

## Literature Review ► Visual Processing Deficits in Schizophrenia

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### ABSTRACT

Schizophrenia has been shown to be associated with deficits in higher-order processing of visual information. This literature review explores evidence supporting deficits and dysfunction in areas of pattern recognition, visual scanning, motion processing, and visual attention resulting in altered perception of visual stimuli and reality in patients with schizophrenia. The goal is to help clinicians better understand the disorder for therapeutic and management considerations. Evidence supporting potential pathophysiological processes in the retina and central nervous system offer potential diagnostic value for optometrists, as well as potential benefit from visual rehabilitation for patients with schizophrenia.

**Keywords:** motion processing, pattern recognition, schizophrenia, visual processing, visual attention

Schizophrenia, a mental illness as complex in appearance as etiology, affects women and men equally with similar prevalence rates around the world. According to the National Institute of Mental Health, schizophrenia occurs in one percent of the general population.<sup>1</sup> Ten percent of people who have a first-degree relative with schizophrenia, such as a parent or sibling, develop the disorder, implying a genetic component to the illness.

The goal of highlighting the impact of schizophrenia on ocular health and the visual system is to help clinicians better understand the disorder for therapeutic and management considerations and attempt to identify early markers in the development of the disorder. Schizophrenia, ranked among the top ten leading causes of disease-related disability in the world, has been shown to be associated with deficits in higher-order processing of visual information.<sup>2</sup> Essentially, since schizophrenia is a disease of the brain, the disorder is expected to have a significant impact on how patients process visual information to interpret reality. Whether the visual processing deficits precede the condition or are a result of the

condition is yet to be determined. This review will present a brief overview of research on this much-discussed mental illness, followed by information specifically related to the findings on the ocular and visual effects of schizophrenia.

As with any illness, much of the research on schizophrenia has focused on etiology. Studies have shown that patients with schizophrenia tend to have higher rates of rare genetic mutations that may disrupt brain development and function. Evidence also shows that environmental factors may be involved, such as exposure to viruses or malnutrition before birth, problems during birth, and other not yet known psychosocial factors. Despite research efforts, the causes of the disorder have not yet been clearly identified. Current treatment of schizophrenia focuses on symptom reduction and relapse prevention. Typical treatments include antipsychotic medications, various psychosocial treatments, and supportive therapies.

The Diagnostic and Statistical Manual of Mental Disorders (5th edition) characterizes schizophrenia by the presence of delusions,

hallucinations, disorganized speech and behavior, and other symptoms that cause social or occupational dysfunction.<sup>3</sup> The diagnosis is based on the patient's symptoms and clinical observations, rather than laboratory tests. Signs and symptoms of the illness are categorized as either positive or negative manifestations. In this context, positive suggests above or in excess, meaning these signs and symptoms are typically behaviors that are not seen in a healthy population. Positive signs/symptoms include the stereotypical psychotic episodes: hallucinations (auditory and visual), paranoid delusions, exaggerated or distorted perceptions, beliefs, and behaviors. Negative suggests absent or decreased, meaning these signs/symptoms reflect a behavior that is dampened in those with schizophrenia compared to healthy individuals. These negative signs/symptoms include a loss or decrease in the ability to initiate plans, speak, express emotions, or derive pleasure. A third category, cognitive symptoms, has been of interest and relevance to neuro-scientists. These symptoms include confused and disordered speech, memory problems, difficulties with logical thinking, and attention deficits.

Although visual disturbances generally are not considered to be among the most prominent clinical symptoms of schizophrenia, the visual system is nonetheless an important site of pathology and dysfunction in this disease.<sup>4</sup> In fact, most of the positive, negative, and cognitive symptoms may be a result of the associated visual processing issues.

Visual processing involves the reception, organization, and assimilation of information obtained through the eyes. This complex sequence of steps that allows us to process and interpret meaning from our environment is compromised in schizophrenic patients. The components of visual processing include visual cognition, visual memory, pattern recognition, motion processing, and visual attention.<sup>5</sup> This review will focus on knowledge

gained from research on pattern recognition, visual scanning, motion processing, and visual attention in patients with schizophrenia.

### **Pattern Recognition**

Pattern recognition is the ability to identify specific features of an object, such as shape, contour, color, shading, texture, etc. Contrast sensitivity deficits and color vision deficits have been observed in schizophrenia patients. Studies conducted by Slaghuis et al. showed a general loss of spatial and temporal contrast sensitivities among the schizophrenic population, with more severely reduced functions in patients demonstrating negative schizophrenic symptoms.<sup>6</sup>

### **Visual Scanning**

Scanning is the ability to obtain details from the environment in an organized and systematic manner. Visual scanning patterns, or scan paths, are composed of saccades, fixations, and pursuits. Atypical scan paths in individuals with schizophrenia have been observed in response to a broad range of visual stimuli and visual tasks.<sup>7</sup> Impairments in the ability to track moving objects with their eyes have been observed in patients with schizophrenia and their first-degree relatives. In particular, healthy relatives of patients with schizophrenia tend to have jerkier pursuit movements than subjects without a family history of the illness. These results, along with the greater similarity of eye tracking proficiency during smooth pursuits found in monozygotic compared to dizygotic twins. Katsanis et al. suggest that smooth pursuit dysfunction is at least partly inherited.<sup>8</sup> These oculomotor impairments in schizophrenia, coupled with pattern recognition impairment, could be the underlying cause of visual search deficits, which are prevalent among schizophrenic patients. Visual search is a perceptual-motor task that involves actively attending to the visual environment with scanning eye movements

for the purpose of locating a particular object or feature (target) in the presence of other objects or features (distractors). Visual search deficit is considered a core symptom of visual attention impairment that interrupts the cognition process as well as social cognition in patients with schizophrenia.<sup>9</sup>

### **Motion Processing**

As stated previously, patients with schizophrenia have impairments in the ability to track moving objects with their eyes. In the brain, the middle temporal (MT) area of the visual cortex is thought to play a major role in the perception of motion, the integration of local motion signals into global percepts, and the guidance of some eye movements. The visual responses of MT neurons are determined principally by five properties of the stimulus: retinal position, direction of motion, speed of motion, binocular disparity, and stimulus size.<sup>10</sup> Using functional MRI, Chen and colleagues measured cortical activation while subjects performed two visual motion tasks (direction discrimination and speed discrimination) and one non-motion task (contrast discrimination). They concluded that those with schizophrenia activated their motion-processing area MT less than controls (non-schizophrenic) while doing motion-processing tasks.<sup>11</sup> As a result, those with schizophrenia may be unable to tell the difference between the speeds of two objects or integrate complex motion information. This study provides evidence that schizophrenia is associated with deficient sensory processing and perception, in conjunction with poor oculomotor control.

### **Visual Attention**

According to the information-processing theory<sup>12</sup> and the feature-integration theory,<sup>13</sup> visual attention is the first step in information processing. We direct our gaze rapidly towards objects in our visual environment field, and bottom-up and top-down processes integrate

the visual information. Integration via top-down visual processing is a deconstructive sequence of identifying a higher-order form stimulus and the subsequent analysis of its lower-order components. Bottom-up processing is a constructive sequence of identifying lower-order form stimuli and the subsequent synthesis into higher-order forms.<sup>14</sup>

A visual attention deficit may adversely influence information processing, thereby causing a cognition deficit, and may even result in poor social cognition.<sup>15</sup> Visual attention also encompasses the ability to shift attention between stimuli. Thus, visual attention requires sound oculomotor function, which, as previously discussed, is reduced in schizophrenic patients. Research indicates that patients with schizophrenia are significantly impaired in real-world tasks that involve shifting attention in cluttered scenes.<sup>16</sup> For instance, finding a book on a shelf or scanning a dinner menu may require significantly more time and effort for people with versus those without schizophrenia.<sup>16</sup>

Abnormal visual information processing in schizophrenia is currently being explored as a potential biomarker of the disorder. Along with the numerous etiologies proposed for schizophrenia, many mechanisms have been suggested as the cause of the visual processing deficits observed in the illness. The ones most relevant to the previously discussed deficits are retinal nerve fiber layer and macular thinning, cerebrovascular abnormalities, and visual cortex dysfunction.

### **Retinal Nerve Fiber Layer and Macular Thinning**

In recent studies, schizophrenic patients have shown statistically significant peripapillary retinal nerve fiber layer (RNFL) thinning, macular thinning, and macular volume reduction compared to normal controls. A study by Lee et al. revealed significant structural thinning of RNFL in schizophrenic

patients that could explain the deficits in visual perception and processing in these patients. They also postulated that the RNFL thinning observed in their study could be attributed to the dopamine dysregulation that occurs in schizophrenia.<sup>17</sup> Deficits in visual functions controlled partially by dopamine, such as contrast sensitivity and color vision, have been observed in dopaminergic pathologies. Dopamine affects color discrimination more in the tritan axis due to the sparsely distributed blue cones and the lack of spatially antagonistic off-center/on-surround receptive field profiles in the blue-yellow pathway. Recall that pattern recognition involves contrast sensitivity and color discrimination, both of which have been found to be deficient in schizophrenia patients. Many studies have investigated dopamine in a hypoactive state, as in Parkinson's, but few have explored dopamine in hyperactive states, as in schizophrenia.

In addition to dopamine dysfunction, damage to the RNFL can be caused by chronically elevated intraocular pressure (IOP), high fluctuation of IOP, inflammation, vascular disease, and hypoxia of any origin.<sup>15</sup> Research is limited concerning elevated or fluctuating IOP within either medicated or non-medicated schizophrenic patient populations. However, some studies have been conducted to determine whether inflammation, vascular disease, and hypoxia play a role in schizophrenia. Whether they precede RNFL damage or occur as a result of the RNFL damage is yet to be determined, but research on cerebrovascular abnormalities in schizophrenia may offer some insight.

### **Cerebrovascular Abnormalities**

Cerebrovascular abnormalities have been discussed as a pathological feature in schizophrenia. Wider venules are thought to result from cumulative structural damage to the microvasculature and may indicate problems with the oxygen supply to the brain. Structural damage caused by inflammation, endothelial

dysfunction/dysregulation of the nitric oxide signaling pathway, and hypoxia/ischemia are all seen in schizophrenia. Hypothesizing that individuals with schizophrenia show microvascular abnormalities, Meier et al. evaluated the utility of retinal imaging as a tool for future schizophrenia research. Their results provided the initial evidence of retinal vessel caliber abnormality in schizophrenia; specifically, wider venular caliber is found in schizophrenia, indicative of microvascular pathology in schizophrenia.<sup>18</sup> These results may be of special interest to optometrists and ophthalmologists, since retinal imaging has the potential to aid in the diagnosis of schizophrenia.

### **Vision Rehabilitation**

Whether the visual signs and symptoms associated with schizophrenia are precursors for the illness, are signs of established illness, or are a result of medication prescribed for the illness remains a topic for debate. Some identified pathophysiological processes, at a minimum, support many of the visual processing component deficits present in schizophrenia. Given the complexity of the disorder, with links to so many functional aspects of the brain, schizophrenia's true pathophysiological process has yet to be determined. While the underlying causes of the visual processing deficits are still under investigation, patients with schizophrenia and schizotypal disorders may benefit from rehabilitative vision therapy. The previously discussed visual processing deficits in schizophrenia are similar to those seen in patients with traumatic brain injury. Effective treatment and rehabilitation for visual processing deficits have resulted in improved functional adaptation, better rehabilitation outcomes, and more favorable prognoses.<sup>5</sup> While the causes of the conditions are different, the potential for rehabilitative therapy for visual processing deficits in schizophrenia may be promising and could be an area of

further research. With the opportunity to improve the function of the visual processing system, patients with schizophrenia may have improved personal interactions, more accurate interpretations of reality, and improved memory, among other functions.

## Conclusion

Even though the symptoms of visual disturbance are not considered to be among the most prominent clinical symptoms of schizophrenia, more research in this area would be of great benefit to clinicians and most importantly, to patients.

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