SCHIZOPHRENIA AND THE MAGNOCELLULAR SYSTEM: A VISUAL BACKWARD MASKING STUDY

by

MEGAN CARLY BOYD

(Under the direction of L. Stephen Miller)

ABSTRACT

Previous research has shown that the Magnocellular pathway in schizophrenia patients may be hyperactive and may be suppressed using red light. This study uses a Visual Backward Masking paradigm to manipulate magnocellular pathway functioning. Participants were shown stimuli presented on a red or green background, quickly followed by a mask, and were asked to locate the stimulus on the screen or attend to a detail in the stimulus. The stimuli and mask were separated by varying time intervals. In the red background condition, schizophrenia patients should show accuracy rates similar to non-psychiatric controls on a green background, regardless of the task. Overall, schizophrenia patients were less accurate than normal controls on both backgrounds; however, only one time interval obtained statistical significance in the location task while two were significant in the identification task. These results suggest schizophrenia patients have general deficits, rather than only hyperactivity, in the magnocellular pathway.

INDEX WORDS: Schizophrenia, Magnocellular Pathway, Visual Processing, Visual Backward Masking, Hyperactivity

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MEGAN CARLY BOYD

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by

MEGAN CARLY BOYD

Major Professor: L. Stephen Miller

Committee: Jennifer E. McDowell
Cynthia M. Suveg

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

General Aspects of Schizophrenia

Schizophrenia is a disorder that affects approximately eight out of 1,000 people in the United States at any given time (Torrey, 2001). It is a disorder whose symptoms are found across cultures and time periods. It affects many aspects of a person's functioning, including social, occupational, and perceptual realms. It is characterized in the DSM-IV-TR by a set of symptoms including "delusions, hallucinations, disorganized speech, grossly disorganized or catatonic behavior, or negative symptoms, i.e., affective flattening, alogia, or avolition" (American Psychiatric Association, 1994). Schizophrenia is believed to be divisible into three classes of symptoms: positive, negative, and disorganized.

Historically, there has been much debate over what is considered the fundamental deficit within schizophrenia. Emil Kraepelin in 1919 described symptoms such as catatonia, paranoia, and hebeprhenia as one underlying disorder that he called dementia praecox (Kraepelin, 1919). He argued that the defining characteristics of dementia praecox were what modern clinicians would call negative symptoms, and that those afflicted with the disorder would deteriorate, as in senile dementia (Andreasen, 1997; Cornblatt, Green and Walker, 1999). Another important contributor to the modern definition of schizophrenia is Eugen Bleuler (1908). He renamed Kraepelin's dementia praecox to schizophrenia because he observed that not all those

suffering from the symptoms deteriorated (Cornblatt, Green and Walker, 1999). He proposed that schizophrenia could be divided into fundamental and accessory symptoms. Fundamental symptoms are considered pathognomonic signs of schizophrenia, while accessory symptoms could be experienced by anyone with a mental disorder. (Andreasen, 1997). Hughlings-Jackson was the first to introduce the terms "negative" and "positive" symptoms. He posited that negative symptoms represented a loss of function, whereas positive symptoms were an exaggeration of normal functioning (Andreasen, 1997). The Bleulerian model of using pathognomonic signs to diagnose schizophrenia has prevailed, however, Schneider proposed that symptoms of the disorder may be due to an inability to define the separation between self and non-self, therefore causing a loss of personal autonomy. This loss of autonomy may explain thought insertion or delusions of persecution (Andreasen, 1997).

Several theories exist in the literature detailing the possible genesis of the disorder within a person. Many factors affecting the onset of psychosis are reviewed by Broome et al. (2005). The developmental model suggests that early stressors in development such as urban upbringing and social isolation predispose an individual to "a cascade of increasingly deviant development" (Broome et al., 2005). Another suggestion states that dopamine is dysregulated within the mesolimbic system, causing environmental stimuli to be more salient. This causes a hyperawareness to the environment and unusual experience. This hyperawareness coupled with social isolation inhibits an individual from conferring with others to correct abnormal perceptual views. Broome et al. (2005) also discuss structural changes within the brain as a result of psychotic episodes. These changes may be due to alterations in the developing brain, or as a result of stress associated with psychotic episodes. Whatever the cause of psychosis, there are many instances of differences between schizophrenia patients and a normal population.

Many examples of perceptual problems exist within the schizophrenia spectrum, one being that schizophrenia patients and their relatives have been shown to have visual perceptual differences when compared to normal participants (Bedwell, Brown and Miller, 2002; Green, Nuechterlein, Breitmeyer, and Mintz, 2005). These differences are apparent in several modalities of the visual system and are discussed below.

Visual Functional Differences in Schizophrenia

Schizophrenia patients have long been shown to have visual perceptual abnormalities when compared to non-psychiatric controls. Differences have been shown to occur in attention and working memory modalities as well (Brenner et al., 2003). Both schizophrenia patients and some first degree relatives have difficulty following a quickly moving stimulus by incorrectly anticipating the location of the stimulus. They show slower and less frequent eye movements. Schizophrenia patients also show more errors on antisaccade tasks and tasks requiring the simultaneous tracking of multiple objects (Abel, Levin and Holzman, 1992, McDowell et al., 2002, Kelemen et al., 2007). In a study done by Brenner et al. (2003), performance on psychometrically-matched visual perceptual tests was compared in schizophrenia patients and normal controls. They found that schizophrenia patients showed difficulty in recognizing stimuli as well as perceiving moving stimuli (Brenner et al., 2003). Patients were also shown to have deficits in velocity discrimination, suggesting visual motion processing impairment in extrastriate regions (Chen, Levy, Sheremata, and Holzman, 2004).

Differences are also apparent in a visual backward masking (VBM) paradigm. Masking paradigms attempt to understand the mechanism by which early visual information is processed. Masking can be accomplished in either a forward or backward manner. In backward masking paradigms, participants are shown a brief target stimulus which is quickly followed by a masking

stimulus that interferes with processing of the target (Green et al. 2003). In forward masking, the mask is presented before the target stimulus (Balogh and Merritt, 1987). The mask is novel and does not include relevant information, and therefore interrupts the flow of information processing. The backward masking effect is mediated by the temporal difference between the onset of the target and the onset of the mask, known as stimulus onset asynchrony (SOA) (Balogh and Merritt, 1987; Rund, 1993). With the SOA method, the target and the mask can overlap.

According to Balogh and Merritt (1987), using SOA to delimit a backward masking paradigm assumes the concept of visual persistence. Visual persistence refers to the phenomenon in which an image of a visual stimulus will be present in memory for a short time if uninterrupted. Visual masking can be explained by two basic concepts that are working together to create the masking effect. Masking is caused by interruption and integration during visual processing. Interruption results when later stage visual processing is disturbed by the mask, while integration occurs when the mask and target merge due to close temporal proximity (Rassovsky, Green, Nuechterlein, Breitmeyer, and Mintz, 2004). This theory of visual masking was tested in a study done by Rassovsky and colleagues (2004) which showed that interruption and integration can be assessed separately using paracontrast and metacontrast techniques. Paracontrast and metacontrast techniques use a mask that surrounds but does not overlap the stimulus during forward masking and backward masking, respectively (Rassovsky et al., 2004). By not overlapping the stimulus with the mask, the mechanism of integration is tested. They also found that schizophrenia patients show a deficit in performance when compared to normal controls even when interruption is the only masking technique used.

Both normal controls and schizophrenia patients process information as a result of the presentation length of the stimulus (Schwartz, Winstead and Adinoff, 1983). However, schizophrenia patients require longer intervals between the target and the mask to accurately locate the placement of a target and escape the "masking effect" (Cadenhead, Serper, and Braff, 1998; Schwartz, Winstead and Adinoff, 1983; Schechter et al., 2003). A study done by Schwartz, Winstead and Adinoff (1983) found that schizophrenia patients require a 90 ms SOA to escape masking while controls need approximately 60 ms to escape the mask when an arbitrary 75% cutoff score was used to distinguish escape from the mask. This effect can be seen especially in patients with primarily negative symptoms (Green and Walker, 1986). The need for a longer time between the stimulus and the mask has been explained as either an interference within the visual system or as a problem with deciding what information is relevant (Rund, 1993). Patients with poor prognoses are especially susceptible to masking effects which may be due to a deficiency in perceptual organization (Green and Walker, 1986). The perceptual disorganization, which likely manifests itself as a need for a longer time between the stimulus and the mask, may be further explained by hyperactivity within the visual system processing pathways. Because these pathways are over active, they may overwhelm sensory processing in schizophrenia patients.

Two Different Visual Pathways

The effect of VBM is thought to be due to the functioning of two separate visual pathways: the transient and sustained pathways (Livingstone and Hubel, 1987; Breitmeyer and Ganz, 1976). The transient pathway responds best to rapid and brief stimuli, as well as low spatial frequency and motion stimuli. The sustained pathway responds best to slow, longer-lasting stimuli and sharply focused stimuli. (Schechter, Butler, Silipo, Zemon and Javitt, 2003;

Breitmeyer and Ganz, 1976). These two channels are distinct from their origins in the retina, through the lateral geniculate nucleus of the thalamus, to the striate cortex (Breitmeyer and Ganz, 1976). These paths continue on to other visual processing areas in the frontal cortex (Ungerleider and Mishkin, 1982). A higher concentration of sustained responding cells are found in the fovea, while transient responding cells are found in the periphery of the retina (Breitmeyer and Ganz, 1976). Visual backward masking is thought to work by the transient channel inhibiting the processing of the sustained channel. Information being rapidly processed by the transient channel takes precedence over information processed by the sustained channel.

The transient and sustained pathways have been shown to map onto specific neural mechanisms. The neuronal correlates of these visual processing streams have been shown to be divided into two parallel processing pathways, the Magnocellular (M) pathway and the Parvocellular (P) pathway, respectively (Livingstone and Hubel, 1987). The M pathway is associated with the dorsal visual stream which is instrumental in motion detection and stimuli location. The P pathway maps onto the ventral processing stream, which is important in object recognition and processing of fine detail (Schechter et al., 2003; Ungerleider and Mishkin, 1986). M pathway neurons project from the retina to the LGN and then continue on through layer 4Cα in area 17 (striate cortex) to the Middle Temporal area (called MT and known as V5 in humans). This constitutes the dorsal stream. P pathway neurons begin in the retina as well, project to the LGN, and then to layer 4Cß of area 17, finally projecting to the inferior temporal cortex (Livingstone and Hubel, 1987).

Important to motion perception, area V5/MT was first discovered in lesion studies done with primates. MT is characterized in primates by neurons selective for motion, and is distinguished from surrounding tissue by an increase in myelination (Ungerleider and Haxby,

1994). It has been questioned as to whether there is an analogous structure to MT in the human brain. Case studies on patients with lesions in this area give strong evidence that humans do have a brain region important to motion processing. A patient described by Zihl, Von Cramon, Mai, and Schmid (1991) acquired a bilateral lesion in the lateral temporo-occipital cortex, analogous to area V5. Upon testing, her vision was normal for stationary tasks. However, on tasks that required her to judge motion, she required much more time than a control participant to perceive a stimulus as moving, and was only able to do so by noticing that the stimulus had jumped from one position to another. She described objects in motion as "restless" and that it was "uncomfortable" to view such objects (Zihl et al., 1991). Because her vision was unimpaired for non-moving stimuli, it suggested a "motion area" within the human brain.

Work done by Huk, Dougherty, and Heeger (2002) has shown that homologous regions important to motion perception do exist in the human visual system. In the visual cortex of macaques, area MT as well as the Medial Superior Temporal area (MST) process motion information. According to Huk and colleagues, previous studies have shown that macaque MT and MST are adjacent, that MT shows a clearer retinotopic organization, and that neurons in MST have larger receptive fields than MT neurons. Using moving stimuli and fMRI, Huk et al. (2002) found human MT and MST-like-areas, and that they also possess characteristics similar to their primate homologues such as being adjacent, and having a retinotopic organization. A recent study done by Wilms et al. (2005) compared cytoarchitectural correlates of area V5 in postmortem brains and functional activation in healthy controls. They found a significant overlap in area V5 between the functional data and the postmortem brains (Wilms et al., 2005). Area V5 serves as the place where motion information is integrated, and it receives most of its

input from the M pathway, therefore making it relevant for the study of motion perception (Chapman, Hoag and Giaschi, 2004).

Differences in the Magnocellular Pathway

Both the magnocellular and parvocellular pathways respond differently to stimuli. The M pathway cells are especially sensitive to luminance contrast and have a larger receptive field than P cells. M cell firing is also suppressed by diffuse red light, but not white light (Livingstone & Hubel, 1987). A recent study from our laboratory (Bedwell, Brown and Miller, 2002) demonstrated the effect of red light in relatives of schizophrenia patients and normal controls using a location-based VBM task presented on either a red or gray (neutral) background. This study found that normal controls showed reduced accuracy during the red background condition, but that the relatives showed no differences between conditions. This suggests that the magnocellular system may show hyperactivity in relatives of schizophrenia patients, indicating the presence of a possible genetic marker for the disorder.

To further test for hyperactivity in the M pathway, a more recent study from our laboratory (Bedwell, Miller, Brown, McDowell, and Yanasak, 2004) used fMRI to look for differences in activation in area V5 (MT) in relatives of schizophrenia patients and normal controls. By using fMRI, a possible mechanism for this phenomenon could be established. Participants were shown a series of moving and stationary concentric rings either on a red or green (neutral) background. For normal controls, activation was suppressed in area V5 in the right hemisphere during the red background condition. However, results in the relatives group were somewhat unclear. Approximately half of the relatives showed a decrease in activation in right hemisphere V5, while the other half showed an increase in right hemisphere V5 activation relative to the left hemisphere (Bedwell et al., 2004).

Other research has shown a possible hypoactivity of the magnocellular path in schizophrenia patients. In a study done by Butler et al. (2001), schizophrenia patients showed lower activation over occipital cortex to stimuli biased towards the M pathway. Participants were shown stimuli that varied in luminance levels and spatial frequency, and their activation was recorded in the EEG environment. There were no differences between schizophrenia patients and normal controls in cortical activation when the stimuli were of high spatial frequency and luminance contrast, therefore activating the parvocellular pathway. However, there were significant differences between groups in cortical activation on low luminance and low spatial frequency stimuli which activate the magnocellular pathway (Butler et al., 2001). Schizophrenia patients showed significantly lower signal-to-noise ratios in response to these stimuli. A lower signal-to-noise ratio in area V5 suggests less activation and possible hypoactivity within the magnocellular pathway (Butler et al., 2001).

Another study suggesting a reduction in M-pathway functioning was performed by Doniger, Foxe, Murray, Higgins, and Javitt (2002). This study utilized a perceptual closure task comparing schizophrenia patients and normal controls. Participants were presented with pictures which became progressively more complete and were asked to identify the picture as quickly as possible. Patients and controls correctly identified a similar number of objects presented, but schizophrenia patients required more complete images to identify the object. This study also employed EEG to measure latency of brain activation. Patients displayed a normal N1 response, indicating normal early visual processing. However, there was a reduction in the dorsal stream P1 activation, also suggesting a reduction in magnocellular pathway functioning (Doniger et al., 2002). These findings suggest that later visual processing is altered in schizophrenia patients,

and that the magnocellular pathway is possibly hypoactive in patients when compared to normal controls (Doniger et al., 2002).

Specific Aims

Understanding schizophrenia has been an elusive goal for countless scientists, practitioners, family members, and patients. Schizophrenia is a disparate cluster of symptoms that may all share a genetic basis. Knowing about visual system differences in schizophrenia patients allows us to possibly locate a specific phenotypic marker for the disorder. If there is a phenotypic marker, then genes that produce that marker can be discovered, and these genes may also be important in identifying the genetic basis of schizophrenia. Evidence for a marker has been found, although unreliably, in first degree relatives of schizophrenia patients. Studies using first degree relatives are quite beneficial to the understanding of schizophrenia, but also have disadvantages. Studies using relatives help determine the possible genetic basis of a disorder by providing markers for the disorder present in both probands and their relatives but not the unaffected population. They also allow a trait to be studied without being confounded by effects of psychotropic medications. While family studies are very useful, the major drawback is that not all relatives are affected in the same manner. Some participants will possess a similar genotype as their affected relative, while some will not. Due to the genetic variability within the sample of relatives within the Bedwell and colleagues study (2004), the effects were not consistent within the group. It appears that a subset of the relatives show hyperactivity in area V5, suggesting that schizophrenia patients may also show similar activation patterns in response to moving stimuli.

Due to these equivocal results, this study attempted to provide clarity by comparing correlates of M pathway functioning in schizophrenia patients and normal controls, addressing

the problems related to genetic variation among relatives. M pathway functioning was elucidated using Visual Backward Masking. VBM was used to measure possible hyperactivity within the M pathway of schizophrenia patients by suppressing its functioning with red light-based stimuli, as performance in a VBM task relies on M pathway resources.

The present study hypothesized that when exposed to a VBM paradigm:

1) schizophrenia patients should show an accuracy rate in a red background condition similar to normal controls in a neutral background condition. Since red light suppresses M pathway functioning, it should negatively impact the accuracy of both schizophrenia patients and controls. If schizophrenia patients have a hyperactive M pathway, they should show higher accuracy rates on the red condition when compared to normal controls.
2) This effect should be more pronounced on a location-based condition as it relies primarily on M pathway functioning.
3) Patients should also show differences from normal participants in escaping from the effect of the mask. Schizophrenia patients should require longer time intervals to escape the effect of the mask than normal controls.

CHAPTER 2

METHOD

Participants

Fourteen schizophrenia patients from the community and 15 normal controls were recruited to participate in this study. They were recruited through newspaper advertisements and flyers at local mental health clinics, as well as from a database within the psychology department. Groups were matched as closely as possible on age, gender, race, and education level. Participants were excluded if they reported a serious head injury or current drug abuse. Participants must have at least 20/60 visual acuity. Schizophrenia patients were required to be living independently and not be actively psychotic. Normal participants could not have a history of psychiatric disorders.

Groups were not of equal size due to a limited population of viable schizophrenia participants in the area. A total of 23 schizophrenia patients were recruited, but only 14 were eligible to participate. Of the 9 patients that could not be used, 3 refused to participate after being recruited and did not come to the laboratory, 1 came to the laboratory but refused to participate once the procedures were explained, 3 patients could not complete the task, 1 could not acquire transportation and lived a great distance from the laboratory, and 1 could not be reached after missing the appointment. In contrast, 19 normal participants were recruited, and only 4 could not be used.

Measures

Upon recruitment, all participants were screened for compatibility with the study in a telephone screening session. This questionnaire was adapted from the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I, First et al., 1997) and screens for possible psychiatric disorders. All participants underwent a SCID-I given by the researcher. For schizophrenia patients, the SCID-I functions to ensure the diagnosis of schizophrenia, while in controls, it was used to rule out psychiatric diagnoses. IQ was estimated using the two-subtest *Wechsler Abbreviated Scale of Intelligence* (WASI, Wechsler, D. 1999) to ensure a more homogenous sample. Visual acuity was measured using the Snellen eye chart.

Stimuli

Visual Backward Masking task

Participants completed a visual backward masking paradigm presented on a NEC FP2414SB CRT monitor with E-Prime software (version 1.1.4.1, Psychology Software Tools, Inc.) running on a Pentium IV processor. Two tasks were presented: a location-based task and an identification task. The location–based task is biased toward the M pathway functioning while the identification task is biased toward P pathway functioning. For both tasks, participants were shown a small square measuring 6 mm by 6 mm with a gap measuring 1 mm in one side subtending 0.37º visual angle for the location-based task and 0.75º visual angle for the identification task (see Figure 2.1). This square can appear in one of four locations around the center of the screen, and the gap can appear either pointing up, to the left side, or down. Stimuli remain on the screen for approximately 13 ms, or two refresh cycles of the monitor at 160 Hz. The stimuli were followed by a high-energy mask in varying SOAs that appears in all four possible locations lasting four refresh cycles (approximately 24 ms). This mask subtends 2.71º

visual angle in the location-based task and 5.59º visual angle in the identification task. Twelve trials at each SOA were randomly shown for each task, as well as 12 trials where no mask appears. The location task required participants to complete 120 trials per background color (240 total), while the identification task required 132 trials per background color (264 total). For the identification task, the SOAs include: 0, 25, 31, 38, 44, 50, 56, 69, 81, and 119 ms. For the location task, the SOAs include: 0, 25, 31, 38, 44, 50, 56, 69, and 81 ms. These intervals were derived from previous research (Green et al., 2003; Rassovsky et al., 2004) where SOAs are determined by the refresh cycle. SOAs between 30 and 50 ms are sampled once every refresh cycle as to properly sample the time interval most deficient in visual processing in schizophrenia (J.S. Bedwell, February 13, 2006, personal communication). Participants were asked to fixate on a cross at the center of the screen. One half of each task was presented on a red background and the other half was presented on a green background. In the location task, participants were asked to report the location of the stimulus, telling the researcher the quadrant in which it appeared. A reminder diagram was posted at the top of the screen. In the identification task, participants were asked to tell the researcher which direction the gap in the square was pointing, either up, to the side, or down. The stimulus also changed positions randomly throughout the task so that it could appear at any of the four locations on the screen.

Procedure

Participants contacted the laboratory and were screened via telephone to assess eligibility for the study. Once participants were determined to be eligible for the study, they came to the laboratory for testing. All participants were given the SCID-I to assess for possible psychological diagnoses in controls and the validity of the schizophrenia diagnosis in patients. Participants were tested for visual acuity using a Snellen Eye Chart. IQ was estimated using the

two-subtest WASI. Participants had the VBM task explained to them, and then were fitted into a chin rest which ensured that their eyes were 18 inches away from the screen for both tasks. The distance was determined based on previous work done by Green and colleagues (1994), as well as pilot data run within our laboratory. The distance allowed for proper accuracy but restricted ceiling effects. Depending on the task, the participant told the experimenter either the quadrant in which the stimulus appeared (location) or the direction it was facing (identification), and the experimenter input the data. Participants were compensated $10 per hour for their participation.

Data Analysis

Demographic data was assessed for differences between groups on age, education, and estimated IQ. VBM data was analyzed using SPSS for percent accuracy across background color and groups for each task. Data was also examined for group differences based on background color, condition, and stimulus onset asynchrony (SOA). Comparisons were made between the performance on the identification- versus location-based tasks across groups, between red background performance of schizophrenia patients and controls, and for percent accuracy within and between groups on each SOA for each background color. Each condition (location and identification tasks) was analyzed using a repeated-measures analysis of variance with SOA as the repeated measure. When significance was found, a Univariate *F*-test was used to determine non-linear trends in the data. Escape from the masking effect was also analyzed. This was defined as the shortest SOA where participants reached 40% accuracy in the identification task and 32% in the location task (Schechter et al., 2003). Escape from masking effect was determined using a repeated-measures analysis of variance, followed by post-hoc *t*-tests if significance is reached.

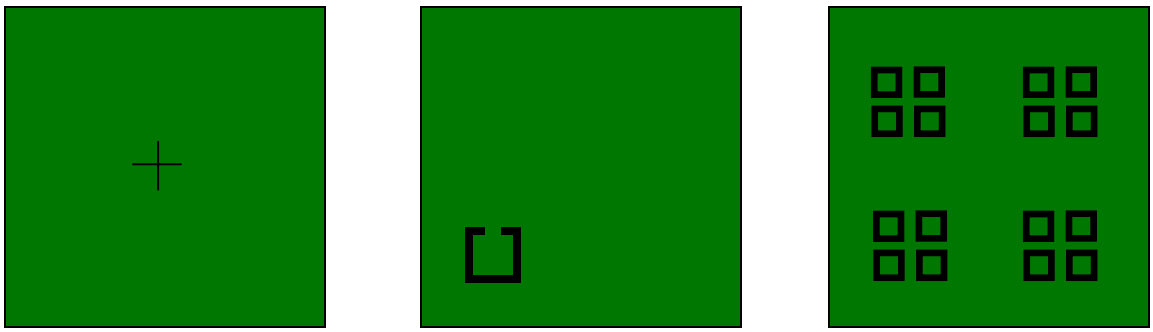

Figure 2.1. Masking stimuli. The target stimuli consist of a fixation cross, followed by a square with a gap in one side. The square can appear at any of four locations around the center. After a brief interval, a high energy mask is presented which covers all four possible locations of the target.

CHAPTER 3

DETERMINING THE DIFFERENCES IN MAGNOCELLULAR PATHWAY FUNCTIONING IN SCHIZOPHRENIA PATIENTS USING VISUAL BACKWARD MASKING

Introduction

Schizophrenia patients have long been shown to have visual functioning deficits when compared to normal controls. These differences include antisaccade and smooth pursuit tasks, as well as tasks requiring the input of quickly moving or location-based information (Abel, Levin and Holzman, 1992; McDowell et al., 2002; Rosenzweig, Breedlove, and Leiman, 2002, Brenner et al., 2003). The processing of quickly moving stimuli is handled by the transient channel, one of two channels within the visual system (Brietmeyer and Ganz, 1976; Ungerleider and Mishkin, 1984). The transient and sustained channels work together to process motion/location information and fine detail/color information, respectively (Brietmeyer and Ganz, 1976). These two processes work in tandem, allowing for detailed information about the environment to be gathered when necessary, and motion information to be processed more quickly when necessary. As such, the transient channel overtakes the processing of the sustained channel when relevant moving stimuli are encountered. These two pathways also map onto neural mechanisms. The transient channel is also known as the Magnocellular (M) pathway and the sustained channel is known as the Parvocellular (P) pathway (Livingstone and Hubel, 1987).

The M pathway responds to spatial information and luminance contrasts, but is not highly sensitive to color. This pathway begins with the rods in the retina, and then progresses through the lateral geniculate nucleus of the thalamus to the primary visual cortex (V1), ultimately

reaching the tempo-parietal cortex, known as area V5 (Livingstone and Hubel, 1987). Despite being relatively insensitive to color, the M pathway can be suppressed by exposure to diffuse red light (Brietmeyer and Ganz, 1976). In contrast, the P pathway begins in the cone cells in the retina and terminates in the temporal cortex. Because the cone cells begin the pathway, the P path is sensitive to color information and fine detail of objects (Schechter et al., 2003; Ungerleider and Mishkin, 1986).

Previous research has shown that there are likely deficits in the M pathway of schizophrenia patients. Overall, a general "deficit syndrome" has been shown in many diagnosed with schizophrenia, but this difference in performance on tasks weighted toward M pathway functioning has been found in those with schizophrenia not suffering from the deficit syndrome (Cimmer et al., 2006) as well as unaffected first degree relatives of patients (Bedwell, et al., 2002; 2006). There is also evidence that M pathway deficits are associated with other perceptual disturbances found in schizophrenia (Kèri et al., 2005). Not only are there differences in the performance of the M pathway evident by psychophysical methods, other researchers have used neuroimaging methods to look at these differences. Butler et al. (2001) found that there is less activation in the dorsal stream in schizophrenia patients using EEG, and Bedwell et al., (2004) also discovered a decrease in activation in area V5, which is associated with the dorsal stream, in first degree relatives during exposure to stimuli biased toward the M pathway.

There is evidence that there are differences in the M pathway in schizophrenia patients and relatives, but there has not been consensus on the direction of these difficulties. Bedwell et al. (2002) suggest that the M pathway is hyperactive in schizophrenia patients. This conclusion is based on a study in which normal participants and first degree relatives of schizophrenia patients were exposed to a task which was biased toward the M pathway. When both groups

were exposed to red light, which has been shown to reduce M pathway functioning, the first degree relatives showed greater accuracy rates than the normal controls. This suggested that the M pathway was hyperactive, as it was still able to perform accurately in a situation where it would have been suppressed. Other studies have used first degree relatives or schizophrenia patients in similar paradigms and have found reduced activity in the M pathway, suggesting hypoactivity (Butler et al., 2001; Doniger, Foxe, Murray, Higgins, and Javitt, 2002).

The purpose of this study was to first establish differences in M pathway functioning between normal participants and schizophrenia patients, and then to elucidate whether the M pathway is hyperactive or hypoactive in schizophrenia patients. This was accomplished using Visual Backward Masking (VBM). In VBM, participants are shown a target stimulus which is quickly followed by a distracter, called a mask. When the mask is displayed, it interferes with the processing of the target stimulus. There are varying intervals of time between the target and the mask, called Stimulus Onset Asynchronies (SOAs). The shorter the SOA, the more difficult it is to process the target stimulus. Also, this task also reveals differences between schizophrenia patients and controls in the time that each group requires to escape from the effect of the mask. Patients have been shown to require longer amounts of time to escape the effect of the mask (Cadenhead, Serper, and Braff, 1998; Schwartz, Winstead and Adinoff, 1983; Schechter et al., 2003). This task can be manipulated by changing the background color. In this study, half of the time the stimuli appear on a red background, which serves to inhibit M pathway functioning, and the other half appear on a luminance-matched green background, which serves as a neutral condition.

In this study, participants were asked to locate the position of the target stimulus, which activates the M pathway. In a second task, participants were asked to focus on a detail of the

stimulus, namely, which direction a gap in the stimulus was facing. The stimuli and background color manipulations were the same as the first task. Differences between groups were determined using both the location and identification tasks. The present study hypothesized that when exposed to a VBM paradigm, schizophrenia patients would show an accuracy rate in a red background condition similar to normal controls in a neutral background condition. Since red light suppresses M pathway functioning, it should negatively impact the accuracy of both schizophrenia patients and controls. If schizophrenia patients have a hyperactive M pathway, they should show higher accuracy rates on the red condition when compared to normal controls. This effect should be more pronounced on a location-based condition as it relies primarily on M pathway functioning. Also related to this phenomenon, schizophrenia patients should require longer time intervals to escape from the effect of the mask.

Method

Fifteen participants without a history of psychiatric diagnosis (9 females) and 14 participants diagnosed with schizophrenia (5 female) were recruited from the community using newspaper advertisements, flyers, volunteers from previous experiments within our laboratory, and from local outpatient mental health facilities. Groups were matched on age, education, and IQ. Normal participants ranged in age from 19 to 54 years old (mean = 38.3, SD = 13.05) and schizophrenia patients were ages 21 to 49 (mean = 36, SD = 10.49). Exclusion criteria included history of head injury resulting in coma, current drug abuse, current psychosis, or visual acuity less than 20/60. Participants were compensated $10 per hour for their time.

Participants were screened for compatibility with the study using a telephone questionnaire based on the SCID-I (First et al., 1994). Patients were informed of the procedures of the study, and then were scheduled. Participants were seen on one occasion, lasting

approximately two and a half hours. The details and procedures of the study were presented once more verbally, and the participants provided written informed consent. Participants were given a SCID-I (First et al., 1994) to ensure a diagnosis of schizophrenia for the patients and to ensure a lack of diagnoses for normal participants. Participants were then administered a two-subtest Wechsler Abbreviated Scale of Intelligence (WASI) to obtain an estimated IQ. Visual acuity was measured using a Snellen eye chart.

Participants were then exposed to computer-generated and -presented Visual Backward Masking identification and location tasks, which were counterbalanced for order. Participants were fitted in a chin rest which was placed 18 inches from the screen to ensure consistency. They began each task on a red or green background, determined randomly by the computer. The stimuli were presented on a NEC FP2414SB CRT monitor with E-Prime software (version 1.1.4.1, Psychology Software Tools, Inc.) running on a Pentium IV processor. For both tasks, the participants were shown a small square measuring 6 mm by 6 mm with a gap measuring 1 mm in one side subtending 0.37º visual angle for the location-based task and 0.75º visual angle for the identification task (Figure 3.1). This square could appear in one of four locations around the center of the screen, and the gap could appear either pointing up, to the left side, or down. Stimuli remained on the screen for approximately 13 ms, or two refresh cycles of the monitor at 160 Hz. The stimuli were followed by a high-energy mask in varying SOAs that appeared in all four possible locations lasting four refresh cycles (approximately 24 ms). This mask subtended 2.71º visual angle in the location-based task and 5.59º visual angle in the identification task. Twelve trials at each SOA were randomly shown for each task, as well as 12 trials where no mask appears, for a total of 120 trials in the location task and 132 trials in the identification task. For the identification task, the SOAs include: 0, 25, 31, 38, 44, 50, 56, 69, 81, and 119 ms. For

the location task, the SOAs include: 0, 25, 31, 38, 44, 50, 56, 69, and 81 ms. These intervals were derived from previous research (Green et al., 2003; Rassovsky et al., 2004) where SOAs were determined by the refresh cycle. SOAs between 30 and 50 ms were sampled once every refresh cycle as to properly sample the time interval most deficient in visual processing in schizophrenia (J.S. Bedwell, February 13, 2006, personal communication). Participants were asked to fixate on a cross at the center of the screen. In the location task, participants were asked to report the location of the stimulus, telling the researcher the quadrant in which it appears. A reminder diagram was posted at the top of the screen. In the identification task, participants were asked to tell the researcher which direction the gap in the square is pointing: either up, to the side, or down. The stimulus could appear at any of the four locations on the screen.

Results

Groups were compared using a one-way between groups analysis of variance on three demographic measures: age, education, and estimated IQ. There was no significant difference between groups on age. The mean age for schizophrenia patients was 36.1 years with ages ranging from 21 to 49 years. The mean age for controls was 37.2 years, ranging from 19 to 54 years of age. There was a significant difference between groups on education, with normal participants having on average two more years of education ($F_{1,26}$=4.233, p=.05). There was also a significant difference between the groups on IQ. The mean IQ for schizophrenia patients was 91 (σ^2 = 18.73), while for normal controls the mean was 104 (σ^2 = 11.77) ($F_{1, 26}$ = 4.624, p = .041).

Data were analyzed by using the number of correct trials each participant had for each SOA. Chance level was determined to be having four or less correct trials per SOA in the no mask condition. Participants were excluded if they achieved four or fewer correct trials in the no

mask condition for either background. On the location task, one normal participant was excluded, for a total of fourteen participants in each group, and in the identification task, three normal participants were excluded, leaving twelve participants in the normal group and fourteen in the schizophrenia group. No schizophrenia patients were excluded from the analyses.

Location Task

To determine group differences, a 2 x 2 x 9 repeated measures analysis of variance was used with SOA and background color as the within-subjects factors and group as the between subject variable. Sphericity for SOA could not be assumed, according to Mauchly's Test of Sphericity (SOA: Mauchly's W = .011, $p \neq .001$; $\varepsilon = .389$, Greenhouse-Geisser correction). Sphericity could be assumed for SOA by color effects. Tests of within-subject effects revealed a significant effect for SOA ($F_{3.110,\ 25} = 37.228$, $p < .001$, Greenhouse-Geisser correction, partial eta squared = .59), indicating that performance improved as SOA lengthened. There was a non-significant effect for SOA by group that approached significance suggesting that there were no discernable differences between the groups, collapsing across background color ($F_{3.110,\ 25} = 1.681$, $p = .059$, Greenhouse-Geisser correction, partial eta squared = .09). There were no significant effects for color, color x group, SOA x background color, or SOA x background color x group (see Table 3.1). Tests of between-subjects effects, collapsing across SOA and color, revealed a non-significant effect for group that approached significance ($F_{1,\ 25} = 3.968$, $p = .057$, partial eta squared = .13).

Within group comparisons measuring accuracy differences on the red background were conducted. A paired samples t-test was conducted to compare the performance differences within the normal group on the red versus the green background. There were no significant differences within the group (t (13) = .392, $p = .702$). A paired samples t-test comparing

performance on the red versus green background in the schizophrenia group also produced no significant differences (t (13) = .361, p = .724).

Groups were compared using a one-way analysis of variance to compare differences between normal participants and schizophrenia patients for each SOA. Schizophrenia patients scored below normal participants on almost all SOAs, but two SOAs (69 ms and 81 ms) produced a significant difference between the groups, with schizophrenia patients scoring well below normal participants (69 ms: $F_{1,27}$=6.022, p=.021, partial eta squared = .19; 81 ms $F_{1,27}$=6.846, p=.015, partial eta squared = .21) (Table 3.2). When comparing each SOA between groups on the red background, there were significant differences on three SOAs: 44 ms, 69 ms, and 81 ms (44 ms: $F_{1,26}$ = 5.265, p=.03, partial eta squared = .17; 69 ms: $F_{1,26}$ = 4.571, p=.04, partial eta squared = .15; 81 ms: $F_{1,26}$ = 4.080, p=.05, partial eta squared = .14) (Table 3.3). Patients scored below normals on these SOAs.

Identification Task

Group differences were ascertained using a 2 x 2 x 10 repeated measures analysis with SOA and background color as the within-subjects factors and group as the between subjects factor. Overall, both groups showed reduced accuracy in this task as compared to the Location task. The sphericity assumption was met for SOA and the interaction of SOA and color, according to Mauchly's Test of Sphericity (SOA: Mauchly's W = .056, p = .062; ε = .575, Greenhouse-Geisser correction; SOA by Color: Mauchly's W = .152, p = .695; ε = .719, Greenhouse-Geisser correction). In tests of within subject comparisons, there was a significant effect of SOA, indicating that as the length of the SOA increased, participants' performance improved ($F_{9, 25}$ = 27.314, p < .001, Greenhouse-Geisser correction, partial eta squared = .53). The interaction between background color and group was also significant, suggesting that there

were differences in performance on the background color between groups ($F_{9, 25} = 2.012$, $p = .039$, Greenhouse-Geisser correction, partial eta squared = .08). No other comparisons yielded significant results (see Table 3.4).

To look for within group differences, a paired samples t-test was conducted to compare each group on background color performance. There were no significant differences for either group in performance between background colors (normal participants: $t(11) = .645$, $p = .532$; schizophrenia patients: $t(13) = -1.619$, $p = .129$).

Comparisons were made between normal participants and schizophrenia patients on the green background at each SOA. Two SOAs (56 ms and 119 ms) provided a significant difference in performance between the two groups, with the schizophrenia patients performing below the normal participants (56 ms: $F_{1, 24} = 5.537$, $p = .027$, partial eta squared = .19; 119 ms: $F_{1, 24} = 12.005$, $p = .002$, partial eta squared = .33) (Table 3.5). The groups were also compared at each SOA for the red background. A significant difference was found for the SOA of 25 ms, with the schizophrenia patients performing more accurately than the normal participants ($F_{1, 25} = 5.842$, $p = .024$, partial eta squared = .20). No other SOA on either background produced significant differences between the groups (Table 3.6).

Escape from the Mask

Comparisons on escape from the mask were conducted within and between groups and for each condition. Each SOA was assigned a unique number, and escape from the mask was determined by the SOA at which they consistently performed above 32% correct for the location task and above 40% correct for the identification task. A paired-sample t-test was conducted to look for differences within groups. On the location task, there was no significant difference in escape from mask time within either group, regardless of the background (normals: $t(13)=1.108$,

p=.288; schizophrenia subjects: *t*(13)=-.216, *p*=.832). On the identification task, there were also no significant differences in escape from mask times within the groups (normals: *t*(11)= .106, *p*=.917; schizophrenia subjects: *t*(13)=.905, *p*=.382).

To compare escape from masking effects between groups, a one way ANOVA was used collapsing across background colors. There proved to be a significant difference between groups on the location task, ($F_{1,26}$ = 5.748, *p* = .024) with the schizophrenia patients escaping on average by the SOA equaling 44 ms and normal controls escaping from the mask by the SOA of 31 ms. There were no significant differences between groups on the identification task ($F_{1,25}$ =.2.024, *p* = .168).

When comparing escape from the mask between groups on the location task, there was a significant difference on the red background, with schizophrenia patients requiring more time to escape, and performance on the green background showed a trend toward significance (red background: $F_{1, 26}$ =7.071, *p*=.013; green background: $F_{1, 26}$ =2.971, *p* = .097). When comparing groups on the identification task, there were no significant differences on either background color (green background: $F_{1, 25}$ =2.553, *p*=.123; red background: $F_{1, 25}$ = .956, *p* = .338).

Discussion

Schizophrenia patients appear to be modestly less accurate than normal controls on both the red and green backgrounds for the location task. Schizophrenia patients performed below the normal controls in almost every SOA. Significant differences were found on the green background in later SOAs. The red background also produced statistically significant differences between the groups which were generally in later SOAs as well. The direction of the findings was inconsistent with the original hypotheses. Generally, greater differences appeared in later SOAs, where normal participants were escaping the effects of the mask, while

schizophrenia patients were not. These differences between the groups suggest that patients may not be aided by suppressing their M pathway via red light.

In contrast, in the identification task, differences were found in later SOAs on the green background, and differences between the groups on the red background were found on an earlier SOA. Differences between groups were less pronounced overall. Performance on two SOAs in the green background were significantly different between groups, with the schizophrenia patients performing less accurately than the normal controls. One SOA in the red background was found to be different between the groups, with schizophrenia patients performing more accurately than the normal controls. This SOA was short, requiring early visual processing to be accessed. Consistent with the findings of the location task, schizophrenia patients performed below normal participants on the green background. However, they showed trends towards improved performance on the red background, and this trend remained for most of the SOAs in the red background.

Schizophrenia patients also showed a reduction in performance in escaping from the mask, but only in the location task. Normal participants escaped from the mask significantly faster on the red background, and they showed a trend toward escaping from the mask sooner on the green background. There was no significant effect on the identification task for either background color, but schizophrenia patients still required more time to escape from the effects of the mask. This suggests that schizophrenia patients may require more time to accurately identify or locate the stimulus without being distracted. Escape from the mask can also be seen as a measure of general visual processing ability. Because patients require longer periods of time to escape from the effects of the mask, even in conditions where the hyperactive M pathway is suppressed, it suggests general visual processing deficits in schizophrenia patients.

Taken together, these results suggest that there may be subtle differences between the groups. However, schizophrenia patients' performance was not significantly improved by introducing red light, which should suppress the magnocellular pathway. These results suggest that the M pathway in schizophrenia patients is not necessarily hyperactive, and may indirectly support a hypoactive hypothesis. This can be suggested from the trend of performance differences between the groups with patients performing worse overall when compared to normal controls. If patients' M pathways were hyperactive, they should show improved performance on the red background. This effect was not found on the location task, which is biased toward M pathway functioning.

The identification task relies on the participant's ability to navigate stimuli with high spatial frequency. Yeshurun and Levy (2003a) found that high spatial frequency stimuli that were cued spatially improved performance, but when participants were asked to attend to the temporal characteristics of the stimuli with the same spatial cuing, performance suffered. They concluded that normally, the temporal frequency of a stimulus is given precedence, therefore meaning that the M pathway inhibits the P pathway. However, when attention is focused on spatial frequency information, the receptive field shrinks, and the P pathway inhibits the M pathway (Yeshurun and Levy, 2003a). Later work by Yeshurun (2004) used isoluminant stimuli and a red background to remove M pathway contributions to attention. These findings also suggest that transient attention to a specific location will activate P pathway neurons, which then inhibit M pathway neurons. This may be the case in our identification task. The red background may have reduced the M pathway contributions to the task, and therefore transient attention facilitated P neurons. These P neurons reduced the receptive field, allowing for more high-spatial frequency information to be processed.

The red background of the identification task is the only component of the study where schizophrenia patients performed more accurately than the normal participants. A possible explanation for this finding is that the M pathway is inhibiting P activity in the identification task, which is biased toward the P pathway. In normal controls, their intact M pathway interferes with performance on the green background on the identification task, whereas schizophrenia patents show dysfunctional magnocellular input. When this pathway is suppressed in the presence of red light, ineffective input from patients' M pathway may allow the P pathway to be the dominant pathway, thus improving patients' performance on the identification task. This is consistent with work described above by Yeshurun (2004) and Yeshurun and Levy, (2003a).

Limitations for this study include a small sample size in both groups and variability within the schizophrenia patients. In order for significance to be demonstrated between groups, the effect sizes had to be large, and non-significant findings often had moderate effect sizes. These findings indicate that there may be a lack of statistical power which would likely be ameliorated with a larger sample. The patients also varied considerably in their level of functioning and reported symptoms, which was reflected in their performance on the tasks. As seen in figures 3.2 and 3.3, the variability within the schizophrenia patients was larger than that of the normal controls. This variability may be responsible for a lack of clear differences between the groups on some SOAs.

Future directions include looking for whether positive or negative symptoms affect the functioning of the M pathway. It is likely that attention and visual persistence my in fact be altered in schizophrenia patients exhibiting mostly positive or negative symptoms. Another possible avenue to follow is determining how the parvocellular pathway contributes to visual

functioning and if this pathway shows differences between schizophrenia patients and normal controls.

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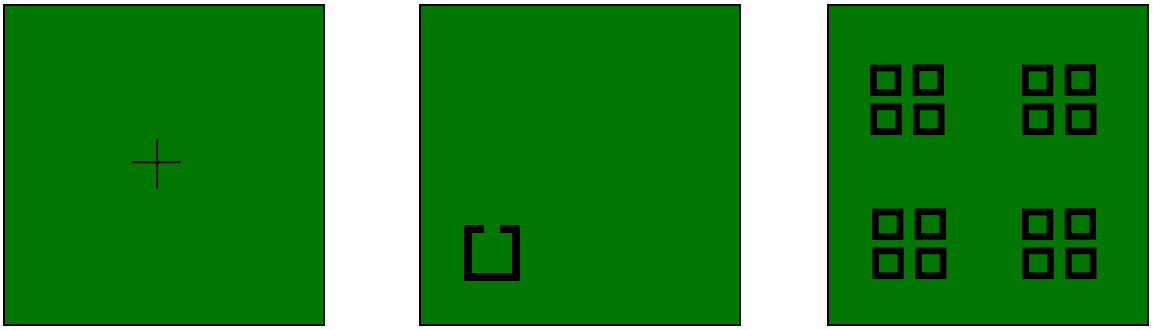
Figure 3.1



Masking stimuli. The target stimuli consist of a fixation cross, followed by a square with a gap in one side. The square can appear at any of four locations around the center. After a brief interval, a high energy mask is presented which covers all four possible locations of the target.

Figure 3.2 Location Task: Differences Between Groups on Background Color

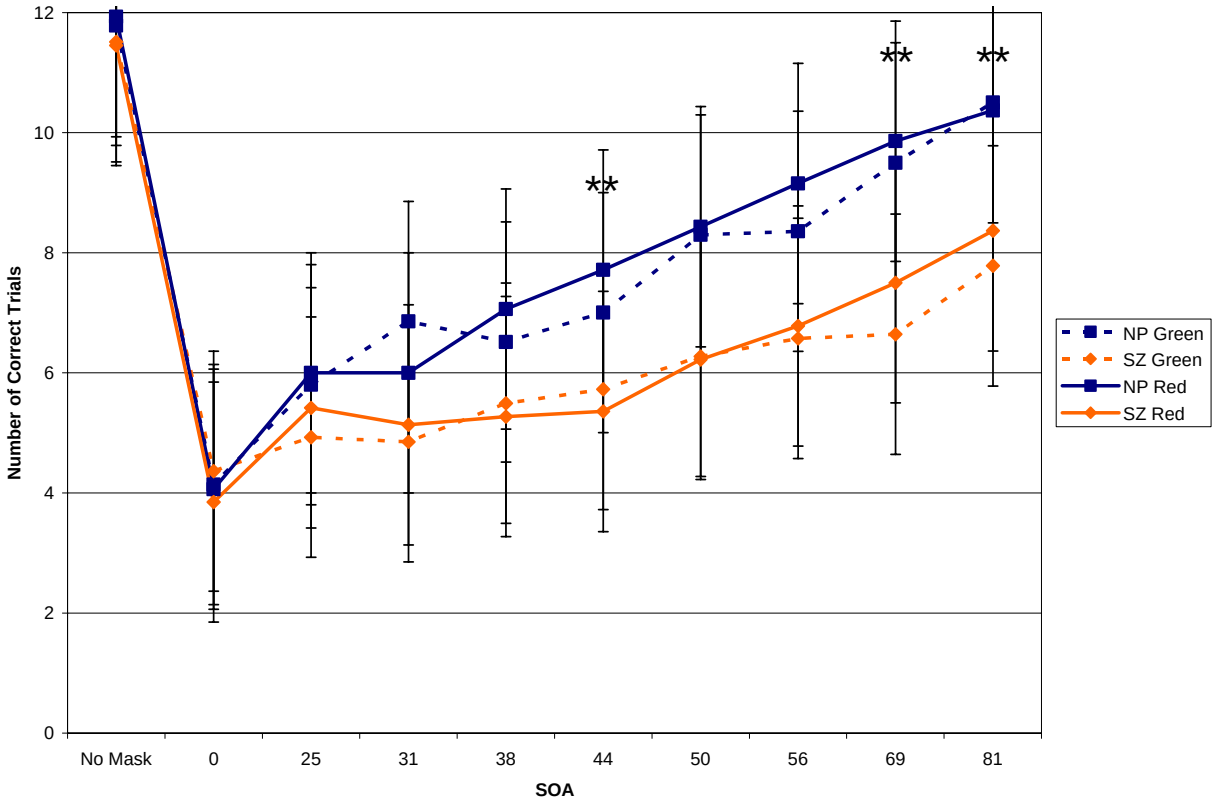


Figure 3.3 Identification Task: Differences Between Groups on Background Color

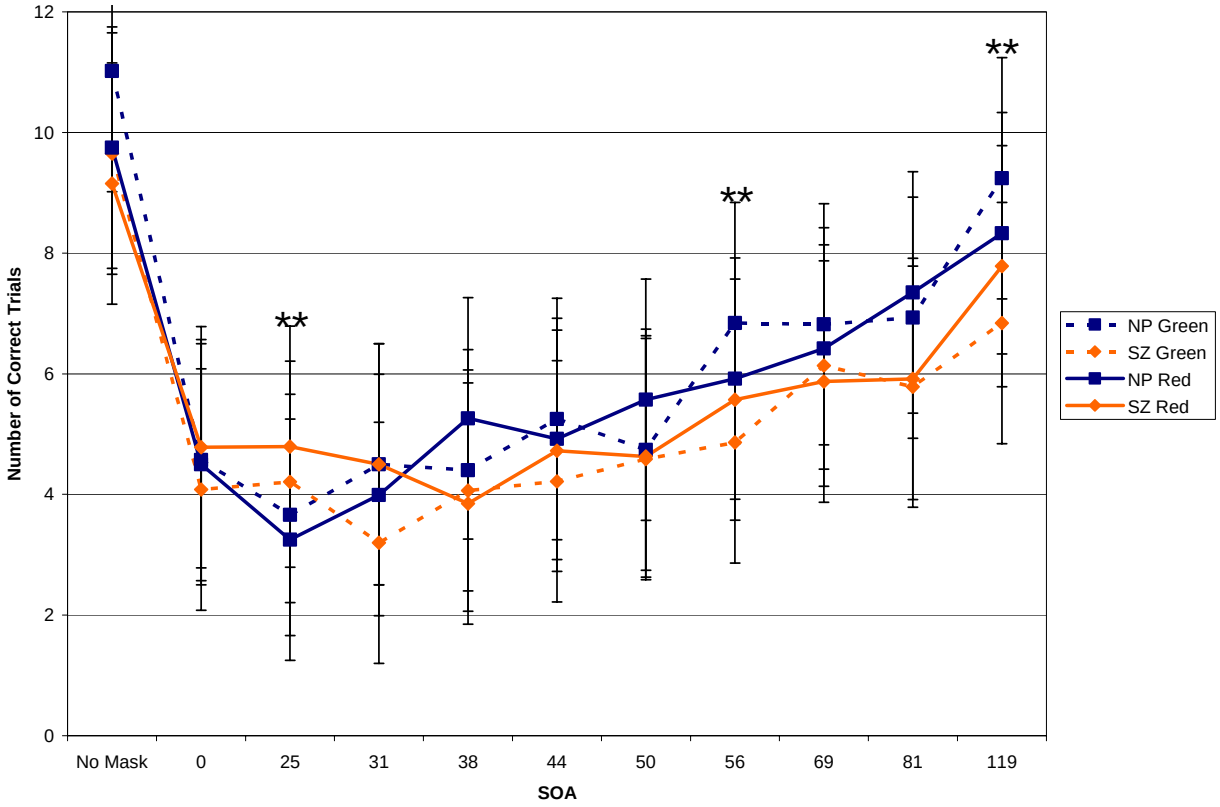


Table 3.1 Two by Two by Nine Repeated Measures Results for the Location Task, Comparing Normal Participants to Schizophrenia Patients.

Source		df	Mean Square	F	Sig.	Partial Eta^2
SOA	Greenhouse-Geisser	3.110	363.366	37.228	.000**	.589
SOA * group	Greenhouse-Geisser	3.110	24.899	2.551	.059	.089
color	Greenhouse-Geisser	1.000	3.500	.282	.600	.011
color * group	Greenhouse-Geisser	1.000	.071	.006	.940	.000
SOA * color	Greenhouse-Geisser	5.769	1.869	.707	.639	.026
SOA * color * group	Greenhouse-Geisser	5.769	2.699	1.020	.413	.038

**Significant at the p <.05 level

Table 3.2. Anova Summary Table and Descriptive Statistics for Schizophrenia Patients' Performance Compared to the Normal Controls' Performance on the Green Background for Stimulus Onset Asynchrony, Location Task.

SOA	Group	Mean ± SD	Sum of Squares	Mean Square	F	Sig.	Partial Eta^2
G_0	normal	4.14± 2.54	.321	.321	.054	.818	.002
	schizophrenia	4.36± 2.34					
G_25	normal	5.79± 2.46	5.14	5.14	.829	.371	.031
	schizophrenia	4.93± 2.53					
G_31	normal	6.86± 3.01	28.0	28.0	3.884	.059	.130
	schizophrenia	4.86± 2.32					
G_38	normal	6.50± 2.79	7.0	7.0	.871	.359	.032
	schizophrenia	5.50± 2.88					
G_44	normal	7.00± 3.14	11.6	11.6	1.127	.298	.042
	schizophrenia	5.71± 3.27					
G_50	normal	8.29± 3.12	28.0	28.0	2.548	.123	.089
	schizophrenia	6.29± 3.50					
G_56	normal	8.36± 2.53	22.3	22.3	2.353	.137	.083
	schizophrenia	6.57± 3.55					
G_69	normal	9.50± 2.96	57.1	57.1	6.022	.021**	.188
	schizophrenia	6.64± 3.20					
G_81	normal	10.5± 1.74	51.6	51.6	6.846	.015**	.208
	schizophrenia	7.79± 3.47					

**Significant at the $p < .05$ level

Table 3.3. Anova Summary Table and Descriptive Statistics for Schizophrenia Patients' Performance Compared to the Normal Controls' Performance on the Red Background for Stimulus Onset Asynchrony, Location Task.

SOA	Group	Mean ± SD	Sum of Squares	Mean Square	F	Sig.	Partial Eta^2
R_0	normal	4.07± 2.09	.321	.321	.083	.776	.003
	schizophrenia	3.86± 1.83					
R_25	normal	6.00± 2.00	2.29	2.29	.543	.468	.020
	schizophrenia	5.43± 2.10					
R_31	normal	6.00± 2.60	5.14	5.14	.797	.380	.030
	schizophrenia	5.14± 2.48					
R_38	normal	7.07± 3.03	22.3	22.3	2.323	.140	.082
	schizophrenia	5.29± 3.17					
R_44	normal	7.71± 2.81	38.9	38.9	5.265	.030**	.168
	schizophrenia	5.36± 2.62					
R_50	normal	8.43± 2.82	34.3	34.3	3.918	.058	.131
	schizophrenia	6.21± 3.09					
R_56	normal	9.14± 2.91	38.9	38.9	4.044	.055	.135
	schizophrenia	6.79± 3.29					
R_69	normal	9.86± 2.38	38.9	38.9	4.571	.042**	.150
	schizophrenia	7.50± 3.37					
R_81	normal	10.4± 2.10	28.0	28.0	4.080	.054**	.136
	schizophrenia	8.36± 3.05					

**Significant at the $p \leq .05$ level

Table 3.4 Two by Two by Ten Repeated Measures Analysis of Variance for the Identification Task, Comparing Normal Participants to Schizophrenia Patients.

Source		df	Mean Square	F	Sig.	Partial Eta^2
SOA	Sphericity Assumed	9	89.0	27.3	.000**	.532
SOA * group	Sphericity Assumed	9	6.56	2.01	.039**	.077
color	Sphericity Assumed	1	2.77	.641	.431	.026
color * group	Sphericity Assumed	1	11.4	2.63	.118	.099
SOA * color	Sphericity Assumed	9	.811	.307	.972	.013
SOA * color * group	Sphericity Assumed	9	3.52	1.34	.220	.053

**Significant at the $p < .05$ level

Table 3.5 Anova Summary Table and Descriptive Statistics for Schizophrenia Patients' Performance Compared to the Normal Controls' Performance on the Green Background for Stimulus Onset Asynchrony in the Indentification Task.

SOA	Group	Mean ± SD	Sum of Squares	Mean Square	F	Sig.	Partial Eta^2
G_0	normal	4.58± 1.38	1.69	1.69	0.679	.418	.028
	schizophrenia	4.07± 1.73					
G_25	normal	3.67± 1.16	1.94	1.94	0.762	.391	.031
	schizophrenia	4.21± 1.89					
G_31	normal	4.50± 2.07	10.7	10.7	2.869	.103	.107
	schizophrenia	3.21± 1.81					
G_38	normal	4.42± 1.51	.770	.770	0.343	.563	.014
	schizophrenia	4.07± 1.49					
G_44	normal	5.25± 1.22	6.93	6.93	2.657	.1161	.100
	schizophrenia	4.21± 1.89					
G_50	normal	4.75± 1.55	.206	.206	0.083	.776	.003
	schizophrenia	4.57± 1.60					
G_56	normal	6.83± 1.99	25.2	25.2	5.537	.027**	.187
	schizophrenia	4.86± 2.25					
G_69	normal	6.83± 2.21	3.08	3.08	0.488	.491	.020
	schizophrenia	6.14± 2.74					
G_81	normal	6.92± 2.19	8.27	8.27	1.261	.273	.050
	schizophrenia	5.79± 2.83					
G_119	normal	9.25± .866	37.0	37.0	12.01	.002**	.333
	schizophrenia	6.86± 2.25					

**Significant at the $p < .05$ level

Table 3.6 Anova Summary Table for Schizophrenia Patients' Performance Compared to the Normal Controls' Performance on the Red Background for Stimulus Onset Asynchrony in the Indentification Task.

SOA	Group	Mean ± SD	Sum of Squares	Mean Square	F	Sig.	Partial Eta^2
R_0	normal	4.50± 1.68	.527	.527	0.292	.594	.012
	schizophrenia	4.79± .975					
R_25	normal	3.25± 1.49	15.2	15.2	5.842	.024**	.196
	schizophrenia	4.79± 1.72					
R_31	normal	4.00± 1.48	1.62	1.62	0.611	.442	.025
	schizophrenia	4.50± 1.74					
R_38	normal	5.25± 2.05	12.5	12.5	3.762	.064	.136
	schizophrenia	3.86± 1.61					
R_44	normal	4.92± .996	.265	.265	0.152	.700	.006
	schizophrenia	4.71± 1.54					
R_50	normal	5.58± 1.88	5.72	5.72	1.630	.214	.064
	schizophrenia	4.64± 1.87					
R_56	normal	5.92± 1.83	.770	.770	0.270	.608	.011
	schizophrenia	5.57± 1.56					
R_69	normal	6.42± 2.54	2.02	2.02	0.383	.542	.016
	schizophrenia	5.86± 2.07					
R_81	normal	7.33± 2.27	12.8	12.8	2.398	.135	.091
	schizophrenia	5.93± 2.34					
R_119	normal	8.33± 2.43	1.94	1.94	0.330	.571	.014
	schizophrenia	7.79± 2.42					

**Significant at the $p < .05$ level

CHAPTER 4

DISCUSSION

Overall, schizophrenia patients showed modest differences in performance when compared to normal controls. Throughout each condition, schizophrenia patients were generally less accurate than normal controls. Our first hypothesis stated that schizophrenia patients would exhibit performances in the red background similar to performances in the normal control group on the green background. In this comparison, we found no statistically significant difference between the groups. This finding could suggest that the schizophrenia patients' visual processing in the magnocellular system is aided by diffuse red light, causing performance to be similar to the control group in the neutral condition. These data are consistent with our first hypothesis.

For both the location and identification tasks, the groups were compared on performance on each background color. In the location task, there were some statistically significant differences in performance between groups when compared on a red background or on a green background. Schizophrenia patients showed the most difference from normal controls on longer SOAs on the green background. This suggests that the possible hyperactivity within the M pathway in schizophrenia patients did not provide an advantage in performance on a neutral background, and they also did not benefit from longer processing time as compared to controls.

To look for the red light effect, performance within groups was analyzed. Each group was compared on background color, collapsing across time intervals. No consistent differences were found within either group. Neither group showed a consistent benefit for a red or green

background that reached statistical significance. Paradoxically, normal controls showed slightly more accurate performance on the red background as the time interval increased, and the schizophrenia patients did not perform consistently with our hypotheses. However, once the SOAs reached the longer intervals, differences between the groups emerged. Overall, there was little difference in performance within the schizophrenia group; however, the differences were most pronounced at longer time intervals. At these intervals, patients showed the best performance on the red background.

In the identification task, some differences between the groups did emerge. On the green background, two SOAs proved to be statistically significant (Green 56 and 119), and the normal controls continued to perform more accurately than the schizophrenia patients. However, on the red background, one SOA attained statistical significance (Red 25), and the schizophrenia patients performed more accurately than the normal controls. Further inspection of performance on the red background revealed a trend toward schizophrenia patients performing more accurately on the red background for this task.

One explanation for these findings may be the role of visual attention in M and P pathway functioning. Work done by Yeshurun and Levy (2003a) and Yeshurun (2004) indicate that generally, attention given to the temporal frequency of the stimulus activates the M pathway, which inhibits parvocellular inputs. However, when attention is directed toward high spatial frequency information, the P pathway inhibits M input. The identification task relies on parvocellular input to identify a characteristic of the stimuli. On the green background, M input may inhibit P input. However, when M input is reduced on the red background, patients may perform more accurately than controls because their M input may already be somewhat dysfunctional, and when the M pathway is further inhibited by red light, the P pathway is

allowed to then be the dominant pathway. In normal controls, however, the M pathway is intact, and is therefore not reduced as much when red light is present.

Escaping from the mask can also be considered a measure of visual system functioning. Because patients required longer amounts of time to escape from the mask on the red background, it may suggest further evidence of general visual processing dysfunction in schizophrenia patients, rather than hyperactivity. If suppression of the M pathway due to red light reduces a hyperactive pathway to be more like a normal control, it would likely cause improvement in the ability to escape from the mask. Instead, patients show more difficulty ignoring the mask, indicating more general dysfunction in the M pathway.

Closer inspection of the data indicate that the schizophrenia patients still performed below the normal controls, especially in the location task. This may be due to global deficits within the visual processing system of schizophrenia patients. These results are inconsistent with the original hypotheses of the study. It was expected that patients would show an improved performance on the red background due to the hyperactivity of the M pathway being suppressed to the level of the normal controls in neutral conditions. These results do not clearly indicate hyperactivity of the M pathway in schizophrenia patients. Because the patients performed consistently below normal controls on both backgrounds, it can be concluded that there are still differences between the groups. These differences may be due to a general dysfunction of the M pathway in schizophrenia patients.

This study was limited by a number of factors. First, the sample size was small. Recruitment was limited by the available resources of the area, as well as the prohibitive time per participant that was required. Statistical power was also low within the populations. Significant differences were only found when there were large effect sizes, and many of the non-significant

findings produced moderate effect sizes, indicating there may be deficient statistical power. Low statistical power may be due to small sample size, and also variability within the groups. The normal group showed relatively small variation within the group. However, schizophrenia patients showed greater variability within the group. Patients varied by factors that were not included in the analyses such as level of independence, medication, and symptomatology. These inherent within-group differences likely caused much more variation. The variability within this group may have reduced the clear differences in performance between the groups.

Future directions include looking for the effect of positive and negative symptomatology on the functioning of the visual system. If the M pathway differences can be attributed to a deficit in the path, it is possible that this deficit would be more pronounced in patients experiencing primarily negative symptoms. It might also be found that patients with positive symptoms perform more like normal participants. The sample size of the current study is not large enough to elucidate differences between symptom types among the schizophrenia patients. Other possible directions include determining parvocellular contributions to visual processing in schizophrenia. Yeshrun et al. (1999) show possible inhibition of the M pathway by the P pathway in visual attention tasks. These results may also generalize to psychiatric populations.

The implications from this study include differences in the visual functioning of schizophrenia patients when compared to non-psychiatric controls. The results suggest little benefit from suppression of the M pathway in patients, which likely indicates general dysfunction in the visual system, rather than the pathway being hyperactive. This is also supported by schizophrenia patients requiring longer amounts of time to escape from the mask compared to normal controls. Visual processing dysfunction has been implicated in previous work, and may be considered an endophenotypic marker for the disorder.

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