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Disruption of Executive Attention in Schizophrenia

by

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ABSTRACT

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Disruption of attention is a hallmark symptom of schizophrenia, and event-related potentials have been instrumental in studying this deficit in these patients. Prior studies have shown consistent reduction of the auditory P300 in schizophrenia, while visual attention findings have been mixed. Both the auditory and visual N2b, an earlier, modality-specific attention index, are often reduced in schizophrenia, sometimes despite sparing of the visual P300. Thus there may be a dissociation between N2b and P300 attention effects in the auditory and visual modalities in schizophrenia. This study used auditory and visual oddball tasks and two bimodal tasks, each with a modality-specific target. Results showed that the N2b was differentially impacted in the patient group across modalities, while the P300 remained intact. This evidence suggests non-reduction of the P300 may be due to effortful compensation for deficits in the more vulnerable N2b component of stimulus classification in patients with schizophrenia.
Acknowledgments

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Introduction

Schizophrenia is a chronic and debilitating psychiatric disorder afflicting approximately one out of every hundred persons worldwide. It seems to strike men more frequently and severely than women, with onset generally in the late teens to early twenties. Even today, with the advent of anti-psychotic drug therapies, schizophrenia accounts for thirty percent of all hospitalizations in this country. Approximately ten percent of people with schizophrenia commit suicide and thirty percent of the nation’s homeless have this illness. (Kandell, Schwartz & Jessell, 2000).

When Emil Kraeplin first identified and described the disease, he called it “dementia praecox”, meaning a dementing illness occurring in young people. The Swiss psychiatrist Eugene Bleuler recognized that not all patients deteriorated into the demented state. He believed, however, that all patients did have some disturbance in thought, and thus coined the term we use today referring to a “splitting of the mind.” (Andreason, 1984).

Schizophrenia is a very complicated illness with diverse symptoms. There is usually an initial psychotic episode (or “first break”) which is preceded by prodromal signs including social isolation and withdrawal, odd behavior and ideas, neglect of personal hygiene and blunted affect. The psychotic episode may be followed by residual symptoms including social isolation, flat affect, poverty of speech, a lack of motivation and poor attention span (Kandell et al., 2000). The American Psychiatric Association has adopted a set of diagnostic criteria in which some symptoms must be present for at least one month with others persisting for at least six months (See Appendix). No single symptom is pathognomonic of schizophrenia. Diagnosis involves recognition of a
combination of symptoms in conjunction with marked social and occupational
dysfunction. These symptoms fall into two broad categories – positive and negative. So-called “positive” symptoms include delusions, hallucinations, disorganized speech and
grossly disorganized behavior. “Negative” symptoms include restrictions in emotional
expression, poverty of speech, loss of initiation of goal-directed behavior and attentional
impairments (American Psychiatric Association, 1994).

Schizophrenic patients have difficulty focusing attention on salient cues and
overcoming the disrupting effects of extraneous stimuli. Therefore, these patients are
subject to cognitive over-stimulation, cognitive fragmentation and thought disorder
induced by this inability to sort out cognitive cues and stimuli from the complex world
that surrounds us (Braff, 1993). Schizophrenic patients also show information
processing deficits. The brain processes of selective attention “serve the purpose of
allowing for and maintaining goal-directed behavior in the face of multiple, competing
distracters.” (Parasuraman, 1998, p. 3). The inability to make appropriate use of
contextual evidence in production and understanding of language and in goal-directed
behavior may be caused by the inability of these patients to keep relevant information “in
mind” while attending to a task (Andreason, 1984).

Localized pathology of cortical areas may not be a sufficient explanation for the
loss of selective attention in schizophrenia. Strong negative symptoms in schizophrenia
have been associated with a neural “disconnectivity” (Brand, Hildebrandt, Cabuk, &
Zimmerman, 2001). It is purported that even symptoms such as hallucinations and
delusions may be better understood in terms of abnormal integration of cortical areas, or
abnormal functional connectivity, particularly the fronto-temporal disconnection.
Numerous studies have evaluated the impairment of attention associated with the negative symptoms of schizophrenia using various techniques. Studies utilizing neuropsychological testing (Elliott R, McKenna PJ, Robbins TW & Sahakian BJ, 1995; Weiss KM, 1996; Capelton RA, 1996; Allen DN, Goldstein G & Weiner C, 2001), volumetric analyses with MRI (Convit A, Wolf OT, DE Leon MJ, Patalinjug M, Kandil E, Caraos C, Scherer A, Saint Louis LA & Cancro R, 2001), functional MRI (Semkovska M, Bedard MA & Stip E, 2001), and PET analyses (Wolkin A, Sanfilipo M, Wolf AP, Angrist B, Brodie JD & Rotrosen J, 1992) have all presented evidence of a frontal lobe dysfunction in schizophrenia. In an event-related potential study of auditory attention (Nagasawa, Kamiya T, Kawasaki Y, Hagashima M, Urata K, Sakai N & Koshino Y, 1999), findings showed a reduced P200 amplitude which was correlated with poor performance on neuropsychological tests of selective attention. In a review by Weinberger and associates (Weinberger DR, Aloia MS, Goldberg TE & Berman KF, 1994) evidence of hypofrontality, particularly in the dorsolateral prefrontal cortex, has been shown. They concluded that executive function deficits in schizophrenia are a result of a dysfunction of the prefrontal cortex in which there is a failure of functional intracortical connectivity which may affect various neural systems. These neural systems may include accessing the limbic system as well as the modulation by the prefrontal cortex (PFC) of dopamine neurons in the ventral tegmental area which affects the dopamine afferent gain back to the PFC. Thus, executive attention disruption in patients with schizophrenia may be attributed to a frontal lobe dysfunction.

Primate studies show that the neural systems involving the prefrontal cortex and associative sensory areas are critical for attending to a task (Fuster, 1989, 1993). In the
visual modality in humans, neurons in the prefrontal cortex integrate information about an object and its spatial location which is necessary to guide behavior. The prefrontal cortex receives this input from the ventral pathway through the inferior temporal lobe, which processes information about the color and shape of objects; and from the dorsal pathway through the posterior parietal cortex that processes information about the location of objects in space. In the auditory modality, the prefrontal cortex receives input from the auditory cortex in the superior temporal lobes (Kandell, et al., 2000).

Event-related potential (ERP) studies have proven instrumental in studying neural generators of auditory and visual attention and their disruption. The P300 component has been put forth as being the principle index of attention (Ford, 1999) and therefore indicative of frontal lobe activity. The reduction of the amplitude of the auditory P300 in schizophrenia is the most documented finding in ERP studies (McCarley, O’Donnel, Nizinkiewicz, et al., 1997; O’Donnell, McCarley, Potts, et al., 1999; and Ford, 1999). However, the P300 component may be a non-specific indicator of global processing, rather than an index of attention allocation, as its peak may occur after a behavioral response (McCarley, O’Donnel, Nizinkiewicz, et al., 1997; O’Donnell, McCarley, Potts, et al., 1999; and Ford, 1999). Also, there is evidence supporting the idea that the P300 reduction may be dissociable from the earlier negative components which may provide more specific indices of stimulus evaluation and attention allocation (Kayser, Bruder, Tenke, Stuart, Amador & Gorman, 2001).

Evidence from auditory studies suggests the importance of several ERP components in auditory target detection and attention. A study of normal subjects showed the N2b component of the ERP is the initial index of target detection. Its scalp
location is consistent with frontal and superior temporal cortex, suggesting selective attention and auditory stimulus representation (Potts, Dien, Hartry-Speiser, McDougal & Tucker, 1998). The N2 component amplitudes have been shown to be bilaterally reduced in schizophrenics when performing auditory tasks (e.g., O’Donnell, Shenton, McCarley, Faux, Smith, Salisbury, et al., 1993). In a detection task, even though schizophrenics performed almost as well as normals, their N2 amplitudes were almost absent suggesting a disturbance in stimulus classification and attention processes directly related to pathology of N2 generators (Salisbury, O’Donnell, McCarley, Shenton, et al., 1994). Additional ERP evidence also shows that in addition to the N2 reduction, there is often a reduction in the amplitudes of auditory and visual N1 component as well (Ford, White, Csernansky, Faustman, Roth & Pfefferbaum, 1994, Bougerol, Benraiss & Scotto, 1996, O’Donnell, Hokama, McCarley, Smith, Salisbury, Mondrow, et al., 1994).

A recent auditory oddball study found an absence of the P2a/N2 component, as well as a reduction of the P300, in patients with schizophrenia (Potts, Hirayasu, O’Donnell, et al., 1998). The scalp topography of the P2a/N2 in that study was consistent with separate frontal and temporal neural generators. The absence of the N2 was especially evident in the target minus difference ERP waveform. The reduction of these components could be indicative of the reduction of auditory selective attention evident in schizophrenia.

ERP studies of visuo-spatial attention have also shown some particular component reductions in patient groups. Schizophrenic subjects have shown a profound reduction of N1 and N2 amplitude in a visuospatial task (Bruder, Kayser, Tenke, et al., 1998). However, the P300 component often appears to remain relatively unaffected in
the visual modality (for a review, see Ford, 1999). A recent study confirmed that in a visual object/spatial attention task, both the P2a and N2 components were reduced in schizophrenic subjects while the P300 was not (Potts, O'Donnell, Hirayasu, & McCarley, 2002). This finding would appear to indicate a specific reduction of the P2a/N2b component and not an overall ERP reduction. Therefore, the P300 component may not be an overall index of attention, as it is spared in the visual but not in the auditory modality in patients with schizophrenia. This evidence suggests that the reduction of the P2a/N2b component may be a better indicator of dysfunction in the neural systems of attention, with the P2a indexing frontal lobe activity and the N2b indexing frontal modulation of modality-specific posterior activity.

In a previous study of selective attention (Wood, S.M., Potts, G.F., Kotrla, K., Hall, J.F., Ulanday, J.B. & Andrews, J., 2004), a group of schizophrenic patients and a group of normal controls performed a selective attention task with simultaneous presentation of auditory and visual stimuli. Subjects were asked to respond to either an auditory or visual target in separate task blocks. It was hypothesized that there would be a reduction of the P2a/N2b component in the patient group across modalities, but that the P300 component would be reduced in the auditory but not in the visual modality. The results from this study showed a reduction of the N2b in both modalities while the P300 component was not different between groups in either modality. The presence of a visual stimulus appeared to mediate the usual finding of reduction of the P300 in auditory attention.

Overall, however, the previous literature suggests a differential impact of schizophrenia on the auditory and visual ERP, specifically a reduction of the N2b
component in both modalities but only a reduction of the auditory P300 in the patient groups. Therefore, as our previous study showed different findings from much of the previous work in this area, the current study was undertaken in order to explore the dissociation of these components across different design conditions and across modalities to elucidate our previous findings. To accomplish this, the present study investigated the ERPs of attention disruption in schizophrenia using simple auditory and visual oddball tasks as well as a simultaneous presentation of auditory and visual stimuli with the instructional set of attending to a target in one modality while ignoring the stimuli in the other modality. This design allowed a comparison of the auditory and visual ERPs across tasks, holding the participants constant. It was hypothesized that patients with schizophrenia would have a reduced P2a/N2b component in all tasks with an intact P300 in the auditory oddball condition only as the visual stimuli in the other conditions would mediate any reduction of the P300.
Method

Participants

Schizophrenic patients.

Twelve medicated outpatients (11 male, 1 female) from the Psychosocial Rehabilitation Outpatient Clinic at the Veteran’s Administration Medical Center - Houston were recruited for this study. The patients met DSM-IV (American Psychiatric Association, 1994) criteria for schizophrenia (paranoid, n = 8; residual, n=1; undifferentiated, n=1) or schizoaffective disorder (bipolar type, n=2). Research consensus diagnoses were based on structured clinical interviews by a trained administrator using the Structured Clinical Interview for DSM-IV (SCID-P) (First, Spitzer, Gibbon & Williams, 2001).

Healthy control subjects.

The patients were compared with 12 (11 male, 1 female) healthy adults who were recruited from several ads in local newspapers in Houston, Texas, and paid $10 per hour for their participation. Controls subjects were evaluated by a trained administrator using the Structured Clinical Interview for the DSM-IV-Non-Patient Version (SCID-NP) (First, Spitzer, Gibbon & Williams, 2001) to rule out Axis I diagnoses.

Participants in both groups were between the ages of 18 and 70. All participants were screened for a history of the following: neurological illness or insult, alcohol or drug abuse in the last 5 years or lifetime history of addiction, and alcohol use 24 hours prior to testing. A desire to participate in the study was evidenced by each participant giving their written informed consent. Subjects were tested for handedness using the Edinburgh Handedness Test (Oldfield, 1971) and rated for parental socio-economic status
using an average between the parents’ scores on the categories of the Hollingshead Two-Factor Index of Social Position (Hollingshead, 1957). There were no significant demographic differences between the patients and the controls along the variables of age, handedness, nor education (see Table 1). The patients had significantly lower parental socio-economic status scores as compared to the control subjects; however parental socio-economic status was not a factor in the performance of the tasks in this study.

All participants’ EEG recordings had at least 20 good trial recordings in each of the 8 categories of the experiment: auditory oddball target, auditory oddball standard, visual oddball target, visual oddball standard, attend auditory target, attend auditory standard, attend visual target, and attend visual standard.

<table>
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<th>Schizophrenic Patients (n=12)</th>
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<td>Mean 53.33  SD 10.11</td>
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<tr>
<td>Education (years)</td>
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<td>Range 36 - 69</td>
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<tr>
<td>Handedness (LQ)</td>
<td>Mean 15.75  SD 1.96</td>
<td>Mean 14.04  SD 2.14</td>
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<td></td>
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<tr>
<td>Parental SES</td>
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<td>Mean 0.30  SD 0.77</td>
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<td>Range (-.95) - 1.</td>
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Table 1. Demographic information for control and patient groups.

-Stimuli and Tasks-

During the experiment, subjects performed four blocked target detection tasks. Each block consisted of 400 trials with a break every 100 trials. The subjects were instructed at the beginning of each block to press a key on the keypad when the target for that block appeared. Stimuli were presented randomly without replacement, and the ratio
of "standard" stimuli to "target" stimuli was 80:20. The stimuli had a 150-msec. on-screen duration with a random inter-stimulus interval between 1000 and 1250 msec.

In the visual oddball task block, a single visual stimulus of either an "X" or a "T" appeared at the center of the screen. During the auditory oddball task block, audible high (1.5 kHz, 97dB SPL) and low (.750 kHz, 97 dB SPL) tones were presented over speakers. Two blocks had simultaneous presentation of the visual and auditory stimuli: one block having a visual target and the other an auditory target. Subjects were asked to attend only to the target and to press the response key on the keypad when the target was presented. The task blocks were counterbalanced with the two simultaneous stimuli presentation blocks in either the third or fourth block positions.

Stimulus Presentation and Behavioral Response Collection

All stimulus presentation and behavioral response collection was controlled by an Apple Macintosh 266 MHz. PPC computer (Apple Computers, Copertino, CA) running E-Prime 1.0 software (PST, Pittsburgh, PA). Visual stimuli was presented on an Apple 15" flat-panel active matrix Studio display to reduce 60 - 75 Hz. monitor refresh electrical noise associated with CRT displays. Auditory stimuli were presented through external speakers. Manual responses were collected with a 4-key micro-switch keypad (Electrical Geodesics, Inc., Eugene, OR).

In the experiment subjects were seated in an adjustable chair with their chin in a chinrest. The chinrest was placed so that the subject's eyes were 50 cm. from the center of the flat panel screen. The chair was adjusted for comfort. Subjects were instructed to remain as still as possible, with their eyes on the fixation mark, throughout each block. Subjects were requested to refrain from blinking as much as possible while the stimuli
were appearing. Breaks were provided every 3 - 4 minutes so that the subjects could rest their eyes.

*EEG Data Acquisition and Signal Processing*

EEG data was acquired continuously referenced to the vertex with .1 - 100 Hz. analog filtering and digitized at 250 Hz. with a 128 channel Electrical Geodesics system (Electrical Geodesics, Inc., Eugene, OR). The EGI Geodesic Sensor Net is a lightweight elastic thread structure containing plastic pedestals. Each pedestal contains a silver/silver chloride electrode housed in a synthetic sponge. The sponges were soaked in a saline solution to render them conductive. Application of all 128 channels took approximately 15 minutes for each participant.

EEG data was segmented off-line into 1000 msec. epochs spanning 200 msec. pre-stimulus to 800 msec. post-stimulus. Data was digitally screened for artifact (eye blinks or movements, subject movement, or transient electronic artifact). Remaining data was sorted by condition and averaged to create the ERPs. Averaged ERP data was digitally filtered at 20 Hz. lowpass to remove residual high-frequency noise, baseline corrected over the 200 msec. pre-stimulus period, and re-referenced into an average reference frame to remove topographic bias due to choice of reference site. The subject-averaged ERPs were averaged together to produce the mean waveforms across subjects, the grand average waveforms. In additional analyses, the ERP components in common to both the targets and standards were removed by creating target minus standard difference waves. Statistical analyses were performed on the subject-averaged target and standard waves as well as the difference waves. The waveforms are illustrated using the grand average target and standard waveforms.
Data Analyses

For the auditory oddball task and the attend auditory condition in the bimodal task, temporal windows were selected around the N1 (71-131 msec.), the N2b (199-299 msec.) and the P300 (299-451 msec.) peaks using visual inspection of the grand average waveforms. Five bilateral electrode pairs were selected over the frontal region for the N1 region of interest (ROI), five pairs over the frontal/superior temporal junction for the N2b ROI, and five pairs over the central-parietal region for the P300 ROI. See Figure 1 for illustrations of the auditory ROI’s.

For the visual oddball task and attend visual condition in the bimodal task, temporal windows were selected around the N1 (131-199 msec.), the N2b (275-375 msec.) and the P300 (400-525 msec.) peaks using visual inspection of the grand average waveforms. Five bilateral electrode pairs were selected over the superior occipital/posterior parietal region for the N1 ROI, five pairs over the temporal/parietal scalp for the N2b ROI, and five pairs over the central-parietal region for the P300 ROI. Also see Figure 1 for illustrations of the visual ROI’s.

Repeated-measures analyses of variance (ANOVAs) were performed on the mean amplitude within each window over the appropriate ROI with the within factors of Stimulus Type (target, standard), and Hemisphere (left, right), and between factor of Group (control, schizophrenic). Additionally, the standard waveform was subtracted from the target waveform to create a difference wave and the mean amplitudes were compared using the same component windows, ROI’s and factors.

For analyses of the behavioral data, reaction times between the two groups were compared using repeated-measures ANOVA with Modality and Task as within-subject
Figure Caption

*Figure 1.* Selected ROI’s illustrating the chosen electrode pairs for each component in both the auditory and visual conditions.
Regions of Interest

N1

Auditory

Visual

N2b

Auditory

Visual

P300

Auditory

Visual
factors and with Group as the between-subject factor. Response accuracy was computed for each participant as a percentage. Any subject with less than 95% response accuracy was excluded from the study.
Results

Target and Standard Waveform Analyses

Auditory oddball condition.

For the N2b component there was a main effect for Stimulus, $F(1, 22) = 8.964, p < .01$, showing more negativity to the target stimuli. The Stimulus effect interacted with Group, $F(1, 22) = 5.846, p = .02$, showing more negativity to the target stimuli in the control group only. There was a Laterality effect in that the N2b amplitude was significantly larger over the left hemisphere, $F(1, 22) = 8.964, p < .04$. Also, there was an effect for Stimulus by Laterality in that the amplitudes to targets were larger over the left hemisphere only, $F(1, 22) = 11.269, p = .003$. (See Figure 2.)

The P300 component showed a main effect for Stimulus, $F(1, 22) = 14.325, p = .001$, with targets showing a greater amplitude than the standards overall. There was also a Laterality effect with the amplitudes greater over the right hemisphere than the left, $F(1, 22) = 12.719, p < .002$. Laterality also interacted with Stimulus with the targets showing larger amplitude over the right hemisphere, $F(1, 22) = 9.316, p < .006$. (See Figure 3.)

Attend auditory condition.

The N2b component showed a Laterality effect, $F(1, 22) = 9.697, p = .005$, with the greater amplitude over the left hemisphere. This effect also interacted by Stimulus with there being a greater amplitude for targets over the left hemisphere but not over the right, $F(1, 22) = 9.483, p < .006$. There was also a three-way interaction of Laterality by Stimulus by Group with the targets having a significantly greater amplitude over the left hemisphere for the control group only, $F(1, 22) = 4.332, p < .05$. (See Figure 4.) The
Figure Caption

*Figure 2.* Grand average target and standard waveforms for the N2b component for each group in the auditory oddball condition by hemisphere.
Figure Caption

Figure 3. Grand average target and standard waveforms for the P300 component for each group in the auditory oddball condition by hemisphere.
P300 - Auditory Oddball Condition

Left Hemisphere

- Patient-Standard
- Control-Target
- Control-Standard

Right Hemisphere
Figure Caption

*Figure 4.* Grand average target and standard waveforms for the N2b component for each group in the attend auditory condition by hemisphere.
P300 component showed an overall effect for Stimulus, \( F(1, 22) = 8.310, p < .009 \), with the targets showing a greater amplitude than the standards. (See Figure 5.)

*Visual oddball condition.*

The N2b component showed an overall effect for Stimulus, \( F(1, 22) = 5.934, p = .02 \), with the targets being significantly more negative than the standards. This effect also interacted with Group, \( F(1, 22) = 8.102, p = .009 \), with the targets being more negative than standards in the control group only. There was also an effect for Laterality, \( F(1, 22) = 5.205, p = .03 \), with more negativity on the left hemisphere than on the right. This also interacted with Stimulus, \( F(1, 22) = 14.629, p < .001 \), with more negativity for the targets in the left hemisphere only. (See Figure 6.) The P300 component showed an overall effect for Stimulus, \( F(1, 22) = 12.880, p < .002 \), with targets having a greater amplitude than standards. (See Figure 7.)

*Attend visual condition.*

For the N2b component, there was an effect for Laterality, \( F(1, 22) = 5.226, p = .03 \), with greater negativity over the left hemisphere than the right. This effect also interacted with Stimulus, \( F(1, 22) = 10.448, p < .004 \), with targets more negative than standards over the left hemisphere only. There was no significant effect for Group, \( p = .14 \). (See Figure 8.) For the P300 component, there was an overall effect for Stimulus with the targets having a significantly greater amplitude than the standards, \( F(1, 22) = 39.766, p = .0001 \). This effect interacts with Laterality with the targets having a greater amplitude over the right hemisphere than the left, \( F(1, 22) = 6.249, p = .02 \). (See Figure 9.)
Figure Caption

*Figure 5.* Grand average target and standard waveforms for the P300 component for each group in the attend auditory condition by hemisphere.
P300 - Attend Auditory Condition

Left Hemisphere

- Patient-Standard
- Control-Target
- Control-Standard

Right Hemisphere
Figure Caption

*Figure 6.* Grand average target and standard waveforms for the N2b component for each group in the visual oddball condition by hemisphere.
N2b - Visual Oddball Condition

Left Hemisphere

- Patient-Standard
- Control-Target
- Control-Standard

Right Hemisphere
Figure Caption

*Figure 7.* Grand average target and standard waveforms for the P300 component for each group in the visual oddball condition by hemisphere.
Figure Caption

Figure 8. Grand average target and standard waveforms for the N2b component for each group in the attend visual condition by hemisphere.
Figure Caption

*Figure 9.* Grand average target and standard waveforms for the P300 component for each group in the attend visual condition by hemisphere.
P300 - Attend Visual Condition

Left Hemisphere

- Patient-Standard
- Control-Target
- Control-Standard

Right Hemisphere


**Difference Wave Analyses**

Analyses on the difference waves were performed with no additional results being found that were not included in the target and standard wave analyses.

**Behavioral Data Analyses**

Mean reaction times were significantly slower for patients \((M = 306.07, SD = 80.52)\) relative to the controls \((M = 229.95, SD = 95.69)\), with a main effect for Group, \(F(1, 22) = 7.196, p < .02\). There was an interaction of Modality by Task in which there was a slower response time for the simultaneous task in the auditory modality, but the oddball task was slower in the visual modality, \(F(1, 22) = 138.930, p = .0001\), as shown in Figure 10.

![Modality X Task Interaction](image)

*Figure 10.* Reaction time interaction of Modality x Task between the 4 conditions.

Post hoc analyses showed that RT’s in the Attend Visual condition \((M = 193.72, SD = 81.59)\) were significantly faster than the RT’s in the Auditory Oddball condition \((M...
= 271.11, SD = 88.57), p < .01. RT’s in the Auditory Oddball condition were faster than
RT’s in the Attend Auditory condition (M = 296.28, SD = 95.02) and the Visual Oddball
(M = 310.93, SD = 81.59), p = .013. These last two conditions were not significantly
different from each other, p = .289.
Discussion

The N2b component was significantly larger in the controls as compared to the patients in all of the study conditions except the Attend Visual condition in bimodal presentation. In the other three conditions, the N2b showed an enhancement to target stimuli as well as showing larger amplitude in the target minus standard difference wave in the control group only. This suggests a deficit in the allocation of attentional resources for the classification and detection of target stimuli regardless of attended modality in the patients. Although the N2b reduction in the patient group was shown in three of the conditions across modalities, it was more impaired in the oddball tasks as compared to the simultaneous presentation task conditions. This deficit may be the result of the oddball conditions' singular target detection task not requiring as much allocation of attentional resources permitting a decline in vigilance and/or an intrusion of positive symptoms.

As previously mentioned, the N2b did not show a significant difference between the groups in the Attend Visual condition. This condition also elicited the fastest reaction times over all other conditions across the groups. Auditory perceptual processing proceeds faster than visual perceptual processing, and the pattern of RT's between the conditions is consistent with that fact. The Auditory Oddball condition showed faster RT's than the Attend Auditory condition which was the same auditory task with an added a visual distracter. The Visual Oddball condition contained only visual stimuli and had the slowest RT's. The Attend Visual condition, however, had the fastest RT's. Similar results have been previously found and attribute this effect to visual dominance in which the visual channel receives a disproportionate amount of attention to the detriment of
attention to auditory stimuli (Colavita, 1982). However, as RT’s are faster to stimuli when those imperative stimuli are preceded by warning cues, perhaps the visual target detection was facilitated by the addition of auditory stimuli. Thus while the auditory and visual stimuli were presented simultaneously, the faster processing of the auditory signal may serve as a warning cue, enhancing processing of the visual item. Along these lines, the lack of a significant reduction of the N2b in the patient group for the Attend Visual condition may have been due to this auditory cue which alerted the patients to the presented visual stimuli and increased their vigilance thus facilitating target detection.

While the P300 showed an overall amplitude enhancement to target stimuli over standards in all of the task conditions, there were no significant differences between the control and patient groups. This replicates the findings of a similar previous study (Wood, et al., 2004), and appears to eliminate some of the possibilities for this somewhat unusual finding of a non-reduction of the auditory P300 in the patients. Apparently the simultaneous presentation of the visual stimuli does not mediate the P300 in the auditory target condition as the usual reduction in the auditory oddball task was not evident. Additionally, the current study’s ratio of targets to standards was identical in each of the conditions (20/80) thus eliminating the notion that the P300 in the previous study (Wood, et al., 2004) was not reduced in the patients due to the use of equiprobable stimuli presentation.

Other studies, however, have shown dissociations between the N2b and the P300 components in patients with schizophrenia. A reduction of the N2b has been correlated with a reduction in gray matter volume of the left superior temporal gyrus (STG) and of the medial temporal lobe bilaterally, whereas the P300 amplitude correlated only with left
STG volume. This finding suggests that the N2b and P300 components actually tap separable anatomic and behavioral abnormalities in schizophrenia (O’Donnell, et al., 1993). Simultaneous presentation of visual and auditory stimuli was used in a recent study (Schall U, Catts SV, Chaturvedi S, Liebert B, Redenbach J, Karayanidis F & Ward PB, 1998) of frontal lobe dysfunction in patients with schizophrenia and results showed an intact P300 component with an auditory oddball target especially over Fz – F3 frontal electrodes. Additionally, in a study of auditory target detection using phonetic and tonal stimuli, Kayser, et al., (2001) found the N2b component reduced in patients with schizophrenia but the P300 intact. They hypothesized that this dissociation was a result of effortful compensation for an early processing deficit. The auditory P300 effect may reflect a compensatory process in the patients by which the impairment at the earlier stages of stimulus classification is corrected so that the task may be accomplished.

The current study would therefore suggest that target detection and stimulus classification is differentially impacted in patients with schizophrenia. When attempting to attend to a task regardless of modality, stimulus classification is initially impaired but is eventually accomplished through a compensatory process which allows the task to be performed accurately, but with longer response latency than healthy control subjects. Thus, this dissociation between the P300 and the N2b components appears to be the result of effortful compensation for an early processing deficit. However, when task demands are lessened with an auditory cue, stimulus classification and target detection are enhanced in both patients with schizophrenia and healthy controls.
References


Elliott R, McKenna PJ, Robbins TW & Sahakian BJ. Neuropsychological evidence for frontostriatal dysfunction in schizophrenia. *Psychological Medicine, 25*(3), 619-630.


Appendix

DSM-IV Criteria for Diagnosis of Schizophrenia

A.  **Characteristic symptoms.** Two (or more) of the following, each present for a significant portion of the time during a 1-month period (or less if successfully treated):
   (1) delusions
   (2) hallucinations
   (3) disorganized speech (e.g., frequent derailment or incoherence)
   (4) grossly disorganized or catatonic behavior
   (5) negative symptoms, i.e., affective flattening, alogia, or avolition

   **Note:** Only one Criterion A symptom is required if delusions are bizarre or hallucinations consist of a voice keeping up a running commentary on the person's behavior or thoughts, or two or more voices conversing with each other.

B.  **Social/occupational dysfunction:** For a significant portion of the time since the onset of the disturbance, one or more major areas of functioning such as work, interpersonal relations, or self-care are markedly below the level achieved prior to the onset (or when the onset is in childhood or adolescence, failure to achieve expected level of interpersonal, academic, or occupational achievement.)

C.  **Duration:** Continuous signs of the disturbance persist for at least 6 months. This 6-month period must include at least 1 month of symptoms (or less if successfully treated) that meet Criterion A (i.e., active-phase symptoms) and may include periods of prodromal or residual symptoms. During these prodromal or residual periods, the signs of the disturbance may be manifested by only negative symptoms or two or more symptoms listed in Criterion A present in an attenuated form (e.g., odd beliefs, unusual perceptual experiences.)

D.  **Schizoaffective and Mood Disorder exclusion:** Schizoaffective Disorder and Mood Disorder With Psychotic Features have been ruled out because either (1) no Major Depressive, Manic, or Mixed Episodes have occurred concurrently with the active-phase symptoms; or (2) if mood episodes have occurred during active-phase symptoms, their total duration has been brief relative to the duration of the active and residual periods.

E.  **Substance/general medical condition exclusion:** The disturbance is not due to the direct physiological effects of a substance (e.g., a drug of abuse, a medication) or a general medical condition.
F. *Relationship to a Pervasive Developmental Disorder:* If there is a history of Autistic Disorder or another Pervasive Developmental Disorder, the additional diagnosis of Schizophrenia is made only if prominent delusions or hallucinations are also present for at least a month (or less if successfully treated).