Spring 4-1-2015

Electrophysiological changes of N100 latency and amplitude in healthy participants performing the Jitter Orientated Visual Integration task: a multi-block design study

Fariya Naz
University of Connecticut - Storrs, fariya.naz@uconn.edu

Recommended Citation

Electrophysiological changes of N100 latency and amplitude in healthy participants performing the Jitter Orientated Visual Integration task: a multi-block design study

Fariya Naz

University Scholar Committee:

Dr. Chi-Ming Chen

Dr. James Chrobak

Dr. Emily Myers

Abstract

The present study investigated the differences in processing during visual integration in healthy adults. The visual N100 indexes early visual discrimination and in this case, was hypothesized to show differences in both latency and amplitude depending on the level of difficulty which corresponds to orientational jitter in a visual integration task. Four blocks with pseudo-random levels of jitter were presented to participants in the Jitter Oriented Visual Integration (JOVI) task. Results looking at the Oz channel showed significant reduction in amplitude in the visual N100 during the more difficult levels condition of the task. The multi-block design, originally expected to show practice effects only exhibited an interaction effect with the easy levels in Event Related Potential (ERP) latency.

Background

Purpose

The current paper is the smaller part of a larger study exploring visual integration differences in healthy participants and patients with schizophrenia through the use of EEGs. This paper is intended to serve as the introductory basis for a separate healthy participant group that would yield optimal outcome for the cognitive task that was employed for this investigation. The constituents of this optimal healthy participant group are current students at the University of Connecticut who are in their late teens through early twenties.

Schizophrenia and Visual Perception

One of the main conditions that makes schizophrenia so disabling is the cognitive deficits that come along with it. Previous studies showed patients with schizophrenia to have difficulty with perceptual processing and thus deficit in visual integration of stimuli (Uhlhaas et al., 2006). Patients with schizophrenia have exhibited reduced visual contrast sensitivity for both static and dynamic stimuli (Kéri et al., 2002). Disorganized schizophrenia is a subtype of

schizophrenia in which disorganized schizophrenia, a subtype of schizophrenia in which disrupted thinking dominates over delusions and hallucinations—this low functioning population cannot perform routine tasks like bathing and getting dressed (Comer, 2013). Patients of disorganized schizophrenia were found to have abnormal organization of stimulus elements based on perceptual context for the concurrent stimulus. The surroundings of the visual stimulus disrupted their perception of the actual visual stimulus. The same deficits were not found in non-disorganized schizophrenia patients (Uhlhaas et al., 2006). Moreover, through treatment, reductions in disorganized symptoms were significantly correlated with improved visual perceptual organization. An fMRI examination of visual integration in patients with schizophrenia showed that during a contour integration task, even when both healthy control and patients with schizophrenia groups answered accurately, they were employing different regions of the brain. The healthy control group recruited more prefrontal and parietal areas whereas the patients group showed greater activation in the frontal regions during perception (Silverstein et al., 2009).

EEG Basics

EEGs measure the potential for electrical current to flow from one location to another. The number of charge units (electrons or protons) that can be measured to flow past a point over a specified amount of time is the current (Rex, 2009). To measure the pressure pushing that electrical current through the conductor, we must look at the voltage "potential" because it is the *potential* of electrical current flow from place to place (Rex, 2009).

In addition to action potentials, neurons also produce post-synaptic potentials (PSPs). When neurotransmitters bind to neuron membranes of a post-synaptic cell, ion channels open or close leading to a graded change in voltage across the membrane, called the PSP. Summed post-synaptic potentials can be measured when voltages are recorded from many neurons. Because action potentials do not fire at exactly the same time from several neurons to the level

of microseconds' degree of difference, action potentials cannot be recorded. Therefore, event-related potentials are products of PSPs instead of action potentials (Luck, 2014).

Pyramidal cells are thought to give rise to scalp event related potentials (ERPs). These cells are perpendicular to the cortical surface with the body and dendrites closer to the white matter and the apical dendrite in the direction of the surface of the cortex. If excitatory neurotransmitters are released, an electrical current in the form of positively charged ions will leave the extracellular space, leaving a net negativity on the outside of the cell body and flowing into the cell body and dendrites, making that region net positive. The flow creates a dipole with one end of a distance being positive and the other being negative charges. When these dipoles are summed together at the scalp, some neurons with varied directions of current can cancel each other's polarities; however, when a majority of the neurons have the same direction of current flow in a functional brain region, they will produce a signal that can be measured with a either a positive or negative polarity, an ERP component. The instantaneous PSP causes a voltage field throughout the head; meaning that without waiting for charged particles to move throughout, the potential for the current to flow, or the voltage can be measured (Luck, 2014).

Jitter Oriented Visual Integration Task

The NIMH sponsored Cognition in Neuroscience Treatment Research to Improve Cognition in Schizophrenia (CNTRICS) project (Henderson et al., 2012) began in 2007, to reduce perceptual disability by pinpointing key cognitive constructs that are essential in schizophrenia and developing a way to identify measures that could be optimized in specific neural systems. One such measure, the Jitter Orientation Visual Integration task (JOVI), has recently tested the goal of assessing visual integration. Findings from that study showed that the jitter manipulation produced the intended effects on visual integration: Patients with schizophrenia performed worse overall in comparison to healthy control participants and they performed more like the healthy control group as the task became harder simply because

everyone's performance decreases past a certain threshold like a floor effect (Silverstein et al.,

2011). The JOVI employs integration systems in the visual field by probing a perceiver in

identifying the orientation of a contour element. Most of the findings of visual contour studies

support the concept of "association field" suggesting that neurons whose orientations are of

similar manner, facilitate the firing of other neurons around them whereas neurons that encode

elements whose orientation is more varied without any particular pattern, tend to portray

inhibitory effects upon one another (Field et al., 1993).

The present paper used a contour integration task to study orientation integration

information across the visual field. The task required identifying the direction of a round/oval

configuration composed of single features within a uniform gray background of randomly

oriented features (Figure 1 in Method Section). The varying number of Gabor elements are

Gaussian-modulated distributions that model known receptive field properties of V1 neurons. In

order to study spatial integration and perceptual organization without the influence of other

cognitive processes, the Gabor elements were the most appropriate option. Linking these

elements required interactions to occur between long-range and local filters which combined

would show the process of visual integration. The long-range connection is technically the

reentrant feedback from the secondary visual cortex or even a higher visual area that has been

implicated for enhancing visual representations of global shape. This is particularly true during

contour detection in the present of noise as is the case with the JOVI task (Silverstein & Keane,

2011).

ERPs and Visual Integration

The visual N100 or N1 is an ERP component that is an index for stimulus discrimination

process (Hopf et al 2002, Vogel and Luck 2000). ERPs are EEG signals that are time-locked to

a stimulus; the components correspond to the amplitude polarity (e.g., P for positive and N for

negative) and temporal range in milliseconds. ERPs' reliable temporal resolution allow for the

study of automatic, subconscious cognitive processing occurring in the brain like attention and memory updating (Coles & Ruggs, 1995a). The visual N100 is greater in amplitude during attentional stimulus processing, known as the N1-effect (Hillyard et al 1973). If a stimulus is presented in a location that is being attended, a larger N1 component is exhibited than if the stimulus were presented in an unattended location (Luck and Hillyard 1995). Using ERP in conjunction with magnetoencephalography greater negativity has been found for N1 during discriminative processing; the effect was largest in the occipital cortex (Hopf et al 2002). The N100's generator at the posterior electrode sites is the extrastriate cortex (Gonzalez et al 1994) with contributions from parieto-occipital and occipito-temporal areas (Hopf et al 2002). When looking at both feature detection (color) in conjunction with the discrimination condition (shape), the discrimination condition requires more attentional processes beyond those required for feature detection (Luck and Hillyard 1995). When gathering more attentional resources for a discriminatory task, visual ERP component, P300 reduced in amplitude (Lavoie et al., 2004). Reduction in amplitude may occur because multiple areas of the cortex are employed to gather attentional resources especially when further effort is required (Lavoie et al., 2004). The present study investigated characteristics of the visual N100 component in the discrimination condition processing to see how it would be modulated at two levels of difficulty. We hypothesize that participants' N100 amplitude and latency will change through manipulation of orientational jitter and the multi-block paradigm for this study.

Method

Subjects

Sixteen right-handed and two left-handed subjects with normal or corrected to normal vision (nine females and nine males; mean age, 18.50 years; SD 1.17 years; age range, 16-21 years).

Screening and Assessments

All participants underwent a thorough mental health evaluation using the Structured Clinical Interview for DSM-IV Axis I disorders (SCID). The participants were also assessed on the Brief Visuospatial Memory Test, Edinburgh Handedness Questionnaire, Sensory Gating Inventory, and the Schizotypal Personality Questionnaire. Healthy participants were then prepared to put on the EEG cap.

Task

After being outfitted with the active gel 64-electrode cap, subjects were situated in front of a monitor in a sound-attenuated room with incandescent lighting. The monitor displayed a script controlled by Presentation software by Neurobehavioral Systems Inc. (Berkeley, CA). Participants saw instructions on how the JOVI task would be presented. Participants were asked to respond as quickly as possible, via a Cedrus RB-834 response pad (Cedrus Corporation, San Pedro, CA), indicate the right or the left of the pointing of an egg shaped contour. Participants were presented with stimuli through a 24" LED monitor distanced 100 cm from the eyes of the participant. The visual stimulus is an egg shaped contour pointing to either the right or the left. The farther the contour element was from $0°$ tangent to its original position, and the closer the adjacent elements become, the visibility of the egg's orientation was reduced. We presented four blocks with 80 trials in each block that contained orientational jitter to the contour elements for six levels: $\pm\ 0°,7°,9°,11°,13°,15°$. Gabor elements' quantity was held constant for all trials. Two of the trials in each block were catch trials where the contour was automatically outlined to make sure the participants were paying attention the task. Chart 1 shows all of the trials as that were presented during one block; when the configuration was presented, the order of orientational jitter and direction of shape were placed in a

pseudorandom order.   The stimulus was presented for two seconds.   Interstimulus interval
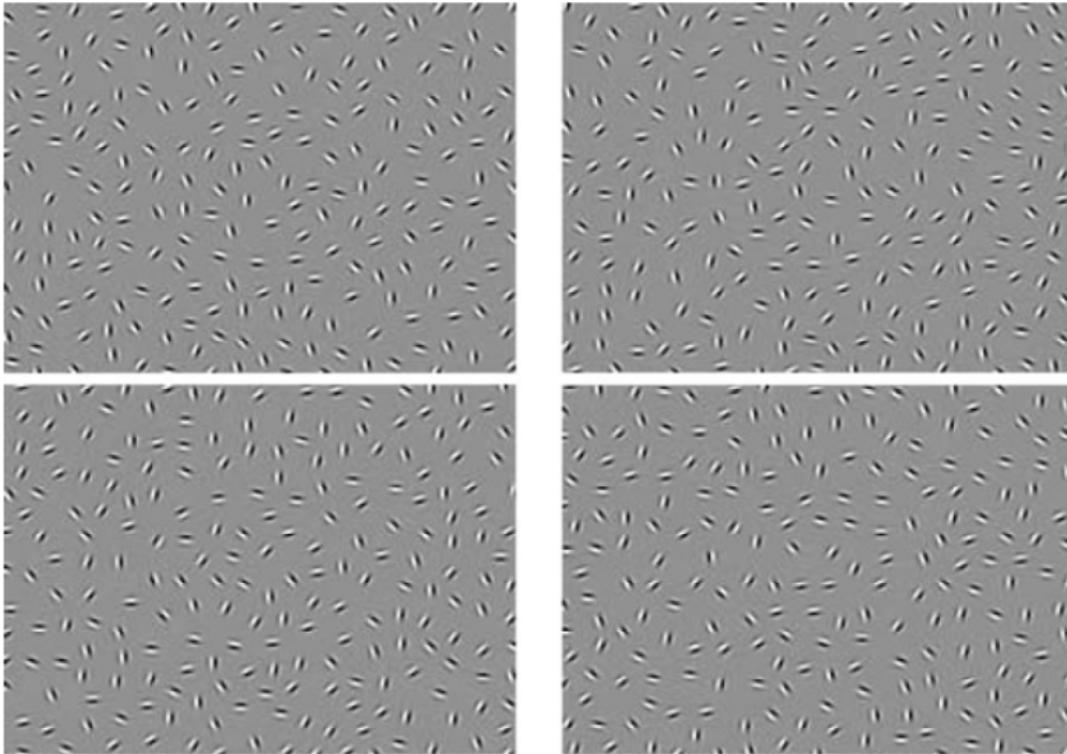
lasted three seconds.

Figure 1: Samples of images from the contour integration task. Top left: 0° jitter, top right: 7–8° jitter, bottom left: 11–12° jitter, and bottom right: 15–16° jitter.

Chart 1: Description of the trials presented for each block in the JOVI task.

Orientational Jitter	Number of Trials	Direction of Shape
0°	6	Left
7°	6	Left
9	6	Left
11°	6	Left
13°	6	Left
0°	6	Right
7°	6	Right
9°	6	Right
11°	6	Right
13°	6	Right
15°	1	Left
15°	1	Right

ERP Data Collection

Once impedances were low enough (below 5 kΩ), participants were seated 100 cm away from the 24" monitor to begin the task. The software system used to collect EEG data was Brain Vision Recorder software (Brain Product GmbH, Gilching, Germany). Data was recorded before, during, and after the JOVI task through a 64-channel active electrode system (BrainAmp MR Plus amplifier, Brain Product GmbH, Gilching, Germany). The sampling rate for this study was 1000 Hz. Direct current EEG data was low-passed at 1 KHz, digitized at 1 KHz.

ERP Data Pre-processing

Data was re-referenced using the average of all of the electrodes that did not have bad channels. Data from the Oz electrode were used for this study. Data was filtered using a band pass filter from .4 to 15 Hz. We also used a notch filter of 60 Hz. Data was segmented at -500.00 ms before stimulus onset and ended at 3000.00 ms leading to a 3500.00 ms epoch length. Overlapped segments were allowed and bad intervals were automatically skipped. Any trials with blinks or other artifacts between the stimulus and response were identified through visual inspection and omitted. Baseline correction was set at -100 ms to -5 ms. The N100 time window was 100-200 ms. For each participant, two combined averages were derived from the six levels of trials such that the easy difficulty composed of $\pm$ 0°,7°, 9° and the hard difficulty trials were thus averages of the $\pm$ 11°,13°, and 15° orientational jitter trials.

Results

Our independent variable is level of difficulty and four block design; dependent variables are N100 amplitude and latency. A repeated-measures multivariate analysis of variance was conducted to evaluate the effect of jitter difficulty on the N100. The dependent variables were:

latency and amplitude.   The two within-subjects factors were difficulty and four blocks.   A difficulty main effect on was significant in the multivariate test (Figure 2 visual), Wilk's Λ = .57, $F(2,16)$ = 6.11, p = .011. Changing the orientational jitter made the task difficult enough to see a difference in performance between easy and difficult trials.   ERP data for some individual participants seemed to show that jitter had an incremental effect of N100 amplitude (Figure 3). Orientational jitter also influenced N100 latency; latency univariate test showed significant results, $F(1,17)$ = 5.98, p = .026 (Figure 4). Orientational jitter effected N100 amplitude; the univariate test for amplitude was significant, $F(1,17)$ = 5.77, p = .028 (Figure 5). The block design showed an interaction effect, $F(1,17)$ = 10.58, p = .005 (Figure 6). After multiple comparison corrections in the behavioral data, BVMT & SPQ measures, and component values, for p values, no correlation coefficients reached significance of .05.
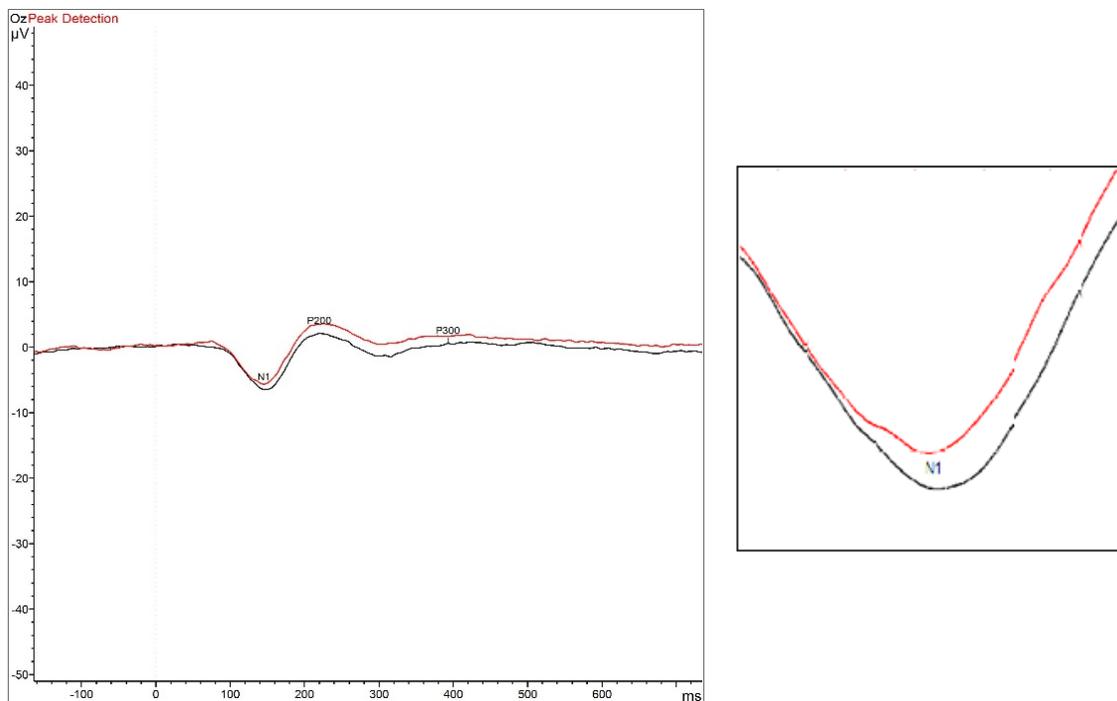
Figures 2a and 2b: Black line is the easy trials (0°,7°, 9°) and the red line is the difficult trials (11°,13°,15°). Grand averaged ERP waveforms for all participants. Zoomed in, difficult trials led to reduced N100 amplitudes Wilk's Λ = .57, $F(2,16)$ = 6.11, p = .011.
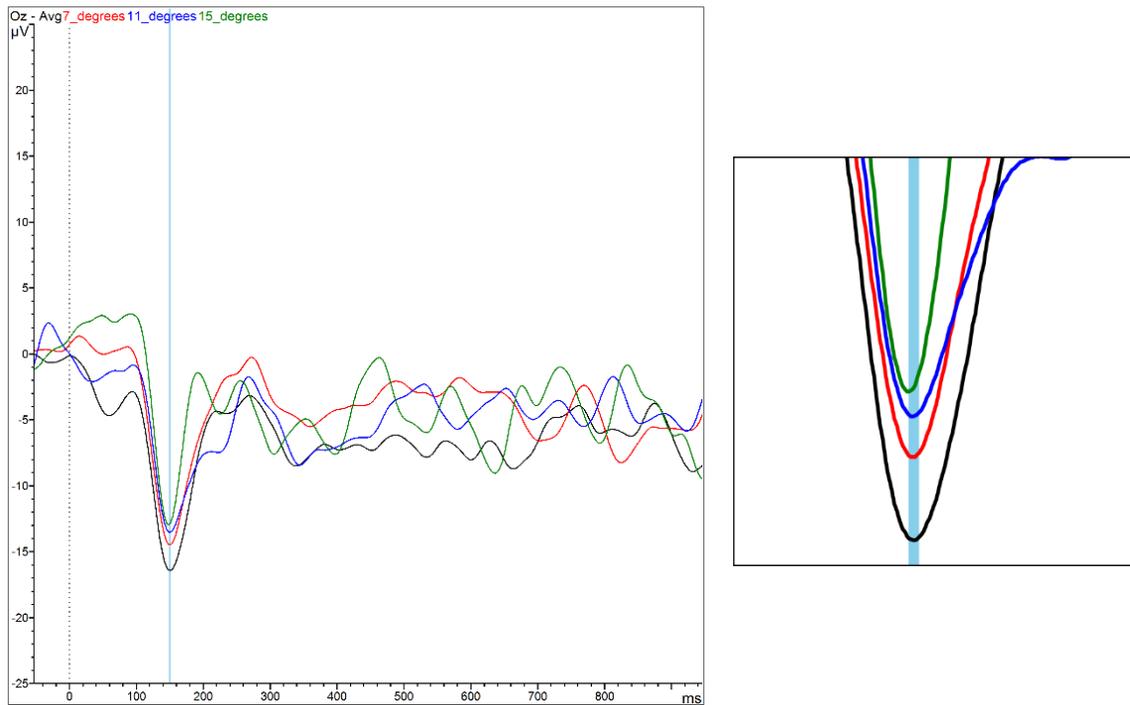
Figures 3a and 3b: Black line is 0°, red is 7°, blue is 11°, and green is 15°. Combined average of one participant including all four blocks for specific levels of difficulty. Zoomed in, as trials become harder, latency and amplitude both decrease.
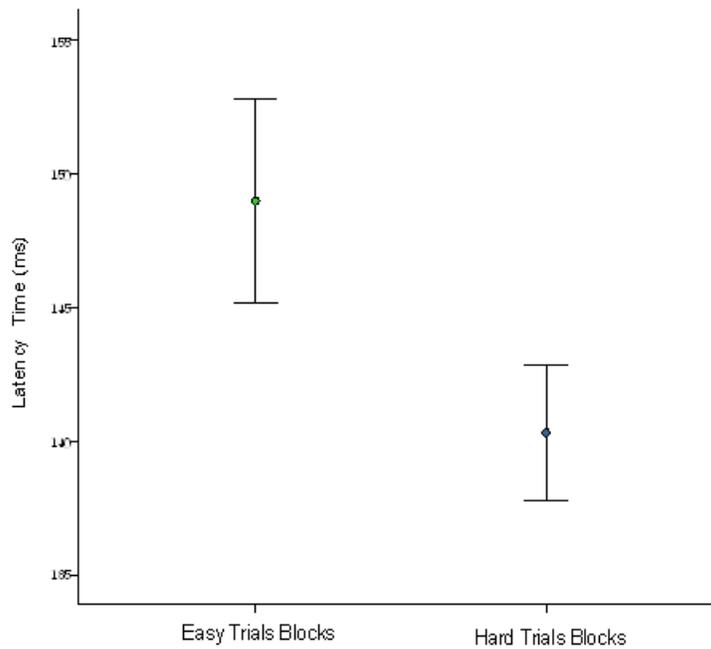
Figure 4: The more difficult levels of the task yielded a shorter N100 latency $F(1,17) = 5.98$, $p = .026$.
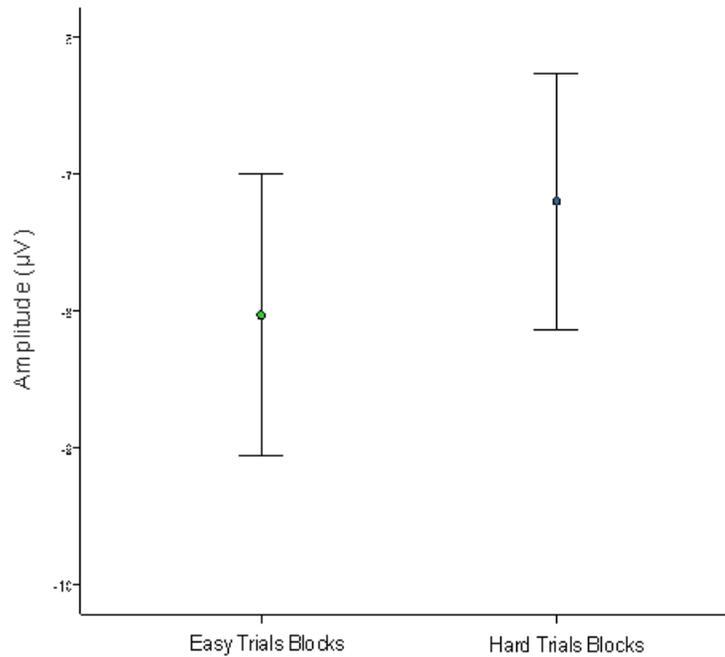

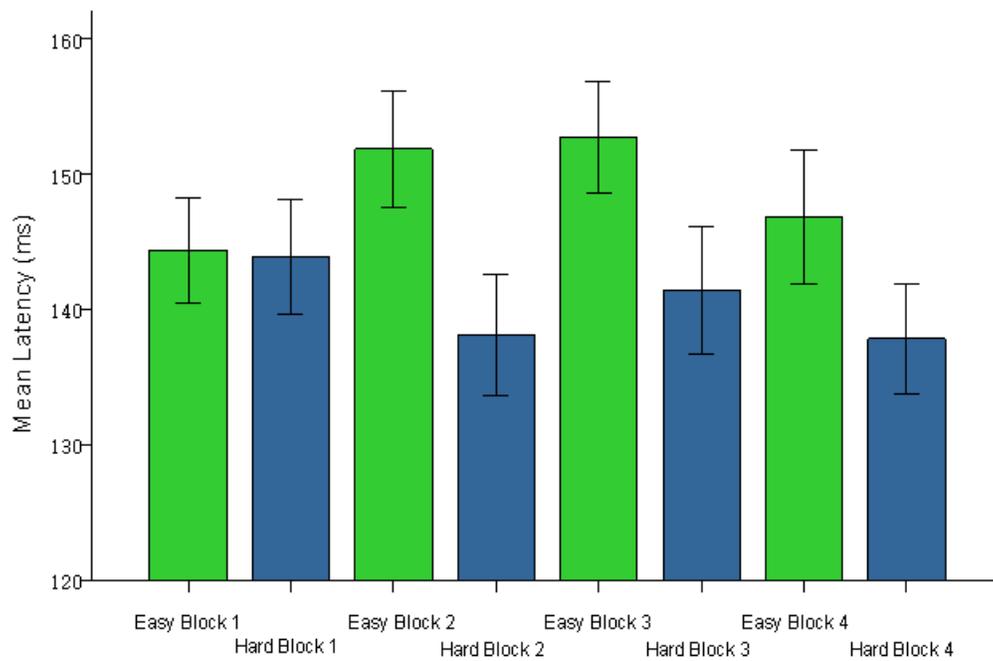**Figure 5: N100 amplitude decreased as the task became more difficult $F(1,17) = 5.77$, $p = .028$.**

Figure 6: The block design statistically shows a quadratic curve only for the easy trials leading to an interaction effect $F(1,17) = 10.58$, $p = .005$ for easy blocks and N100 latency.

Discussion

The present study found that the visual N100 amplitude is varied depending on the level of jitter in the JOVI task. N100 reduction was exhibited as the task became more difficult. The block design did not produce any practice effects, but a quadratic relationship became apparent as the interaction effect between latency and easy blocks. In Figure 6, we can see that for the first block, participants treated the easy and hard trials the same way, but adjusted strategy moving forward. For the easy blocks, participants took their time in trying to figure out a response, but they seemed to give up and respond more quickly when they were below the threshold of confidence in their response. The only other study that has explored the N100 component in the JOVI task found that the low condition in jitter produced a smaller peak, which is consistent with our findings for the easy trials (Butler et al., 2013). No significant N100 amplitude differences in patients with schizophrenia and healthy participants were found for the task (Butler et al., 2013), but this may be due to the fact that the high level jitter used was 27-28°, a level too high for any population to detect whether or not they have perceptual impairments leading to identical performance for both groups.

Further analysis of behavioral measures and memory assessments will occur in the future. The findings here will provide a baseline for what is typical in the JOVI task. The gradation in our healthy controls was strong (Figure 4); however, patients with schizophrenia will probably not show this same amount of change with each level of difficulty (Silverstein et al., 2011). Performance for patients should be different in comparison to our optimal healthy control group because patients' faulty feedback mechanisms will cause them to perform differently in the JOVI task relative to our healthy optimal group. To an extent, patients with schizophrenia habituate to all stimuli as a compensatory measure because of the reduced feedback from attention regions that would typically amplify relevant visual information relative to irrelevant information (Silverstein et al., 2009). Another possibility is an impaired contour integration

system that reduces involuntary shift in attention for the target, inhibiting form discrimination at the simplest levels of jitter orientations (Silverstein et al., 2011).

Based on previous findings for patients who have schizophrenia and specifically looking at the mismatch negativity (MMN) component, there should be differences in cognitive processes between the two groups (Light & Swerdlow, 2015). Future direction of this study would be to assess the differences in early visual integration by creating an oddball variation of the JOVI task to evoke the MMN. Like the N100, MMN is a pre-attentive ERP component that can be elicited without an overt behavioral response. It is presumed to index the automatic, preconscious processing of mismatch detection between a deviant stimulus and a memory trace. Impaired MMN predicts development of psychosis, conversely, spared MMN predicts response to treatment (Light & Swerdlow, 2015). MMN has been supported as a biomarker for psychosis and should therefore also be studied in a basic visual integration paradigm to see how modulation of this ERP component effects cognitive processing in patients with schizophrenia (Light & Swerdlow, 2015).

One weakness of the present study was the inclusion of left-handed individuals. With the intention of screening out participants who did not meet this criteria eventually leading to below target sample number for our study, we decided to include two participants who were left handed. Additionally, the mean age for our participants was 18.50 years which is still an age where the brain is developing. These students were enrolled in a four year college program who passed our SCID screenings which meant that they were high functioning individuals. These factors allow our sample to be considered an optimal third group in addition to a separate healthy control group in the larger study looking at visual integration in patients with schizophrenia before and after therapeutic interventions.

Neural mechanisms for visual integration deficits in schizophrenia can be attributed to any stage of visual processing and also vary by the kind of schizophrenia that the patient has. Stimulation of receptive fields in neurons expose a long-distance integration of visual signals

within primary visual cortex exceeding the typical receptive field of single neurons taking local signals and generating global precepts (Angelucci et al. 2002). Patients with schizophrenia who have pronounced negative symptoms show an impairment in figure-ground segregation due to weak center-surround suppression in motion (Tadin et al. 2006). Schizophrenia patients also have shown impairments in perceptual grouping of input requiring top-down processing (Phillips & Silverstein 2003). Furthermore, distinguishing between context-processing mediated through working memory and that which is driven through concurrent stimulus can again, have different effects based on the types of schizophrenia symptoms that are exhibited. For example, in the concurrent cognition, the surrounding visual context is responsible for changing the perception of a stimulus while the elements of the stimulus stay the same. Thus leaving the abnormal organization of stimulus elements (Uhlhaas et al., 2006).

Finally, the results of both the manipulations of orientational jitter and presenting the task in a multi-block procedure provide a strong compliment to the validity of the JOVI task as it was intended to be used (Silverstein et al., 2011) to see differences in visual integration. Healthy participants were able to show significant electrophysiological differences based on the difficulty of the task. Ergo, visual integration can be modulated through the JOVI task and these differences can be referenced through the use of ERPs leading to promising potential in future study of this task in patients who have schizophrenia especially on its implications for their visual integration and how that will differ.

References

Angelucci, A., Levitt, J. B., Walton, E. J., Hupe, J. M., Bullier, J., & Lund, J. S. (2002). Circuits for local and global signal integration in primary visual cortex. *The Journal of Neuroscience*, *22*(19), 8633-8646.

Butler, P. D., Abeles, I. Y., Silverstein, S. M., Dias, E. C., Weiskopf, N. G., Calderone, D. J., & Sehatpour, P. (2013). An event-related potential examination of contour integration deficits in schizophrenia. *Frontiers in psychology*, *4*.

Coles, M.G.H., & Ruggs, M.D. (1995a). Event-related potentials: An introduction. In M.D. Rugg & M.G.H. Coles (Eds.), Electrophysiology of mind: Event-related potentials and cognition (pp. 1–23). New York, NY: Oxford Psychology Series.

Comer, R.J. (May 22, 2013). *Abnormal Psychology* . : Worth Publishers; Eighth Edition edition .

Field, D.J., Hayes, A., Hess, R.F., 1993. Contour integration by the human visual system: Evidence for a local "association field". Vision Research 33, 173-193.

Gomez-Gonzales, C. M., Clark, V. P., Fan, S., Luck, S., Hillyard, S. A., Sources of attention sensitive visual event-related potentials, Brain Topogr, 1994, 7, 41–51.

Henderson, D., Poppe, A.B., Barch, D.M., Carter, C.S., Gold, J.M., Ragland, J.D., Silverstein, S.M., Strauss, M.E., MacDonald, A.W., 2012. Optimization of a Goal Maintenance Task for Use in Clinical Applications. Schizophrenia Bulletin 38, 104-113.

Hillyard, S.A., Hink, R.F., Schwent, V.L., Picton, T.W., Electrical signs of selective attention in the human brain, Science, 1973, 182,177–180

Hopf, J., Vogel, E., Woodman, G., Heinze, H., & Luck, S. J. (2002). Localizing Visual Discrimination Processes in Time and Space. Journal Of Neurophysiology, 88(4), 2088-2095.

Kéri, S., Antal, A., Szekeres, G., Benedek, G., & Janka, Z. (2002). Spatiotemporal visual processing in schizophrenia. *The Journal Of Neuropsychiatry And Clinical Neurosciences*, *14*(2), 190196. doi:10.1176/appi.neuropsych.14.2.190

Lavoie, M. E., Dupuis, F., Johnston, K. M., Leclerc, S., & Lassonde, M. (2004). Visual P300 effects beyond symptoms in concussed college athletes. Journal Of Clinical And Experimental Neuropsychology, 26(1), 55-73. doi:10.1076/jcen.26.1.55.23936

Light, G. A., & Swerdlow, N. R. (2015). Future clinical uses of neurophysiological biomarkers to predict and monitor treatment response for schizophrenia. *Annals of the New York Academy of Sciences*.

Luck, S. J. (2014). *An Introduction To The Event-Related Potential Technique* (2nd ed., Vol. 1, p. 406). Cambridge, Massachusetts: The MIT Press.

Luck, S. J., & Yard, S. A. H. (1995). The role of attention in feature detection and conjunction discrimination: An electrophysiological analysis. International Journal of Neuroscience, 80(1-4), 281-297.

Phillips, W. A., & Silverstein, S. M. (2003). Convergence of biological and psychological perspectives on cognitive coordination in schizophrenia. *Behavioral and Brain Sciences*, *26*(01), 65-82.

Rex, A. (November 6, 2009). *Essential College Physics 2.* : Addison-Wesley.

Silverstein, S. M., Berten, S., Essex, B., Kovacs, I., Susmaras, T., & Little, D. M. (2009). An fMRI examination of visual integration in schizophrenia. *Journal of integrative neuroscience*, *8*(02), 175-202.

Silverstein, S. M., Keane, B. P., Barch, D. M., Carter, C. S., Gold, J. M., Kovács, I., & ... Strauss, M. E. (2012). Optimization and validation of a visual integration test for schizophrenia research. *Schizophrenia Bulletin*, *38*(1), 125-134. doi:10.1093/schbul/sbr141

Tadin, D., Kim, J., Doop, M. L., Gibson, C., Lappin, J. S., Blake, R., & Park, S. (2006). Weakened center-surround interactions in visual motion processing in schizophrenia. *The Journal of neuroscience*, *26*(44), 11403-11412.

Uhlhaas, P.J., Phillips, W.A., Schenkel, L.S., Silverstein, S.M., 2006. Theory of mind and
        perceptual context-processing in schizophrenia. Cognitive Neuropsychiatry 11, 416-436.
Vogel, E.K., Luck, S.J., The visual N1 component as an index of a discrimination process,
        Psychophysiology, 2000, 37, 190-203