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The Effects of Anxiety on Sensory Gating

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I. Abstract

Sensory gating is a proposed important physiological process of inhibiting neuronal responses of repetitious stimuli in the central nervous system to allocate more cognitive resources to additional salient information (Freedman, Adler, Olincy, Waldo, Ross, Stevens, et al., 2005). Sensory gating is currently being studied to better understand psychiatric illnesses, especially those characterized by emotional changes and the inability to concentrate such as schizophrenia, ADHD, anxiety disorder, and Parkinson's (Castellanos, Fine, Kaysen, March, Rapoport, and Hallett, 1996; Jessen, Kucharski, Fries, Papassotiropoulos, Hoenig, Maier, and Heun, 2001). Anxiety is a strong feeling of nervousness that occurs in all individuals at varying degrees and is associated with detrimental health effects as well as hindering concentration (Corr and Fajkowska, 2011). Numerous brain regions are associated with anxiety levels such as the anterior limbic system, paralimbic system, hippocamus, and prefrontal cortex (Grunwald, Boutros, Pezer, Oertzen, Fernandez, Schaller, and Elger, 2003).. These systems have also activity related to sensory gating. Data was obtained from 10 Caucasian, undergraduate females. We used a set of inventories to determine participants' level of anxiety as well as measuring their auditory gating through the click-pair paradigm, with 500ms between clicks and 10 seconds between pairs of clicks. We hypothesize that increasing levels of anxiety will be correlated with impaired gating, indicated by increased ratios. To determine this, participants engaged in the cold-pressor task to induce stress. Baselines were established before the cold-pressor tasks and measured after its completion. Stress levels were shown to increase after the application of the cold-pressor task, but gating ratios were demonstrated to be unaltered. Future studies are proposed further explore the relationship between anxiety and sensory gating.

II. Introduction

Inhibitory Gating

Event-related potentials (ERPs) are the measured electrical response of the brain due to the onset of a stimulus (Luck, 2005). The study of ERPs has greatly advanced work in the area of cognitive neuroscience and psychophysiology by characterizing these electrical changes of the brain in response to specific sensory events (Woodman, 2010). Studying ERPs is one of the most commonly used methods to study how the human brain reacts to its constantly changing environment and is measured through the use of a electroencephalogram, or EEG (Woodman, 2010). EEG is a device that measures the electrical signals of the scalp surface produced by the brain. EEGs are a commonly used tool to effectively and noninvasively measure ERPs with a temporal resolution down to the millisecond (Luck, 2005; Woodman, 2010). An ERP is indicated by an observed alteration of the brain waves produced by an EEG recording that is the direct result of a stimulus (Woodman, 2010). The use of EEG to measure ERPs has allowed researchers to cheaply study the direct response of the human brain following a stimulus, and infer the cognitive operations that occur during information processing (Luck, 2005).

Sensory gating is a neurological process thought to be used to filter out perceived irrelevant information (Freedman et al., 2002). When identical information occurs in close temporal proximity, the brain will suppress the redundant information to efficiently allocate cognitive resources to more salient information (Freedman et al., 2002). Sensory gating occurs in a number of central nervous system (CNS) networks, including the prefrontal cortex, temporo-parietal region, striatum, amygdala, and the hippocampus (Grunwald et al., 2003).

The most common method to measure sensory gating involves testing the p50 ERP through the paired-click procedure. This procedure tests auditory gating that occurs approximately 50ms after a click onset (Rentzsch, Jockers-Scherubl, Boutros, and Gallinat, 2007). Two clicks are presented to

participants 500ms apart, and the subsequent EEG readings are recorded to determine how the brain suppresses the second of the two identical stimulus pairs. By examining the depression of the second of the two clicks, a ratio can be calculated to examine the diminished response of the brain to the repetitive stimuli. This procedure has been shown to effectively examine the inhibitory circuits of healthy individuals (Rentzsch et al., 2007).

Sensory gating ratios have been demonstrated to be altered due to a number of variables. Attentional performance scales have been positively correlated with stronger gating ratios, presumably because of the decrease of conflict between stimuli (Wan, Friedman, Boutros, and Crwaford, 2008). Many neuropsychiatric conditions have also been shown to disrupt gating and subsequently alter the filtration of insignificant information. These include Huntington's disease, Parkinson's, ADHD, Alzheimer's, and obsessive compulsive disorder (Castellanos et al., 1996; Jessen et al., 2001). These disorders are often characterized by the inability to properly cognitively function in regards to sensory input resulting in attentional difficulties. Schizophrenia is arguably the mostly widely studied disorder in regards to its impairment of gating, and this deficit has been indicated in the disease pathology (Tregellas, Davalos, Rojas, Waldo, Gibson, Wylie, et al., 2007). By combining paradigms that test for P50 inhibition and antisaccade errors, researchers have been able to discriminate participants with schizophrenia and the parents of schizophrenic participants (la Chapelle, Nkam, Houy, Belmont, Menard, Roussignol, et al., 2005). It has been theorized that schizophrenic patients cannot filter out stimuli that are presented almost simultaneously causing a flood of irrelevant information. The inability to filter out this information has been proposed to be associated with higher levels of hallucinations or may result in an increase of negative symptoms (la Chapelle, Levillain, Menard, Van der Elst, Allio, Haouzir, et al., 2003). This idea has been supported by the finding that non-paranoid schizophrenic patients have stronger gating suppression than their paranoid counter parts (Boutros, Zouridakls, and

Overall, 1991). P50 gating deficits have also been related to hypodopaminergia in abstinent chronic cocaine abusers (Fein, Biggins, and Mackay, 1996). Understanding the role that sensory gating plays in these disorders should help in comprehending the attention dysfunction typically expressed in their pathology (Jessen et al., 2001).

Anxiety

Anxiety is a multidimensional construct encompassing cognitive, affective, physiological, and behavioral components associated with negative mood and emotion (Corr and Fajkowska, 2011). Anxiety causes a large array of symptoms including fatigue, headaches, muscle tension, and most notably, difficulty concentrating (DSM-IV). A number of neural structures have been associated with anxiety, including the paralimbic, anterior limbic, orbital frontal cortex, and hippocampus (Grachev and Apkarian, 2000). Anxiety disorders are found in up to a quarter of the general population, making them one of the most prevalent psychiatric disorders (Grachey and Apkarian, 2000). Extraordinary levels of anxiety can characterize an anxiety disorder such as panic disorder, which has been correlated with weaker levels of sensory gating (Ghisolfi, Heldt, Zanardo, Strimitzer, Prokopiuk, Beker, et al., 2006). OCD is correlated to weaker levels of inhibitory gating and is also implicated in the same brain regions that control anxiety (Castellanos et al., 1996; Grachey and Apkarian, 2000).

Stressors are a critical component to developing feelings of anxiety, and are associated with a number of detrimental health effects (Gallagher and Mckinley, 2007). This has resulted in a surge of research to mediate these effects by understanding the nature of anxiety. Stressors are outside events or chronic conditions that endanger the physical or psychological health of a person (Grant, Compas, Thurm, McMahon, and Gipson, 2004). Stressors are measured through a number of means, such as self-report checklists and interviews (Grant et al., 2004). Perceived stress has been shown to impair gating in healthy individuals as well as effect females to a greater extent (White, Kanazawa, and Yee,

2005).

Aims and Predictions

One aim of this study is to characterize sensory gating differences among healthy individuals because the majority of sensory gating research has previously focused on gating deficits associated with neurological disorders. The second aim of the study is to examine how anxiety and gating are related in typical college undergraduates. The neurological disorders linked with impaired gating have a symptom of concentration deficits. Higher levels of anxiety are characterized by this inability to concentrate, but adversely affect healthy individuals in varying degrees. Stress, the major cause of anxiety, has been shown to distort the ability of an individual to gate effectively (White et al., 2005). Inhibitory gating is a stated dependent function demonstrated to be correlated with anxiety and stress (Grachev and Apkarian, 2000; Grunwald et al., 2003). This has lead us to question how varying levels of anxiety in healthy individuals will correlate with the effectiveness of sensory gating because gating deficits are associated with concentration difficulties, a common psychophysiological manifestation of anxiety.

Brain mechanisms that are involved in stress and anxiety have similarly been linked to inhibitory gating (Grachev and Apkarian, 2000; Grunwald et al., 2003). As a result of this, we hypothesize that higher levels of anxiety in healthy individuals will be associated with diminished abilities to gate sensory information. This novel study will examine how the emotional state of healthy individuals will relate to their sensory gating ratios. We will investigate this by inducing stress in participants, and measuring how their gating is altered from baseline in correlation with their changing levels of anxiety. This will offer a foundation of work for the understanding of the state-dependency of inhibitory gating.

III. Methodology

Participants

The participants used in the study were 10 Caucasian females that were currently enrolled at Bowling Green State University. Females have been shown to be more reactive to stress in terms of gating alterations, thus offering a higher likelihood of exhibiting detectable differences in their gating (White et al., 2005). Ages of participants ranged from 18 to 30 years old, due to consistent levels of inhibitory gating that occur during adulthood (Myles-Worsley, Coon, Byerly, Waldo, Young, and Freedman, 1996). Participants were screened prior to the study, with the criteria of: having never been diagnosed with a neurological disease, not currently receiving medical treatment for any known neurological conditions, no circulatory problems such as Reynaud's disease, and normal hearing. Due to the method of EEG recording, we excluded any participants who had irremovable piercings on her head or face. Participants were recruited through BGSU's Sona system, by offering required credit to undergraduate psychology students or entry into the drawing of a $10 gift card. Participants were asked to refrain from consumption of alcohol and non-prescription drugs 24 hours prior to the start of the experiment. They were also asked to not consume nicotine 30 minutes prior to the start of the experiment by reason of nicotine administration linked with improved gating in healthy participants (Knott, Salle, Smith, Phillipe, Dort, Choureiry, et al., 2013).

Scales

Participants were given a number of self-report questionnaires before and after EEG data was collected. These were completed on a Dell PC using the Qualtrics survey system. The first of these surveys was the PANAS inventory, which is designed to determine a participant's individual emotional positive and negative affect. The inventory consists of 20 questions of which there are 10 questions to indicate current positive affect and 10 items for determining current negative affect. These questions

are done on a 5 point scale with 1 = *very slightly or not at all* to 5 = *extremely.* All questions were randomly distributed throughout the study. The scale has been shown to have a high degree of internal consistency, as well as stability in regards to perceived current positive and negative affect (Watson, Clark, and Tellegen, 1988). Positive and negative questions will be totaled and scored separately for each individual.

Participants were also required to complete the State Anxiety Inventory (SAI). This survey is designed to measure a participant's current state of anxiety differentially from depressive symptoms (Spielberg, Gorssuch, Lushene, Vagg, and Jacobs, 1983). The SAI is a 20 item, two-factor questionnaire, using a 4-point Likert scale in which participants report their current state of anxiety (e.g *I feel calm*; *I feel tense).* Participant's answers indicate if they currently feel the presence or absence of anxiety to a high or low degree. The structure of this test has been shown to be an accurate measure in determining an adult's level of current anxiety (Vagg, Spielberg, and O'Hearn, 1980).

An emotional regulation questionnaire (ERQ) was also given to each participant. This 10 question, two-factor survey is structured in a way to evaluate a participant's tendency to reappraise and suppress emotion (Gross and John, 2003). The survey uses a 7 point Liket scale in which participants answer with 1=*strongly disagree* to 7=*strongly agree* on their tendency to regulate emotion (e.g. *I keep my emotions to myself).* This survey has been shown to be internally consistent in evaluating emotion regulation of adult participants (Gross and John, 2003). A collectivism scale was also used for data collection of a different study involving gating of different cultures, and was only administered at the start of the study. It is a 10 question study to determine a participant's level of collectivism or individualistic tendencies (Hofsted, 1984).

Cold-Pressor Task

A cold-pressor task was used to induce stress of each participant. This technique has been used previously to suppress P50 gating and has been shown to have no long lasting effects on participants (Johnson and Adler, 1993). A cooler was used to house ice and water, and was kept at 32-34^{o}F. A plastic screen was used to create a section of the mixture containing no ice, so that participants had no direct contact with the ice. A stop watch, held by the experimenter, was used to record the length of time each participant submerged her hand during the cold-pressor task.

EEG Equipment Electro-Cap Systems, Eaton, OH

A number of pieces of equipment were used to obtain the EEG readings from each participant. We used a 16-electrode Biopac CAP100C to obtain the electrical readings from each participant's scalp, with the use of a Biopac MP150 unit and a Biopac ERS100C amplifier to modify the readings into a useable state (BIOPAC Systems, Inc., Goleta, Ca; Electro-Cap Systems, Eaton, OH). EEG readings were recorded using AcqKnowledge 4.2 software while simultaneously presenting the paired clicks through the use of E-prime 2.0 software and noise-canceling Sennheiser headphones calibrated to 80 dB SPL on an adjacent Dell computer (BIOPAC Systems, Inc., Goleta, Ca; Psychology Software Tools, Pittsburgh, PA). The paired-click paradigm has been shown to be a reliable technique to induce and measure p50 auditory gating (Dalecki, Croft, and Johnstone, 2011). The EEG recorded the central brain region (Cz), as previous labs have done to obtain a strong documentation of p50 suppression (Yee and White, 2001). To minimize the noise of the EEG recording, two reference electrodes were placed on the earlobes and another on front end of the EEG cap. A ChekTrode was used to make sure that the impedance of the cap was below 15Kohms for each participant (BIOPAC Systems, Inc., Goleta, Ca).

Procedure

Each participant was brought into the lab and a screening form was read to them to ensure that

she met the criteria of the study. After completing and passing the screening form, informed consent was obtained. She was then seated in front of a Dell computer to complete the previously mentioned surveys. The participant was then instructed to remove all metal objects from her head, including but not limited to: piercings, glasses, and bobby pins. She was placed in a comfortable chair and made to part her hair down the center of her scalp so as to obtain accurate EEG readings. The ears were cleaned using an alcohol swab and exfoliated using Nuprep (Weaver and Company, Denver, CO). Reference ear electrodes were placed on the ears after being filled with thick Ten20 conductive gel (Weaver and Company, Denver, CO). The electrode cap was centered on the head of each participant, and the cap was secured down by two straps snapped to a chest band placed on the participants (Electro-Cap Systems, Eaton, OH). The reference electrode on the cap was exfoliated with Nuprep and then filled with conductive gel to better reduce noise (Electro-Cap Systems, Eaton, OH). The Cz electrode site was also filled with conductive gel. Impedance was then checked and recorded manually using the ChekTrode and the headphones were placed on her head (BIOPAC Systems, Inc., Goleta, Ca).

Participants were then instructed to relax and remain still. A cross fixation point was presented on the computer screen in front of them, and they were instructed to stare at the cross or close their eyes to reduce ocular noise. Noise canceling headphones presented the paired-clicks while the EEG reading was recorded. Paired-clicks were presented 500ms apart, a trial, with 10 seconds in between pairs, a block (Dalecki et al., 2011). EEG was recorded for about 8.5 minutes as 49 click pairs were presented at 80 dB (Dalecki et al., 2011).

After completing the first block, the participants then took part in the cold-pressor task to induce stress (Johnson and Adler, 1993). Participants were instructed to place their left hand completely in the cold water for 30 seconds while they kept quiet and still. The experiment silently recorded the time behind them and advised the participants when to remove their hands. Participants were also

instructed that if the pain or discomfort became too much then they may remove their hands. All participants completed the full 30 seconds without any excessive pain or discomfort observed.

Immediately following the cold-pressor task, participants were again briefed on the procedures given during the first block. The second block was completed identically to the first. Once the second block was completed, participants filled out the previously mentioned surveys, excluding the collectivism scale, to assess their anxiety and mood. The entire procedure took approximately 60 minutes.

Statistical Analysis

ERP data recorded from EEG caps was analyzed offline using AcqKnowledge software (BIOPAC Systems, Inc., Goleta, Ca; Electro-Cap Systems, Eaton, OH). The data was sampled at 1,000 Hz and amplified and band-pass filtered at 1.0 to 100 Hz prior to be recorded. A digital band-pass filter was then applied, eliminating data below 10Hz and above 50Hz, due to the P50 frequency being within that frequency (Arnfred, Chen, Glenthoj, and Hemmingsen, 2003). Each onset of a click was manually marked on the Cz reading using the digital inputs sent from E-prime to AcqKnowledge (BIOPAC Systems, Inc., Goleta, Ca; Psychology Software Tools, Pittsburgh, PA). The p50 ERP data and time was recorded by manually selecting the highest peak 30 to 90ms after the click onset, excluding the first pair of clicks (Zhang, Liu, Liu, Hong, Chen, Xiu, et al., 2012).

We examined 10 participants with two blocks each (N=10); one pre-stress and one post-stress. All analysis was done on Statistical Package of Social Science (SPSS) and Microsoft Excel. P50 amplitudes and latencies were all recorded from the Cz electrode site (Davies, Chang, and Gavin, 2009). T/C ratios were calculated by taking the second stimulus p50 amplitude of the pair (T) and dividing that by the amplitude of the first or control click ERP amplitude (C). This resulted in the numerical expression of p50 suppression due to gating, with a small ratio indicating strong gating

(White et al., 2005).Each block contained 49 analyzed click pairs, totaling 980 calculated T/C ratios. These ratios were then averaged for each trial of each participant. Latencies were calculated by taking the recorded time of the p50 amplitude minus the click onset and were averaged for each trial of each.

IV. Results

P50 Gating

The study assessed the correlation of anxiety and inhibitory gating by first establishing T/C ratios in relation to stress induced by the cold-pressor task. Block 1 T/C ratios convey the baseline gating for each participant (M=1.04, Sd.=.04), as well as latencies (M=59.8, SD=2.09). After the application of the cold-pressor task T/C ratios (M=1.08, SD=.096) and latencies (M=60.2, SD=2.02) were again calculated. These can all be seen in Table 1.

Paired sample t-test were used to determine the effect of stress on gating produced by the cold-pressor task. T/C ratios showed no significant mean differences between baseline and post-stress ratios, $t(9)=-1.23$, p=.26. Latencies also showed no significant effect, $t(9)=-.57$, p=.25.

Scales

The PANAS scale was edited so all participant scores were organized so an answer of 5 meant positive affectivity for all participants. Scores were then averaged for both pre-stressor and post-stressor blocks (Watson et al., 1988). Minimum, maximum, mean, and standard deviation was then obtained for pre-stress (Min=3.70, Max=5.80, M=3.52, SD=1.17) and post-stress (Min=3.10, Max=5.70, M=3.55, SD=1.49). A paired sample t-test found no significant change resulting from the cold-pressor task ($t(9)=-1.37$, p=.20, Table 2).

The SAI scale was then organized so that all item values were arranged to indicate an answer of 5 being a high level of anxiety. Each participant's score was then averaged for pre-stressor and post-stressor trial (Spielberg et al., 1983). Minimum, maximum, mean, and standard deviation was then

obtained for pre-stress (Min=2.26, Max=3.63, M=3.06, SD=.45) and post-stress (Min=2.47, Max=3.38, M=3.40, SD=.41). SAI scores, as expected, showed statistical significance below the .05 level ($t(9)$=-2.41, p=.039, Table 2) indicating the cold-pressor task induced stress.

The ERQ scale was edited so all questions were indicated with high emotional regulation were indicated by an answer of 7. All answers were then averaged similarly to the previous scales (Gross and John, 2003). Minimum, maximum, mean, and standard deviation was then obtained for pre-stress (Min=2.60, Max=4.00, M=4.50, SD=1.13) and post-stress (Min=3.20, Max=4.30, M=4.34, SD=1.10). A paired sample t-test comparing baseline to post-stress was not significant below the .05 level ($t(9)$=1.95, p=.082, Table2).

Relationships

To determine the correlation of anxiety and inhibitory gating, a Pearson Correlation was done on the differences between pre and post stressor task of the SAI and T/C values. No significance was determined with this test (r=.12, n=10, p=.75, Figure 2).

The final statistical test was a multivariate test to determine how T/C ratios and SAI score changes were related to one another in regards to the application of the cold-pressor task. There was no significant results found, Wilks' Lambda=.57, F(2,8)=2.99, p=.12. This can be observed in Table 3.

V. Discussion

The aim of this study was to establish a relationship between anxiety and sensory gating. By having each participant engage in the cold-pressor task, we attempted to alter the participant's current state of anxiety. All but one participant showed an increase in their SAI scores after the cold-pressor task as seen in Figure 1. This was an expected result and indicates that the task was effective for our purposes (Tashani, Alabas, and Johnson, 2010). However, we did not see any increase of T/C ratios as

previously shown by Johnson and colleagues (1993). Latencies of the p50 ERP also showed no significant change. The insignificant result of the Pearson Correlation as well as the Covariate test would seem to disprove our hypothesis by establishing no significant relationship between different levels of anxiety and their corresponding T/C ratios.

Limitations

A number of factors may have contributed to our inability to reject the null hypothesis. One such factor may be due to our lack of participants resulting in a low N. The most notable issue of the study would be that our obtained T/C ratios are not congruent with previously established mean of .59 and standard deviation of .38 (Campbell, Torello, and Boutros, 2000). None of our subjects showed normal gating and averaged 1.06. The lowest block recorded had a T/C ratio of 0.97.

The experiment was limited to the use of only Caucasian, female subjects as a consequence of the collaborative nature with the collectivism study done in conjunction with this study. This may have caused the data collected to be affected by sex characteristics exhibited by the female only subjects. Sex differences have been found by White and colleagues (2005), through the discovery that stress reactivity was greater in females through the elevation of p50 T/C ratios as compared to male subjects as well as differences in baseline T/C ratios. They found that the mean baseline T/C ratios for men and women were .48 and .35 respectively. After the application of a stressor task, the mean T/C ratios for men was .5, and females was .74 (White et al., 2005). The females of our current study showed no T/C ratio differences resulting from stress, but the known sex differences may have altered the data obtained. There may also be an effect caused by the relatively low sample size of just 10 participants, causing and insufficient amount of data to be obtained.

It is clear that we were unable to establish normal gating with any of our subjects, and it is reasonable to assume that this is due to a hardware or software issue. There was no notable consistent

ERP seen at the p50 interval by experimenters during any of the blocks. This may be due to the EEG setup not accurately reading the electrical activity of the scalp or the click parameters improperly producing p50 ERP's. Clicks were presented at 80 dB which may have failed to produce a noticeable p50 ERP. According to the meta-analysis of p50 studies by de Wilde and colleagues (2011), the optimum sound intensity is between 85 and 90 dB. The experiment presented here is slightly below that intensity but a more notable difference is seen in the sound duration. Clicks were presented for a duration of 10ms while other studies, such as the one done by Rentzsch and colleagues (2008), have a duration of 1ms or less. We recorded the highest EEG amplitude in relation to the click onset but the extended duration of the sound may have caused the ERP to be shifted to a later latency. Another cause may be due to the filters that the EEG recordings were passed through prior to calculating T/C ratios. Four of the trials depicted what was referred to as "sine" readings. These recorded EEG waves appeared to be unnatural sinusoidal by having very consistent amplitudes and periods, which is a noted problem with the Biopac system.

Interpretations

An alternative interpretation can be made to the hypothesis presented in a paper by Cromwell and colleagues (2007). Cromwell looked at inhibitory gating through the use of single unit recordings in the striatum of rats undergoing the click-pair paradigm. They found that gating occurred in many of the neurons but a large portion showed no signs of inhibitory gating, even while still demonstrating and ERP in response to the tones. Cromwell suggests that inhibition is not the dominant response of the individual striatal neurons, which differs from what has been shown in the field potential recordings (Cromwell, Klein, and Mears, 2007). This would convey that heterogeneity of inhibitory gating does not occur within the CNS. The gating response seen in the overall field potential recorded by an EEG is not indicative of the inhabitation response of the brain as whole, but a representation of the

intercommunication of the sub regions of the brain. This line of thinking supports the idea that to accurately determine the effects of anxiety on gating, each sub region of the CNS must be measured for anxiety induced changes to the inhibitory response. This may also explain why gating was not seen in the data obtained in the study presented by this experiment. Gating differences may have occurred in individual regions of the brain in response to anxiety but the intercommunication of these regions did not express that change.

The extrapolation of the striatal gating data should be read with caution, as expressed by Cromwell and collegues (2008), in which Cromwell argues that when examining sensory gating, discretion must be practiced when predicting human physiological functions from rodent data. The P50 gating ratios of rodents have been shown to be stable over time but human studies have had unpredictable ratios over a period of 5 days (Mears, Klein, and Cromwell, 2006; Hetrick, Ozgur, Yousseff, Jin, Potkin, Sandman, and Bunney, 1995). Gating has been shown to occur in the temporo-parietal region, prefrontal cortex, and hippocampus of both humans and rats (Grunwald et al., 2003). This does that mean that these processes are directly correlated between these two species though because the two species use these same brain regions in different ways (Cromwell, Mears, Wan, and Boutros, 2008).

The hippocampus has been demonstrated to be a major contributor to the sensory gating of rodents and has thus been the focus of extensive research (Moxon, Gerhardt, Bickford, Austin, Rose, Woodward, and Adler, 1999). Cromwell and colleagues (2008) feel that this is not completely analogous to humans. When studying the hippocampal activity in humans, accuracy cannot be assured through non-invasive EEG due to the closed electric field being measured below the scalp. Grunwald and colleagues (2003) appear to bolster this through the implantation of intracranial electrodes on epileptic patients and recording during the paired-click procedure. A P50 ERP is seen in the primary

auditory cortex and prefrontal cortex, but the hippocampal ERP occurs at about 250ms after the click onset (Grunwald et al., 2003). This increased latency is theorized to occur because of the differing cortical structures and relative brain size of the human and rat brain (Cromwell et al., 2008). When studying the effects of anxiety and stress have on inhibitory gating, we must be careful to not over extrapolate the underlining causes of this physiological process. The way in which we attempted to measure the changes of anxiety on gating may not have been effective due to the measured ERP not resulting from the cortical regions associated with anxiety.

V. Conclusions

The study presented here has yielded insignificant results, but this is likely due to the inaccurate detection of the p50 ERP. By not obtaining typical ERP amplitudes we were unable to exhibit normal T/C ratios for our participants. As a result, our hypothesis has not been sufficiently disproven. A follow-up study is needed to satisfactorily test the proposed hypothesis.

The replication of this study with more typical T/C ratios will bring a number of interesting ramifications. If the hypothesis is shown to be correct then it will show how variations of healthy individuals relate to sensory gating. This will increase our understanding of the influences on sensory gating, and explain some of the diversity seen between participants in gating studies. It may indicate also that the role of the hippocampus, or at least the effects it has on anxiety levels, plays an early role in the sensory gating of humans. This could be tested by a theoretical, though not ethical, study in which neurons are measured directly through intracranial electrodes. This hypothetical scenario would result in the understanding of how each individual brain regions would respond to anxiety in terms of gating. By doing this it would be possible to explain the theories of Cromwell and colleagues (2007, 2008) and give us an understanding of the intercommunication of cortical structures in regards to gating.

If the hypothesis is again shown to be invalid with legitimate T/C ratios, then it will help further establish the theory laid out by Cromwell and colleagues (2008). To further examine this theory, the study can be repeated looking at the ERP that occurs 250ms after the click onset to determine the role the hippocampus plays during auditory gating in relationship with an individual's level of anxiety. Regardless of the results, this study will help increase the knowledge base of this protective physiological process.

This study may also present a number of clinical purposes. Through the use of measuring and tracking gating differences in individuals, it may be possible to diagnosis or identify at risk individuals for a number of psychophysiological disorders. Baker and colleagues (1987) have already found that sensory gating procedures proved to be an effective tool in measuring specific biological differences of schizophrenia. Perry and colleagues (2007) were also able to note physiological differences in adults with autism compared to controls through the use of sensory gating analysis. Often these psychophysiological disorders need to be diagnosed through behavioral traits which are often qualitative. The use of sensory gating techniques in conjunction with other measurements, may allow for a desirable quantitative approach for the diagnosis these mental illnesses.

VI. References

American Psychiatric Association. (2000) *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.). Washington, DC.

Arnfred, S.M., Chen, A.C., Glenthøj, B. Y., & Hemmingsen, R.P. (2003). Normal p50 Gating in Unmedicated Schizophrenia Outpatients. *The American Journal of Psychiatry, 160(12),* 2236-2238.

Baker, N., Adler, L.E., Franks, R.D., Waldo, M., Berry, S., Nagamoto, H., Muckle, A., & Freedman, R. (1987). Neurophysiological Assessment of Sensory Gating in Psyciatric Patients: Comparison Between Schizophrenia and Other Diagnoses. *Biological Psychiatry, 22(5),* 603-617.

Boutros, N.N., Zouridakls, G., & Overall, J. (1991). Replication and Extension of P50 Findings in Schizophrenia. *Clinical Electroencephalography, 22(1),* 40-45.

Campbell, D., Torello, M., & Boutros, N.N. (2000) P50 Sensory Gating has a Normal Distribution in Normal Adults. *Biological Psychiatry, 47(8),* S139.

Castellanos, F.X., Fine, E.J., Kaysen, D., Marsh, W.L., Rapoport, J.L., & Hallett, M. (1996) Sensorimotor Gating in Boys with Tourette's Syndrome and ADHD: Preliminary Results. *Biological Psychiatry, 39(1),* 33-41.

La Chapelle, S.L., Levillain, D., Menard, J.F., Van der Elst, A., Allio, G., Haouzir, S., Dollfus, S., et al. (2005) P50 Inhibitory Gating Deficit is Correlated with the Negative Symptomatology of Schizophrenia. *Psychiatry Research, 136,* 27-34.

La Chapelle, S.L., Nkam, I., Houy, E., Belmont, A., Menard, J.F., Roussignol, A.C., et al. (2005) A Concordance Study of Three Electrophysiological Measures in Schizorphrenia. *The American Journal of Psychiatry, 162(3),* 466-474.

Corr, P.J., & Fajkowska, M. (2011). Introduction to Special Issue on Anxiety. *Personality and Individual Differences, 50(7),* 885-888.

Cromwell, H.C., Klein, A., & Mears, R.P. (2007). Single Unit and Population Responses During Inhibitory Gating of Striatal Activity in Freely Moving Rats. *Neuroscience, 146(1),* 69-85.

Cromwell, H.C., Mears, R.P., Wan, L., & Boutros, N.N. (2008) Sensory Gating: A Translational Effort from Basic to Clinical Science. *Journal of Clinical EEG & Neuroscience, 39(2),* 1-4.

Davies, P.L., Chang, W., & Gavin, W.J. (2009) Maturation of Sensory Gating Performance in Children With and Without Processing Disorders. *Int J Psychophysiol, 72,* 187-197.

Dahir, N.S. (2014) Stress Regulation and Its Impact on Inhibitory Gating: Cross-Cultural Analysis. *Unpublished Manuscript*

Dalecki, A., Croft, R.J., Johnstone, S.J. (2011). An Evaluation of P50 Paired-Click Methodologies. *Psychophsiology, 48(12),* 1692-1700.

de Wilde O, Bour L, Dingemans P, Koelman J, & Linszen D. (2007). A meta-analysis of P50 studies in patients with schizophrenia and relatives: Differences in methodology between research groups. *Schizophrenia Research*, 97, 137–151.

Freedman, R., Adler, L.E., Olincy, A., Waldo, M.C., Ross, R.G., Stevens, K.E., & Leonard, S. (2002) Input Dysfunction, Schizotypy, and Genetic Models of Schizophrenia. *Schizophrenia Research, 54(1),* 25-32.

Fein, G., Biggins, C., & MacKay, S. (1996). Cocaine Abusers have Reduced Auditory P50 Amplitude and Suppression Compared to both Normal Controls and Alcoholics. *Biological Psychiatry, 39(11),* 955-965.

Gallagher, R., & Mckinley, S. (2007) Stressors and Anxiety in Patients undergoing Coronary Artery Bybass Surgery. *American Journal of Critical Care, 16(3),* 248.

Ghisolfi, E.S., Heldt, E., Zanardo, A.P., Strimitzer, I.M., Prokopiuk, A.S., Becker, J., et al. (2006) P50 Sensory Gating in Panic Disorder. *Journal of Psychiatric Research, 40(6),* 535-540.

Grachev, I.D., & Apkarian, A.V. (2000) Chemical Mapping of Anxiety in the Brain of Healthy Humans: An in Vivo H-MRS Study on the Effects of Sex, Age, and Brain Region. *Human Brain Mapping,* 11, 261-272.

Grant, K.E., Compas, B.E., Thurm, A.E., McMahon, S.D., & Gipson, P.Y. (2004). Stressors and Child and Adolescent Psychopathology: Measurement Issues and Prospective Effects. *Journal of Clinical Child and Adolescent Psychology, 33(2),* 412-425.

Gross, J.J., & John, O.P. (2003) Individual Differences in Two Emotional Regulation Processes: Implications of Affect, Relationships, and Well-Being. *Journal of Personality and Social Psychology, 85,* 348-362.

Grunwald, T., Boutros, N.N., Pezer, N., Oertzen, J.V., Fernandez, G., Schaller, C., & Elger, C.E. (2003) Neuronal Substrates of Sensory Gating Within the Human Brain. *Biological Psychiatry, 53(6),* 511-519.

Hetrick, W.P., Ozgur, B.M., Yousseff, M.M., Jin, Y., Potkin, S., Sandman, C.A., & Bunney, W.E. (1995) Reliability of P50 Gating in Normal Subjects. *Schizophrenia Research, 15(2),* 178.

Hofstede G. (1984) *cultures consequences: international differences in work-related values.* Beverly Hills: Sage.

Jessen, F., Kucharski, C., Fries, T., Papassotiropoulos, A., Hoenig, K., Maier, W., Heun, R. (2001) Sensory Gating Deficit Expressed by a Disturbed Suppression of the P50 Event-related Potential in Patient's with Alzheimer's Disease. *The American Journal of Psychiatry, 158(8),* 1319-1321.

Johnson, M.R., & Adler, L.E. (1993). Transient Impairment in P50 Auditory Sensory Gating Induced by a Cold-Pressor Test. *Biological Psychiatry, 33(5),* 380-387.

Knott, V., De La Salle, S., Smith, D., Phillipe, T., Dort, H., Choureiry, J., et al. (2013). Baseline Dependency of Nicotine's Sensory Gating Actions: Similarities and Differences in Low, Medium, and High P50 Suppressors. *Journal of Psychopharmacology, 27(9),* 790-800.

Korzyukov, O., Pflieger, M.E., Wagner, M., Bowyer, S.M., Rosburg, T., Sundaresan, K., et al. (2007) Generators of the Intracranial P50 Resoponse to Auditory Sensory Gating. *Neurolmage, 25(2),* 814-826.

Luck, S. (2005). An introduction to event-related potential technique. Cambridge, Massachusetts: A Bradford Book.

Mears, R.P., Klein, A.C., & Cromwell, H.C. (2006). Auditory Inhibitory Gating in Medial Prefrontal Cortex: Single Unit and Local Field Potential Analysis. *Neuroscience, 141(1),* 47-65.

Moxon, K.A., Gerhardt, G.A., Bickford, P.A., Austin, K., Rose, G.M., Woodward, D.J., & Adler, L.E. (1999) Multiple Single Units and Population Responses During Inhibitory Gating of Hippocampal Auditory Response in Freely-moving Rats. *Brain Res, 825,* 75-85.

Myles-Worsley, M., Coon, H., Byerly, W., Waldo, M., Young, D., & Freedman, R. (1996). Developmental and Genetic Influences on the P50 Sensory Gating Phenotype. *Biological Psychiatry, 39(4),* 289-295.

Perry, W., Minassian, A., Lopez, B., Maron, L., & Lincoln, A. (2007). Sensorimotor Gating Deficits in Adults with Autism. *Biological Psychiatry, 61(4),* 482-486.

Rentzsch, J., Jockers-Scherubl, M.C., Boutros, N.N., & Gallinat, J. (2008). Test-Retest Reliability of P50, N100, and P200 Auditory Sensory Gating in Healthy Subjects. *International Journal of Psychophysiology, 67(2),* 81-90.

Spielberger, C.D., Gorssuch, R.L., Lushene, P.R., Vagg, P.R., & Jacobs, G.A. (1983) Manual for the State-Trait Anxiety Inventroy. *Consulting Psychologists Press,* Inc.

Tashaini, O.A., Alabas, O.A., & Johnson, M.I. (2010) Cold Pressor Pain Responses in Healthy Libyans: Effect of Sex/Gender, Anxiety, and Body Size. *Gender Mdicine, 7(4),* 309-319.

Tregellas, J.R., Davalos, D.B., Rojas, D.C., Waldo, M.C., Gibson, L., Wylie, K., et al. (2007). Increased Hemodynamic Response in the Hippocampus, Thalamus and Prefrontal Cortex During Abnormal Sensory Gating in Schizophrenia. *Schizophrenia Research, 92(1),* 262-272.

Vagg, P.R., Spielberg, C.D., & O'Hearn, T.P. (1980). Is the State-Trait Anxiety Inventory Multidimensional? *Personality and Individual Differences, 1(3),* 207-214.

Wan, l., Friedman, B.H., Boutros, N.N., & Crawford, H.J. (2008) P50 Sensory Gating and Attentional Performance. *International Journal of Psychophysiology, 67(2),* 91-100.

Watson, D.C., Clarck, L.A., & Tellegen, A. (1988). Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales. *Journal of Personality and Social Psychology, 54(6),* 1063-1070.

White, P.M., Kanazawa, A., & Yee, C.M. (2005) Gender and Suppression of Mid-Latency ERP Components During Stress. *Psychophysiology, 42(6),* 720-725.

Woodman, G.F. (2010) A Brief Introduction to the Use of Event-Related Potentials in the Studies of Perception and Attention. *Attention, Perception, & Psychophysics, 72(8),* 2031-2046.

Yee, C.M., & White, P.M. (2001) Experimental Modification of P50 Suppression. *Psychophysiology, 38(3),* 531-539.

Zhang, X.Y., Liu, L., Liu, S., Hong, X., Chen, D.C., Xiu, M.H, et al. (2012) Short-Term Tropisetron Treatment and Cognitive and P50 Auditory Gating Deficits in Schizophrenia. *Am J Psychiatry, 169(9),* 974-981.

VII. Tables and Figures

Table 1.
Descriptive Statistics (N=10)

Measures	Minimum	Maximum	Averages	Std. Dev.
Pre-stress Latency (ms)	56.52	63.11	59.84	2.09
Post-stress Latency (ms)	57.90	63.42	60.22	2.02
Pre-stress T/C Ratio (mV)	.97	1.09	1.04	.04
Post-stress T/C Ratio (mV)	.98	1.30	1.08	.09
Pre-stress PANAS	3.70	5.80	3.52	1.17
Post-stress PANAS	3.10	5.70	3.55	1.49
Pre-stress SAI	2.26	3.63	3.06	.45
Post-stress SAI	2.47	3.84	3.40	.41
Pre-stress ERQ	2.60	4.00	4.50	1.13
Post-stress ERQ	3.20	4.30	4.34	1.10
T/C Difference	-.08	.28	.04	.11
PANAS Difference	-.40	-.10	.03	.32
SAI Difference	-.11	1.37	.34	.44
ERQ Difference	.60	0.00	-.16	-.03

Note. The differences were found by subtracting the Post-stress values from pre-stress

Table 2.
Paired Samples T-test

Measures	Df	Std. Deviation	Std. Error Mean	T value	Sig. (2-tailed)
Latencies	9	2.08	.66	-0.57	0.59
T/C Ratio	9	.11	.03	-1.23	0.25
PANAS	9	1.33	.44	-1.37	.20
SAI	9	.44	.14	-2.41	.039*
ERQ	9	1.12	.37	1.95	.082

*Note. *p<.05*

Table 3.
Multivariate Test of Changes in T/C and SAI

Effect	P Value	F	Hypothesis df	Error df
Pillai's Trace	.43	2.99	2.00	8.00
Wilks' Lambda	.57	2.99	2.00	8.00
Hotelling's Trace	.75	2.99	2.00	8.00
Roy's Largest Root	.75	2.99	2.00	8.00

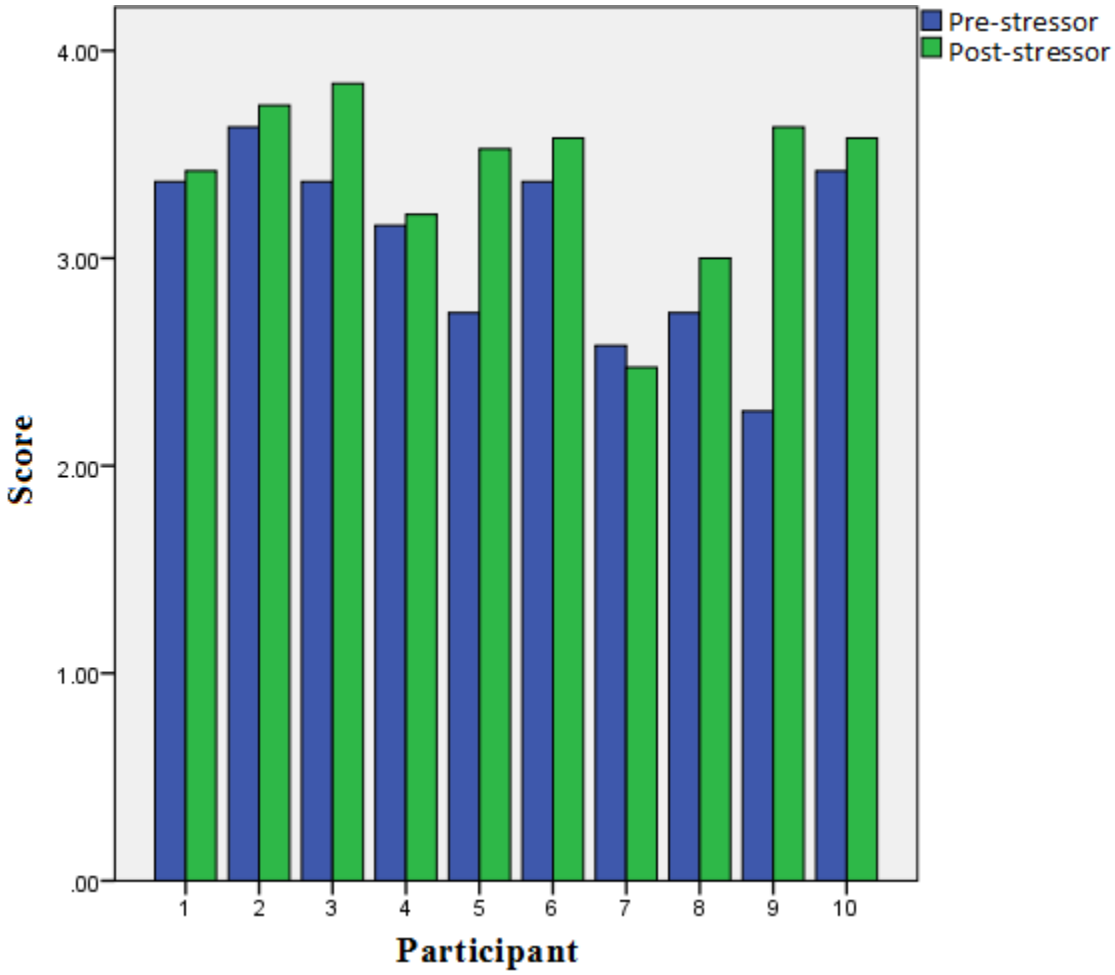

Figure 1. Changes of SAI scores with green bars being post-cold pressor task and blue indicating pre-cold pressor task.

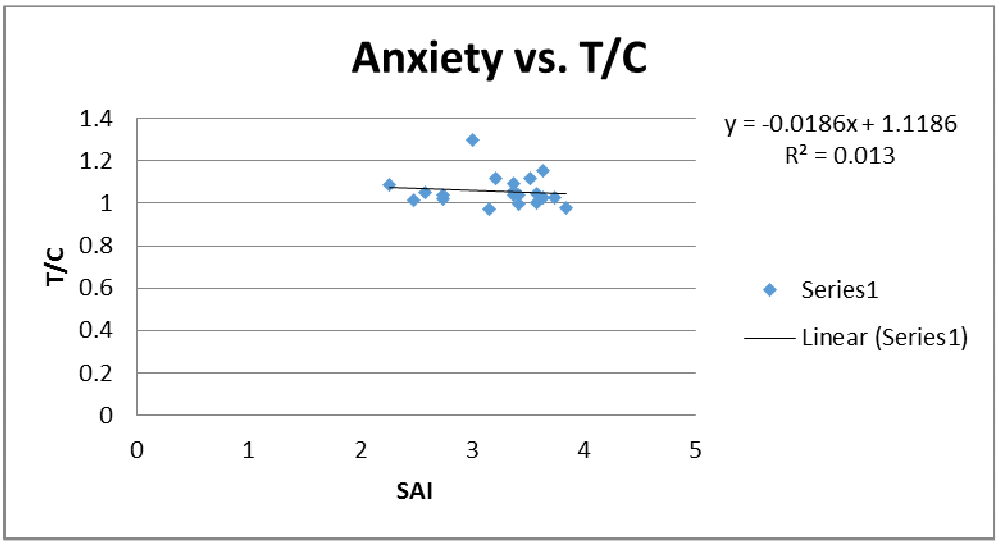

Figure 2. The correlation of the T/C ratios and the SAI scores.