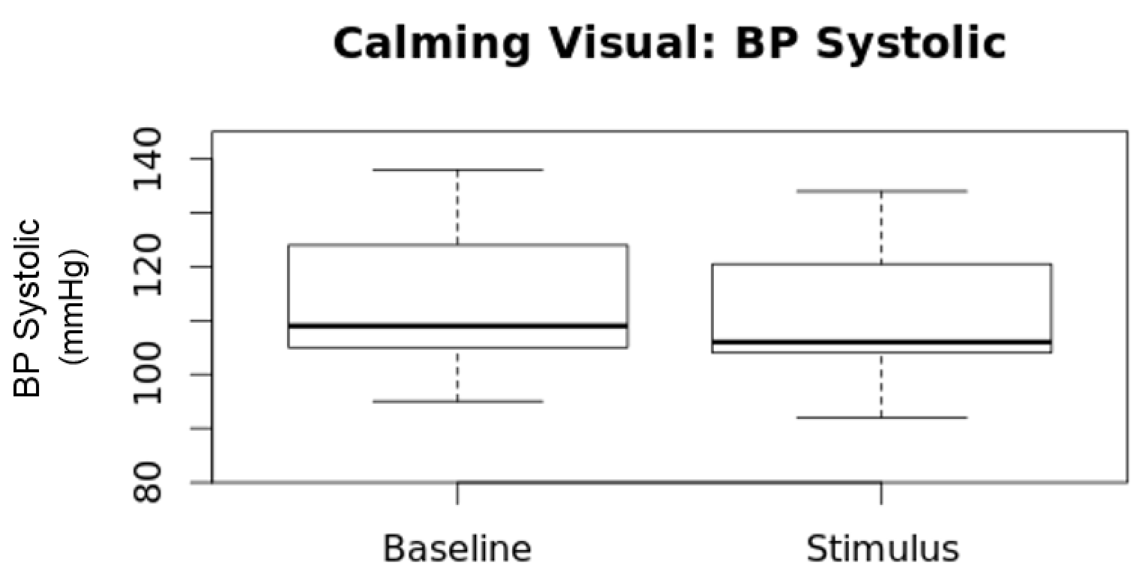

Figure 4. Comparison of baseline and stimulus systolic blood pressure during calming visual stimulus. The above boxplot depicts a significant difference in mean systolic blood pressure at baseline and exposure to calming visual stimulus. Mean of baseline = 114.4 mmHg; mean of stimulus = 111.4 mmHg; difference between means = +3.0 mmHg; p-value = 0.0195. Refer to Figure 2 for instructions on how to interpret a boxplot.

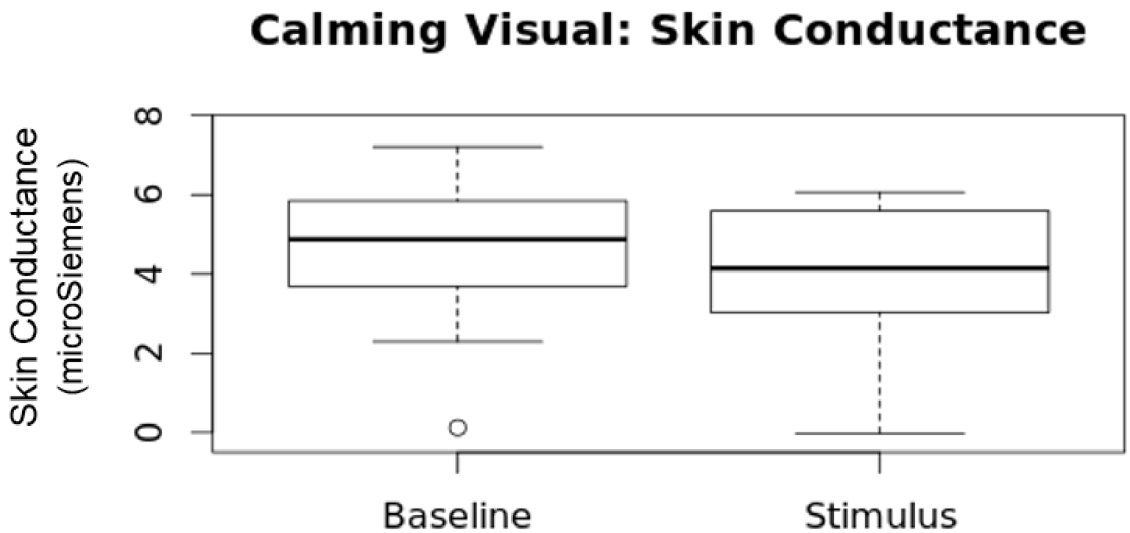

Figure 5. Comparison of baseline and stimulus skin conductance response during calming visual stimulus. The above boxplot depicts a significant difference in mean skin conductance response at baseline and exposure to calming visual stimulus. Mean of baseline = 4.5 microSiemens; mean of stimulus = 4.1 microSiemens; difference between means = +0.4 microSiemens; p-value = 0.03351. Refer to Figure 2 for instructions on how to interpret a boxplot.

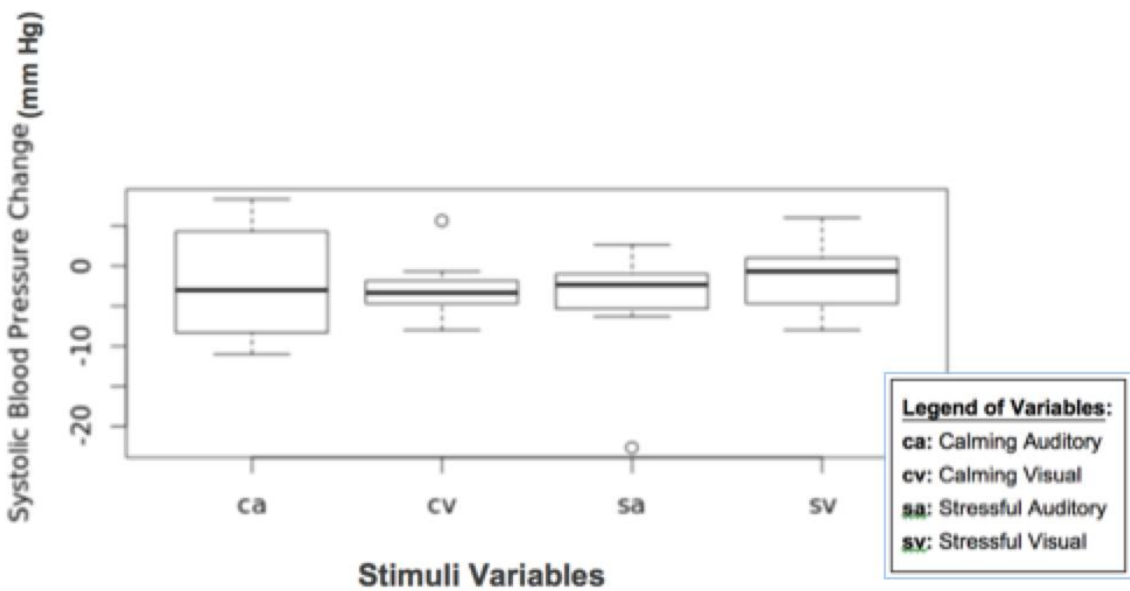

Figure 6. Comparison of auditory and visual stimuli in systolic blood pressure change induced by calming and stressful stimuli. The above boxplot depicts the difference in mean systolic blood pressure change in auditory and visual exposure for both calming and stressful stimuli. All four stimuli treatments resulted in a slight decrease in mean sBP change. Neither of the comparisons resulted in a statistically significant difference. Calming auditory and visual p-value = 0.6518; stressful auditory and visual p-value = 0.3463. Refer to Figure 2 for instructions on how to interpret a boxplot.

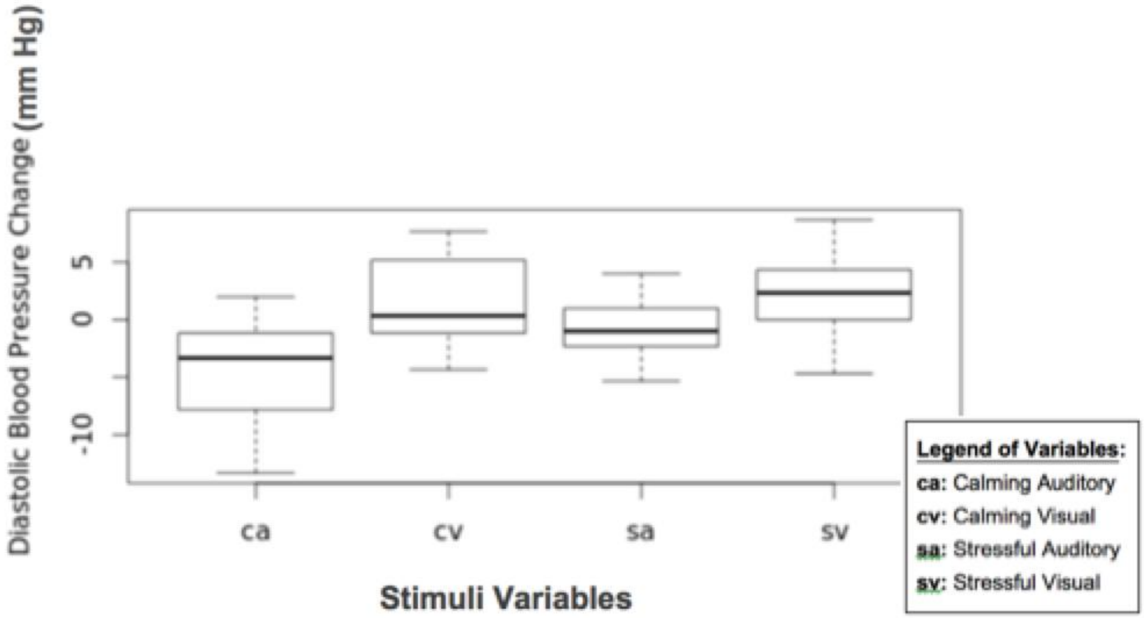

Figure 7. Comparison of auditory and visual stimuli in diastolic blood pressure change induced by calming and stressful stimuli. The above boxplot depicts the difference in mean diastolic blood pressure change in auditory and visual exposure for both calming and stressful stimuli. The mean dBP for calming auditory stimuli decreased significantly, whereas the mean dBP for calming visual stimuli increased slightly. The mean dBP for stressful auditory stimuli displayed a slight decrease, while the mean dBP for stressful visual illustrates a slightly more significant increase. The differences between the mean dBP for calming auditory and visual stimuli as well as stressful auditory and visual stimuli were determined to be statistically significant. Calming auditory and visual p-value = 0.01231; stressful auditory and visual p-value = 0.03304. Refer to Figure 2 for instructions on how to interpret a boxplot.

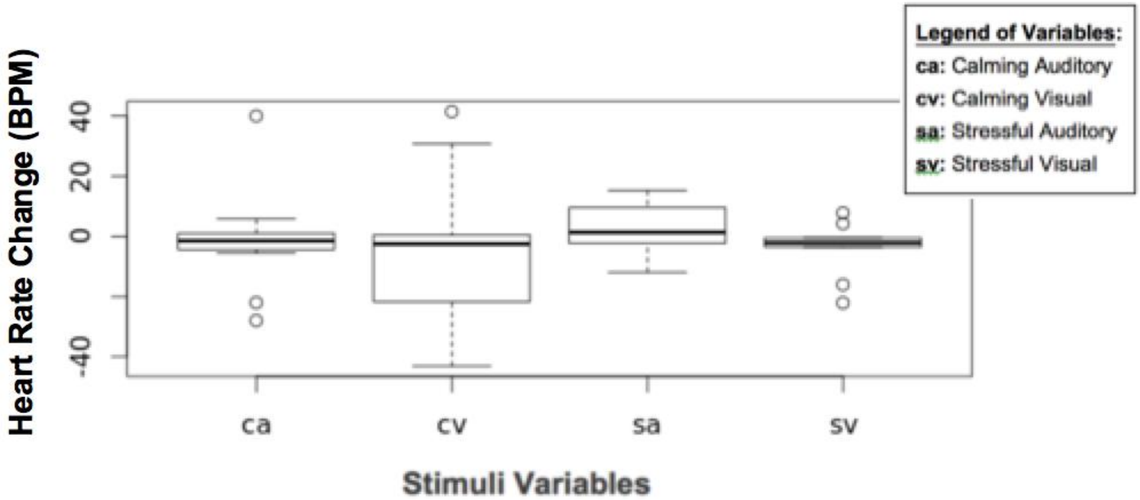

Figure 8. Comparison of auditory and visual stimuli in heart rate change induced by calming and stressful stimuli. The above boxplot depicts the difference in mean heart rate change in auditory and visual exposure for both calming and stressful stimuli. A slight decrease in mean HR was observed for calming auditory, calming visual, and stressful visual stimuli, while a slight increase in mean HR was observed for stressful auditory stimuli. Neither comparison of auditory and visual stimuli resulted in a statistically significant difference. Calming auditory and visual p-value = 0.463; stressful auditory and visual p-value = 0.09459. Refer to Figure 2 for instructions on how to interpret a boxplot.

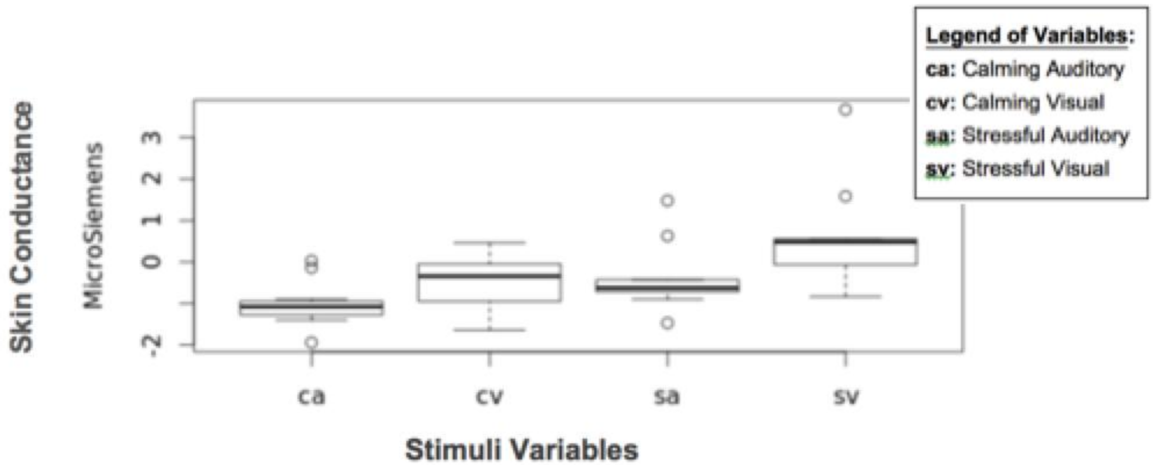

Figure 9. Comparison of auditory and visual stimuli in sympathetic skin conductance response change induced by calming and stressful stimuli. The above boxplot depicts the difference in mean SCR change in auditory and visual exposure for both calming and stressful stimuli. Calming auditory stimuli had the largest decrease in mean SCR, followed by calming visual stimuli, and then stressful auditory stimuli. Stressful visual was the only stimulus to induce a slight increase in SCR. A statistically significant difference was determined in the comparison between stressful auditory and visual stimuli. The comparison between calming auditory and visual stimuli was not statistically significant, although the difference was near the threshold of significance and is therefore considered 'approaching significance'. Calming auditory and visual p-value = 0.05117; stressful auditory and visual p-value = 0.01912. Refer to Figure 2 for instructions on how to interpret a boxplot.