Optical Illusions to Schizophrenic Delusions: How Your Brain Can Alter Reality

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OPTICAL ILLUSIONS TO SCHIZOPHRENIC DELUSIONS: HOW YOUR BRAIN CAN ALTER REALITY

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ABSTRACT

Widely misunderstood, stigmatized and understudied, schizophrenia is often misdiagnosed and incorrectly treated. While people diagnosed with schizophrenia are often thought to misinterpret reality, they may be more adept at processing visual sensory information and perceive reality better than those without schizophrenia. Studies involving patients with schizophrenia have shown consistent and extensive insusceptibility of these patients to a variety of optical illusions. In this paper, I propose that when processing visual information, people with schizophrenia rely greater upon the dorsal stream and areas in the brain associated with bottom-up processing, as opposed to those without schizophrenia that utilize the ventral stream and areas of the brain associated with top-down processing of visual information. Furthermore, I speculate that this difference in visual information processing begins around age 8, but can take decades to fully develop, much like other symptoms characteristic of schizophrenia. In order to test these hypotheses, I suggest a feasible experiment in which adult and juvenile participants with schizophrenia or genetic predisposition to schizophrenia, are matched with healthy participants without schizophrenia and are observed under fMRI technology to assess activity in various regions of the brain while viewing images reflective of dimensional, optical illusions. Like any disease, illness or mental disorder, the key to successful treatment of patients with schizophrenia is early diagnosis. Ultimately, the introduction of the use of optical illusions in medical settings to assist in diagnosis and justifying further testing for schizophrenia may prove essential in providing patients with timely treatment.
# TABLE OF CONTENTS

I. **Background** 1  
   A. What is Schizophrenia? 1  
   B. How are Patients Diagnosed with Schizophrenia? 2  
   C. Why Do People Develop Schizophrenia? 4  
   D. How Does Top-Down Processing Present in Optical Illusions? 6  

II. **Investigating Schizophrenia with Experiments Using the Hollow Mask Illusion** 9  
   A. Experimental Setup 9  
   B. Collecting fMRI Data 10  
   C. Results from fMRI and Survey Data 11  
   D. Models Proposed from fMRI Data 12  
   E. Interpretation of fMRI and Survey Data 13  

III. **Difference in the Interpretation of Optical Illusions** 15  
   A. Are People with Schizophrenia Susceptible to All Optical Illusions? 15  
   B. How Can Similar Optical Illusions Use Different Methods of Deception? 16  
   C. What are the Different Ways in Which Visual Information is Processed in the Brain? 17  
   D. Do Cultural Differences Affect Perception? 19  

IV. **Speculative Differences in Visual Processing by People with Schizophrenia:*** 21  
   A. Does Reliance on Both Visual Processing Streams Result in Unsusceptibility to Illusions? 21  
   B. Can Differences in Top-Down Processing Result in Unsusceptibility to Illusions? 22  
   C. Proposed Experimental Setup 24  
   D. Possible Results and Their Significance from Proposed Experiment 25  

V. **Conclusion** 28  
   A. Summary of Proposed Hypothesis 28  
   B. Possible Importance and Implication of Results 28  

VI. **Bibliography** 30  

VII. **Appendix** 32  

VIII. **Author’s Biography** 42
CHAPTER I

BACKGROUND

A. What is Schizophrenia?

Coined by psychiatry professor Eugen Bleuler of Switzerland in a lecture in 1908, the term schizophrenia comes from the Greek words “schizein,” meaning splitting, and “phren,” meaning mind. Now well known for his dedication to clinical observation of and research on patients with schizophrenia, Bleuler was adamant that this “splitting of different psychic functions” and the ultimate “loss of unity” patients experienced was a key component of the disorder and understanding its origins. Bleuler was also one of the first doctors to present the concept of primary and secondary symptoms in the disorder, and played a critical role in acknowledging the difference that these types of symptoms play in the disorder. Bleuler's research suggested that primary symptoms stemmed from the split between thought processes and emotion or behavior whereas secondary symptoms were the result of the primary symptoms and often included depression, hallucinations or social deficits. Today, medicine has not only preserved Bleuler’s naming of the disorder but also the concepts of the splitting of different mental domains and primary and secondary symptoms. While psychic functions are not widely accepted in today’s fields of scientific study, psychiatrists and researchers have adapted Bleuler’s “split-mind” notion to instead relate to the “pathological connectivity” between areas of the brain. Additionally, modern day psychiatrists have built upon Bleuler’s concept of secondary symptoms by further differentiating these symptoms as positive, negative, or cognitive symptoms. Positive symptoms, also sometimes called psychotic symptoms, are the hallmark symptoms that people often associate with the disorder such as
hallucinations, delusions and thought disorders like disorganized speech or thought. These types of symptoms are categorized as “positive” since they are not thought to have a standard physiological counterpart in people who do not have schizophrenia. On the other hand, negative symptoms that can include lack of motivation, reduced motion, social withdrawal, or difficulty displaying emotion, are categorized as negative symptoms since they are considered to be deviations from normal processing or functioning. Finally, cognitive symptoms are defined as symptoms that reflect challenges with memory, learning, or understanding and can present as forgetfulness, decision making, or limited attention span, making them more difficult to detect.

B. How are Patients Diagnosed with Schizophrenia?

Despite a multitude of tangible and documented symptoms, as well as hundreds of years of research, a diagnosis of schizophrenia is difficult to obtain as the disorder is thought to only affect less than one percent of the world’s population. Currently, it is still even debated whether or not schizophrenia should be classified as a disorder or a syndrome. While these symptoms and their association with schizophrenia have allowed patients to be diagnosed with schizophrenia as a disorder, schizophrenia is often broadly categorized as a clinical syndrome due to a lack of a clear disruption to a specific bodily structure or function and its variation of signs and symptoms. However, a diagnosis of schizophrenia allows it to be qualified as a chronic brain disorder and will be referred to as a disorder throughout this text. Diagnosis of schizophrenia varies from patient to patient, with some being diagnosed as early as their teenage years and others not receiving a diagnosis until their thirties, if they are able to receive a diagnosis at all. It is
thought that the disorder begins to develop during this time frame as well since it is exceedingly rare to receive a diagnosis prior to late adolescence or after turning forty\textsuperscript{16}. A typical diagnosis can occur after the first episode of psychosis, but for a definitive diagnosis of schizophrenia the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders requires two or more positive symptoms (specifically delusions, hallucinations, or disorganized speech, grossly disorganized or catatonic behavior) and negative symptoms to each be “present for a significant portion of time during a 1-month period” and at least one of these symptoms must be either delusions, hallucinations, or disorganized speech\textsuperscript{12}. In addition to these positive symptoms, the DSM-5 also clarifies that these symptoms cannot be traced back to any other underlying diseases, disorders or substance abuse and any other negative or cognitive symptoms must also be present for at least six months\textsuperscript{12}. These requirements and specific symptoms require self-reporting and involve a critical duration, making it difficult for those with the disorder to receive a timely diagnosis. Furthermore, schizophrenia typically cycles through three phases which can also pose a challenge to clinical diagnosis. The first phase, or the prodromal phase, typically involves negative symptoms and can result in a delayed diagnosis due to the similarity of these symptoms to other more common disorders such as depression or anxiety disorders. This prodromal phase is usually followed by an active phase in which patients present with positive symptoms that are more characteristic to schizophrenia and most critical to diagnosis. However, the active phase can be extremely brief for some patients and is followed by a third phase, known as the residual phase. During this final phase, the cognitive symptoms of the disorder are more likely to present and can again be
misdiagnosed as other more common disorders like attention-deficit disorder or bipolar disorder.

C. Why Do People Develop Schizophrenia?

In addition to being difficult to diagnose, the underlying causes of schizophrenia and the pathophysiology of the disorder are still not fully understood. Current and widely accepted research presents two theorized factors involved in the development of schizophrenia: genetic factors and environmental factors. Like many other disorders, genetics plays a large role in determining whether or not a person will present with a certain characteristic or disorder as well as the extent to which a characteristic or disorder manifests. While some characteristics are straightforward and linked to a single gene, studies funded by NIMH involving hundreds of thousands of participants with and without schizophrenia have been unable to find a single gene linked to the disorder. Though some participants with schizophrenia in these genetic studies shared the same genotypes as other participants with schizophrenia, these same genotypes can also be found in participants without schizophrenia and vice versa. Nonetheless, this study was still able to identify “over 250 places in the genome” that could contribute to overall risk for schizophrenia. While this research shows that genetics is unlikely to be able to predict or diagnose schizophrenia, in combination with familial studies that show that schizophrenia could run in families, this genetic analysis allows researchers to attribute certain genetic traits to the likelihood of the development of schizophrenia and provides insight on the influence of certain combinations of genetic differences in disorders. Another classification of factors that researchers have attributed to schizophrenia include
environmental factors, such as stressful surroundings or trauma and exposure to viruses, nutritional problems or drugs both before birth and early adolescence\textsuperscript{16}. Though many studies document these risk factors in the history of patients with schizophrenia and these risk factors are easily replicated in animal studies, the positive symptoms of schizophrenia are more difficult to recognize in animals, resulting in this theory being understudied and thus seldom acknowledged as a definitive causation\textsuperscript{16}.

However, like Bleuler who suggested schizophrenia stemmed from a “splitting of the mind,” recent studies on various stimuli processing pathways in the brain have now suggested a new factor that could contribute to some of the underlying causes of schizophrenia, specifically miscommunication between or misuse of bottom-up and top-down processes\textsuperscript{5}. When the brain interprets sensory information, visual, auditory, etc., this information is thought to be handled in either a bottom-up or top-down manner. Bottom-up processing is one of the first methods of sensory information processing that is developed in early infancy and depends solely upon the raw data that the sensory organs and brain receive. In bottom-up processing, information is processed in real-time and does not require the interpretation or use of prior experience or knowledge. In this process, the sensory information is taken in by sensory receptors that then send this information to the brain via a series of action potentials that the brain is able to use to interpret and construct a particular perception based on these signals\textsuperscript{13} (see appendix Figure 1 & Figure 2). Alternatively, top-down processing takes time to develop, as this manner of processing information utilizes past experiences and knowledge to interpret new sensory information. Like bottom-up processing, the sensory receptors take in sensory information and send this information to the brain as action potentials, but in top-
down processing the brain also inputs previously stored information to assist in constructing a perception in tandem with the direct sensory signals\textsuperscript{14}. There are multiple theories as to why the brain has developed this variation of sensory processing, one of which includes Richard Gregory’s theory of perception. Gregory's theory states that sensory information alone is not sufficient for perceptual processing as over 90% of information can be lost between the sensory organ and the brain. Gregory’s theory also discusses the idea that top-down processing can assist in alleviating the brain from having to directly interrupt the endless stream of sensory information the brain receives at all times\textsuperscript{14}. Other theories conclude that top-down processing has evolved as a method of survival which is evident when observing various optical illusions.

D. How Does Top-Down Processing Present in Optical Illusions?

One of the optical illusions involved in top-down processing includes Adelson’s Checker-Shadow Illusion in which a checkerboard pattern of black and white squares with a cylindrical object casting a shadow on the pattern is presented to observers; The illusion makes two squares, one within the shadow cast by the object and one outside the shadow, appear to be two different colors or one black and the other white (see appendix Figure 3). However, in an alternative composition of the image, if bars joining the two squares are placed across the image, it is clear to observers that these squares are in fact the exact same shade of gray (see appendix Figure 4). The initial interpretation of this illusion, in which the two squares appear to be different colors, is the result of top-down processing. In Adelson’s Checker-Shadow Illusion, the eye is able to interpret the true brightness of the two squares in both the complete and incomplete compositions of this
illusion, but the brain uses top-down processing, specifically recognition of patterns and shadows, to construct a perception in which these two squares are different brightnesses\textsuperscript{18}. This illusion utilizes the brain’s implementation of lightness constancy that has evolved over millions of years in order to help detect edges and forms even in limited light\textsuperscript{18}. Over time, our brains learn that patterns, like the checkerboard pattern, are typically consistent as well as the fact that shadows cast on objects typically make them appear darker than they actually are. As a result, this previous knowledge and experience helps to create this illusion that the squares are in fact two different colors. Outside of the illusion, this processing mechanism helps the brain “fill in the blanks” in otherwise possibly dangerous situations in which pure sensory information alone is unable to provide the brain with a clear and efficient perception of a scene.

Other optical illusions that exemplify the visual discrepancies that can be created through the brain’s use of top-down processing include the Hollow Mask Illusion (HMI) and Landscape Perspective Illusion (LPI) (see appendix Figure 5 & Figure 6). Like Adelson’s Checker-Shadow Illusion, these two illusions rely on the brain’s use of previous experience and information as well as the brain’s implementation of top-down processing. The HMI consists of a hollow mask of a human face in which both sides of the mask are colored and shaded to reflect a three-dimensional version of a human face. Whether observing either the convex or concave sides of the mask, participants typically only perceive convex faces due to top-down processing that prevents the brain from understanding or perceiving the image of a concave face. From previous experience with shadows and an object as common as a convex, human face or due to lack of experience with concave human faces, the brain assumes that the face must be convex even if the
brain receives information from the eye that the face in the illusion is in fact concave. In a similar way, the LPI is composed of an alternating convex and concave structure painted in a way to depict a seemingly flat image of a cityscape. In this image, streets converge in the distance and buildings closer to the front of the image appear to be convex, much like how these objects were to appear in real life. However, areas of the image that appear to be concave or converge in the background, such as the streets, are in fact convex and areas that appear to be convex or jut forward, like the buildings, are in fact concave. In both of these illusions, the brain uses top-down processing in order to override the actual and accurate sensory information that the eye sends to the brain due to previous understanding of shadows, depth perception and objects that are interacted with daily. However, studies involving these two particular illusions have shown that observers with schizophrenia do not appear to utilize top-down processing and are unable to perceive these illusions. Therefore, understanding the nature of these optical illusions provides insights into the causes and origins of schizophrenia.
CHAPTER II

INVESTIGATING SCHIZOPHRENIA WITH EXPERIMENTS USING THE HOLLOW MASK ILLUSION

A. Experimental Setup

One study conducted by researchers at Hannover Medical School in Germany studied the brain activity of both participants with schizophrenia and participants without schizophrenia when observing the HMI. This research, carried out by Dima et. al. in 2009, sought out to determine which areas and pathways of the brain could be responsible for the disparity in observed dimensionality that was reported between the two groups of participants. These researchers hypothesized that the difference in experiencing the illusion is due to “top-down influences from the fronto-parietal network” in observers without schizophrenia, whereas “normal or strengthened bottom-up influences from visual areas in the absence of top-down input from the fronto-parietal network” prevent observers with schizophrenia from experiencing the illusion\(^5\). To test this hypothesis, they assembled a testing population of thirteen patients that fulfilled DSM-IV and ICD-10 criteria for schizophrenia, were taking atypical antipsychotic medication and were without any other psychiatric disorders or substance abuse history, and matched them with sixteen healthy control participants. All of the participants in this study were right hand dominant and had normal or corrected to normal vision. These participants were observed under event-related functional magnetic resonance imaging or fMRI and were exposed to three different experimental conditions: three-dimensional normal faces, three-dimensional depth-inverted faces, and two-dimensional faces. In
order to create the 3D normal and depth-inverted images, a custom-made prism stereoscope was employed. To produce a single 3D normal image of a face in the middle of the display, two pictures of the same subject were taken from very slightly different angles and the prism stereoscope presented the left picture to the left eye and the right picture to the right eye. To produce the depth-inverted images, the left picture was shown to the right eye and the right picture to the left eye (see appendix Figure 7). Alternatively, the 2D images were created by presenting the same picture, taken at a front-on angle, to both eyes. The experiment was organized into 24 trials involving both of the 3D conditions and 27 trials involving the 2D conditions, all presented in a random order with consistent inter-trial intervals of fifteen seconds. Each stimulus pair was presented for six seconds, followed by a nine second blank-screen resting period during which the last three seconds of the rest period before the next stimulus pair was displayed, a preparatory tone was played via participants headphones. During the observational periods, subjects were instructed to press a key to indicate whether the face they saw was 3D or 2D. Only after the trials were the subjects asked in a survey whether or not they perceived any of the faces as hollow.

B. Collecting fMRI Data

The fMRI images collected from the experiment were processed and smoothed so that they could be analyzed via a statistical technique known as multiple regression and an AR(1) model of serial correlations to determine the relationship between the dependent and independent variables in this study. This experiment specifically looked into the event-related responses to the face displays with independent variables or
regressors including all faces, 3D faces and 3D face inversion. From these images and responses, three regions of interest were selected, the supramarginal gyrus, intraparietal sulcus and inferior frontal gyrus, based on significant effects present in these particular areas of the brain. Other areas such as the primary visual cortex, or V1, was also selected based on its association as an input region with all faces, as well as areas like the lateral occipital cortex since imaging showed it was an area demonstrating inversion across all participants (see appendix Figure 8). From there, researchers used dynamic causal modeling and research involving anatomical connections between the regions of interest, to determine effective connectivity between the regions of interest as well as any modulation that the visual task created in these areas.

C. Results from fMRI and Survey Data

The results of this experiment revealed that none of the controls reported seeing any of the faces as “hollow”, while all of the patients with schizophrenia reported seeing hollow faces. Researchers’ analysis of the reaction time data from the initial experiment showed no significant difference between the patients and control groups. In the patients, relative to the controls, fMRI data identified brain regions including the supramarginal gyrus and intraparietal sulcus as exhibiting significant group and inversion interactions or an increased blood-oxygenation level dependent (BOLD) response to the 3D inverted faces in comparison to the 3D normal faces. In the controls relative to the patients, the reverse interaction showed brain regions including the inferior frontal gyrus and other frontal areas as exhibiting significantly increased BOLD responses to 3D inverted faces relative to 3D normal faces. However, in all subjects, the lateral occipital cortex showed
significantly increased BOLD responses to 3D inverted faces relative to 3D normal faces. Furthermore, due to the nature of the illusion itself, researchers found that the controls occasionally and mistakenly classified a 3D inverted face as a 2D face, but the patients almost never made this mistake and this difference was found to be highly significant. Researchers interpreted this difference to exemplify the control participants' susceptibility to the illusion and the patients’ lack of susceptibility. Researchers further confirmed this theory with a follow-up experiment in which participants were asked to simply classify faces as 3D normal or 3D inverted; Controls proved to be highly susceptible to the illusion, noting almost all 3D inverted faces as 3D normal and patients not as susceptible, very rarely making such errors.

D. Models Proposed from fMRI Data

With these results, dynamic causal modeling and Bayesian model comparison strategies, researchers created two different models for the extent to which endogenous connections were modulated by depth inversion in the pathways of the visual system. These two modulated pathways had the same endogenous connectivity, but different modulation of effective connectivity based on the face-type observed (see appendix Figure 9). One model (Model 2) utilized the data from the experiment to produce a modulation of the bottom-up connection from the lateral occipital cortex from V1, but another model (Model 1) suggested a more significant explanation of the data with the effect of depth inversion stemming from modulation of the top-down connection to the lateral occipital cortex from the intraparietal sulcus. In looking at the experimental data through Model 1, researchers found that the controls significantly increased effective
connectivity from the intraparietal sulcus to lateral occipital cortex when presented with the 3D inverted faces, whereas the patients did not experience an increase. However, in looking at the experimental data through Model 2, researchers noted that both groups significantly increased effective connectivity from V1 to the lateral occipital cortex when presented with 3D inverted faces, but this effect was much stronger in the patients than in the controls.

E. Interpretation of fMRI and Survey Data

In the controls without schizophrenia, researchers explain that greater amounts of activity in these participants when observing the 3D inverted face-type suggests that the top-down influences from the fronto-parietal network are what contribute to the perception of this illusion. Researchers note that their primary model (Model 1) places the “dynamic modulation of connectivity according to face-type on the backwards connection between the intraparietal sulcus and lateral occipital cortex” for these control participants. The intraparietal sulcus, found in the parietal lobe or area of the brain that processes somatosensory information in a top-down manner, is responsible for movement responses and spatial attention while the lateral occipital cortex is involved in object recognition through a bottom-up processing of visual information. However, patients with schizophrenia did not have greater activity and connectivity in the parietal lobe when observing the HMI. Instead, these patients showed modulation on the forward connection between V1 and the lateral occipital cortex. Unlike the prefrontal cortex, area V1 is responsible for simply processing and sending out visual information to other parts of the brain rather than drawing conclusions like the prefrontal cortex is known to do.
Therefore, this lack of activity and modulation in the fronto-parietal network is consistent with a lack of modulatory top-down control and could result in incoming sensory data being “constrained in referencing stored information from past experience”\textsuperscript{5}. Ultimately, these researchers concluded that "schizophrenic patients rely on stimulus-driven processing and are less able to employ conceptually-driven top-down strategies during perception,” thus making them less susceptible to various visual optical illusions such as the HMI\textsuperscript{5}. While this experiment demonstrates that patients with schizophrenia and healthy controls can differ in modulation of neural connectivity and utilize different areas of the brain when presented with visual stimuli, the researchers noted that there is still no study to date that has “investigated the neural mechanisms underpinning the failure to perceive visual illusions in schizophrenia”\textsuperscript{5}. 
CHAPTER III

DIFFERENCES IN THE INTERPRETATION OF OPTICAL ILLUSIONS

A. Are People with Schizophrenia Susceptible to All Optical Illusions?

Patients with schizophrenia have not been found to be susceptible to all visual illusions and, in some cases, can perceive visual illusions with more strength than their control counterparts. For example, studies have shown that patients with schizophrenia show greater reception of the Müller-Lyer Illusion in which two arrows with tails facing in different directions fallaciously appear to have middle segments of different lengths (see appendix Figure 10). One explanation of the illusion is that the middle segments appear to be different lengths due to top-down processing related to depth cues. In this illusion, when the fins are pointing inward toward the middle line, the brain uses this visual information in combination with past experience with 3D objects that slope backward and away from us, much like the corner of a building, and perceive this middle segment as further away and thus smaller. One of these studies that focused on the Müller-Lyer Illusion was done by researchers from the Maimonides Medical Center Department of Psychiatry and included other geometrical visual illusions such as two Horizontal-Vertical illusions, a Perspective Drawing, and the Sander Parallelogram as well (drawings and illusions were not clearly defined with imagery in experimental report). In this experiment, 17 patients who were diagnosed with chronic, paranoid schizophrenia with acute exacerbation, were selected and matched with 14 control participants without any pertinent psychiatric history. While almost all the patients were receiving neuroleptic medication during the time of testing, researchers ensured that these patients did not have significant coexisting current or prior medical or neurologic
problems or any significant affective component to their diagnosis. Participants’ illusion-supported responses to each of the various illusions were recorded and researchers found highly statistically significant results showing that the patients were more susceptible to the Müller-Lyer Illusion and less susceptible to the Perspective Drawing, whereas all other illusions showed no significant difference between the groups.

B. How Can Similar Optical Illusions Use Different Methods of Deception?

Other studies have also found optical illusions such as the Ebbinghaus Illusion to also show no significant differences between perception by patients with schizophrenia and control populations, despite the similarities between the inner workings of many of these illusions (see appendix Figure 11). The Ebbinghaus Illusion may appear to be similar to the Müller-Lyer Illusion as it relates to object size perception and is composed of two variations of a circle surrounded by other circles, but the understanding of the origins of these illusions is in fact very different. In the Ebbinghaus Illusion, while both center circles in the two different variations of the pattern are measurably the same size, the illusion makes these circles appear to be different sizes. This is due to the center circles being surrounded by circles of different sizes, either surrounded by circles all larger than the center circle or surrounded by circles all smaller than the center circle. As a result, the center circle surrounded by smaller circles appears to be larger than the other center circle that is surrounded by all larger circles. One theory used to explain this illusion is known as the size contrast theory, in which top-down processing causes these circles to appear to be different sizes by contrasting size-related visual perception cues from the surrounding circles and applying this understanding of comparable size to the
center circle\textsuperscript{17}. While observation of the center line in the arrows in the Müller-Lyer Illusion is considered to be affected by the directionality of the tails and ultimately other objects providing contrasting visual cues, the source of Ebbinghaus Illusion relies entirely on size-relation cues has not been connected to depth perception like the Müller-Lyer Illusion has been. Another theory, contour interaction theory, makes the difference between these two illusions even clearer as it posits that the level of interaction between the contours of the shape, or how close the contours of an object is to another object, creates the illusion\textsuperscript{17}. This theory notes that “contours closer to each other attract each other, leading to size overestimation of the central stimulus” whereas “contours of larger inducers tend to be further away from those of a central stimulus…repel each other” and result in size underestimation\textsuperscript{17}. Ultimately, these two theories make it evident that Ebbinghaus Illusion and the Müller-Lyer Illusion, while both utilizing top-down processing guesswork done by the brain in order to induce illusion, utilize different methods of deception.

C. What are the Different Ways in Which Visual Information is Processed in the Brain?

While the Ebbinghaus Illusion is just one optical illusion on a list of many that illustrate how top-down processing can result in various visual discrepancies across different illusions, the Ebbinghaus Illusion is also an important illusion used in “debate over the existence of separate pathways in the brain for perception and action”\textsuperscript{6}. Today, these two separate pathways, known as the dorsal stream and the ventral stream, are widely supported by most as the two different pathways in the brain involved with visual information (see appendix Figure 12). While these two different streams are hypothesized
to travel through very distinct and different regions of the brain, they both begin in the primary visual cortex and are heavily interconnected, making it difficult to allocate exact or specific processing to just one of the pathways\textsuperscript{11}. However, it is understood that the ventral stream, which originates in V1 and extends along the ventral surface of the brain into the temporal cortex, is the vision-for-perception pathway and is responsible for recognition and differentiation of objects\textsuperscript{7}. The dorsal stream, or vision-for-action pathway, also originates in V1 but travels across the dorsal surface of the brain into the parietal lobe and thought to be responsible for visually guided movement, interaction with or grasping of objects, as well as deducing information related spatial location and orientation\textsuperscript{7}. Experiments using the Ebbinghaus Illusion show that adult participants can incorrectly perceive the size of the circles, likely through involvement of information sent through the perceptual or ventral stream, but accurately reach out and grasp the circle by processing information in the action or dorsal stream\textsuperscript{6}. However, in studying the ontogenetic development of differentiating between perception and action, researchers found that young participants in these same experiments misjudged the size of these circles both perceptually and in action\textsuperscript{6}. While the data from this experiment is inconclusive as to whether or not younger juveniles predominantly use one visual stream or another for perceptual or motor tasks, the data shows that these juveniles rely on both of the “visual processing streams during perceptual as well as visuomotor tasks”\textsuperscript{2}. Ultimately, due to their reliance on both pathways, the younger participants were just as susceptible to the illusion perceptually as the adults, but unable to solidly rely on just the information processed through the dorsal pathway which prevented them from being able to accurately grasp the circles.
D. Do Cultural Differences Affect Perception?

Other factors that should be considered when studying the variation in susceptibility to visual illusions are cultural differences or variation in environmental exposure. While the Müller-Lyer illusion is considered to be the result of misinterpretation of depth cues, other studies have shown that depth perception is not the only factor in perceiving this type of optical illusion. An early study, completed in 1901 by English anthropologist and neurologist W. H. R. Rivers, found significant differences in the perception of the Müller-Lyer illusion dependent upon culture. In this experiment, Rivers showed the illusion to a group of aboriginal people known as the Melanesians, who live off the coast of Australia and are not exposed to urban areas, and found that these participants were significantly less susceptible to the illusion and able to more accurately identify both the midpoint of the arrow and length of the lines compared to European patients. Additional and more recent studies involving other groups from various environments and cultures have shown similar results, including a study done by Segall et. al. in 1966. In this experiment, researchers recorded the reactions to the illusion of seventeen different populations of people, including “European and American urban dwellers”. The results of their study concluded that urban American and European populations are more “vulnerable to the line-length modifying wings of the Muller-Lyer illusion” due to their environment. Researchers believe that these participants that grew up in and live in urban areas, an environment that exposes them to a more rectilinear shapes with “right-angled buildings and streets,” are more likely to be susceptible to the Müller-Lyer illusion because of their daily interactions with this type of environment. Due to these participant’s interactions with such an environment, including accurately
perceiving converging edges of buildings in order to walk around them or perceiving current location and the end of a street while driving down one, this visual information is used for action and thus is related to the dorsal pathway in the brain.
CHAPTER IV

SPECULATIVE DIFFERENCES IN VISUAL PROCESSING BY PEOPLE WITH SCHIZOPHRENIA

A. Does Reliance on Both Visual Processing Streams Result in Unsusceptibility to Illusions?

Much like how younger participants in the experiment related to the Ebbinghaus Illusion were not able to accurately reach out and grasp the disc, since they could not rely solely on their dorsal streams when processing visual information, I hypothesize that patients with schizophrenia are less susceptible to visual illusions like the HMI and Ebbinghaus Illusion due to reliance on both pathways, specifically the dorsal stream. Research completed by Hanisch et. al., regarding the variation in grasping ability between juveniles and adults in relation to the Ebbinghaus Illusion, suggests that as we age, we rely less on the visual feedback from the ventral stream and more on the information from the dorsal stream when processing action related visual information. This results in shorter movement times and earlier maximum hand opening during grasping, ultimately allowing for more efficient movement. Nonetheless, the top-down processing that occurs in the fronto-parietal network and ventral stream is able to override the dorsal stream, deceiving participants visually even if they are able to accurately reach out to grasp the discs. This experiment not only illustrates a clear difference between the application of information processed in the dorsal and ventral streams, but also makes it evident that even though both pathways process usable information, top-down processing only allows for the perception of information from the
ventral stream. Alternatively, people with schizophrenia may fall unsusceptible to certain visual illusions due to an ability to perceive information from both pathways when processing visual information. If people with schizophrenia are able to interpret all information from both pathways or rely more heavily upon the information processed in the dorsal stream, the result would be the ability to see past many types of optical illusions.

B. Can Differences in Top-Down Processing Result in Unsusceptibility to Illusions?

While I hypothesize that people with schizophrenia are able to interpret and perceive information from both pathways, I also hypothesize that people with schizophrenia lack fully developed top-down processing networks. As the experiment by Hanisch et. al. suggests, over time, we learn to prioritize different information from different pathways in order to function and interact more efficiently with our environments. The development and institution of top-down processing to alleviate having to explicitly interpret the constant stream of sensory information, as explained by Richard Gregory’s theory of perception, is what allows sensory information processed in the ventral stream to be misperceived in optical illusions. With less influence from the top-down processing networks, found in the parietal areas of the brain, people with schizophrenia would be able to directly and correctly perceive visual information obtained when looking at optical illusions, ultimately allowing these patients to be less susceptible to the illusion. This limitation on top-down processing is reflective of the fMRI data collected from the experiment by Dima et. al. (2009), as patients with schizophrenia showed significantly less BOLD responses in the inferior frontal gyrus and
other frontal areas around the prefrontal cortex when observing the 3D inverted images. The control participants showed BOLD responses in these areas in the frontal lobe, which are associated with working memory as well as other top-down-related processing systems and I hypothesize to correlate with susceptibility to optical illusions. Instead, the patients with schizophrenia showed increased activity or BOLD responses in the supramarginal gyrus and intraparietal sulcus, which are associated with spatial analysis and dorsal stream activity. As a result, I hypothesize that people with schizophrenia are unable to utilize top-down processing as well as their control counterparts, ultimately allowing people with schizophrenia to see through or be less susceptible to optical illusions.

However, people with schizophrenia are not void of all visually-related top-down processing and many may still fall susceptible to some optical illusions by utilizing information from the ventral stream and environmental exposure. While patients with schizophrenia showed susceptibility to the Müller-Lyer illusion in the experiment done by Capozzoli & Marsh, this susceptibility could be the result of their environment. Research conducted by Segall et. al. indicates that environmental exposure to urban structures allows participants to be more susceptible to this particular illusion than those lacking exposure to a more rectilinear world. The experiment by Capozzoli & Marsh specifies that the patients with schizophrenia they studied were admitted to Maimonides Hospital in Brooklyn, New York, which means that it is highly likely that these patients had been exposed to an exceedingly urbanized environment. If patients with schizophrenia are entirely unable to use the ventral pathway and top-down processing to interpret visual information, it would be highly unlikely that they would be able to
function in their day to day lives. Additionally, if patients with schizophrenia were entirely unable to use the ventral system to process visual information, fMRI data, like the data from the experiments from Dima et. al. (2009), would likely show clear lack of activity in the fronto-parietal areas of the brain or possibly atrophy in these areas. However, fMRI data from Dima et. al. noted that there were occasional blips of activity in the fronto-parietal areas of the brain while patients were under observation. As a result, rather than a completely underutilized ventral stream or lack of the stream that processes perceptual-related visual information, I hypothesize that people with schizophrenia are still able to utilize top-down processing and ventral stream interpretations of information despite a primary dependence upon the dorsal stream and bottom-up processing.

C. Proposed Experimental Setup

In order to test these hypotheses, I propose an experiment similar to the experiment by Dima et. al. (2009) in which patients diagnosed with schizophrenia, as well as two groups of younger, juvenile participants with genetic predispositions to schizophrenia and control counterparts, observe 3D normal, 3D inverted, and 2D images of faces, all while under fMRI observation. In such an experiment, at least a dozen patients diagnosed with schizophrenia under DSM-IV and ICD-10 criteria, all taking atypical antipsychotic medication and without any other psychiatric disorders or substance abuse history, would be matched with at least a dozen healthy control participants. In addition to the adult patients diagnosed with schizophrenia, this experiment would also include juvenile participants separated into four experimental groups with at least a dozen participants per group. Two of the groups would be
composed of juvenile participants with genetic predispositions to schizophrenia; This would include participants that have a parent, grandparent, or significant number of family members diagnosed with schizophrenia, but without a diagnosis themselves due to their age. One of these groups of genetically predisposed participants would be 5-7 years of age while the other group would be composed of participants ages 8-12 years old. All of these juvenile participants would not be taking any psychotic medication, would not have any other psychiatric disorders and would otherwise be considered to be healthy participants. The remaining two groups of juvenile participants would be other healthy juvenile participants matched with the predisposed participants, with these twin participants not having a family history of schizophrenia, and again separated into age groups of 5-7 years old and 8-12 years old. Part 1 of the proposed experiment would include fMRI data collection from all participants while observing the 3D normal, 3D inverted, and 2D images produced via a prism stereoscope, much like the one used in the study conducted by Dima et. al. Again, like the experiment by Dima et. al., only after observation would these participants be asked to label these images as 3D normal, 3D inverted, or 2D faces. During the presentation of these images, all participants would be observed under an fMRI scanner in order to determine areas of the frontal and occipital cortices showing BOLD responses.

D. Possible Results and Their Significance from Proposed Experiment

Possible results from my proposed experiment would likely reflect similar data to the experiment by Dima et. al. (2009) for the adult patients and controls, however if significant differences in perception are recorded from the four different groups of the
juvenile participants, these differences could either reflect their adult counterparts in perception of the images and fMRI data based upon genetic predisposition or based upon differences by age group. While in the experiment by Dima et. al., there were clear and significant differences between perception of the 3D inverted faces as hollow by patients and as 3D normal faces by the control participants, it is unlikely that the juvenile participants will reflect such clear differences. The experiment by Hanisch et. al. suggests juveniles do not have not yet fully developed the ability to prioritize different information from different pathways or efficiently implement top-down processing when it comes to processing visual sensory information at ages 5-7 years old. This experiment found that the younger the participant, the less the participant depends upon perceptual judgements. As a result, it is probable that both the genetically predisposed participants and healthy control participants in the 5-7 year old age group will perceive the 3D inverted faces as 3D normal faces. However, in the two groups of juvenile participants ages 8-12, it is more likely that differences in perception could appear. In these older juvenile participants, it is possible that the participants without a genetic predisposition to schizophrenia will be able to apply more developed top-down processing and a differentiation between ventral and dorsal streams, ultimately perceiving the 3D inverted faces as 3D normal. In contrast, if the juvenile, genetically predisposed participants were to develop schizophrenia in adulthood, I expect that these participants, ages 8-12 years old, would perceive these 3D inverted faces as hollow. Similarly, when looking at the fMRI data from these six experimental groups, I expect the patient and control adult experimental groups to reflect the respective fMRI data collected from the adult patients and controls in the experiment by Dima et. al., while both the juvenile groups ages 5-7
years old to have fMRI data similar to that of the adult controls in the experiment by Dima et. al., the juvenile participants ages 8-12 without a genetic predisposition to schizophrenia to also have fMRI data similar to that of the adult controls, and finally the juvenile genetically predisposed participants ages 8-12 to have fMRI data similar to that of the adult patients with schizophrenia. Should both the perception of the images and the fMRI data collected from this experiment show that juvenile participants with a genetic predisposition to schizophrenia, ages 5-7 years old, have data similar to that of the adult control participants, and the juvenile participants with a genetic predisposition to schizophrenia, ages 8-12 years old, have data similar to that of the adult patients with schizophrenia, it could be concluded that this age difference and its timely correlation to the differentiation of the ventral and dorsal streams is critical in determining the onset of the development or origin of schizophrenia.
CHAPTER V

CONCLUSION

A. Summary of Proposed Hypothesis

In summary, I propose that people with schizophrenia experience visual discrepancies and differences in perception related to optical illusions due to a greater dependence on the dorsal stream as well as a limitation on the ability to implement top-down processing of visual sensory information from the ventral stream in the prefrontal cortex. I postulate that this reliance on the dorsal stream and underutilization of the ventral stream and top-down processing begins to develop around the age of 8 years old, but can take upwards of a decade or two for this deviation in processing to manifest alongside other symptoms characteristic to schizophrenia. It can be inferred that this timeline of visual information processing divergence is reflective of other sensory information processing differences and why schizophrenia may not present until later in adulthood. As a result, further research similar to my proposed experiment is warranted in order to better determine the period of time in which the disorder develops as well as how it develops.

B. Possible Importance and Implication of Results

The importance of such an experiment and continuation of research regarding the perception of various optical illusions by patients with schizophrenia is not to be understated. Currently, optical illusions are not used in clinical settings to assist in diagnosis of schizophrenia. However, not only would the continuation of such research provide insight into both what is considered to be “normal” perception of visual sensory
information as well as deviations from this norm, but this research could also be critical in providing timely and lifesaving diagnoses to those living with the disorder. Implemented as a diagnostic tool in a medical setting, monitored observation of and response to various optical illusions like the HMI and the Ebbinghaus Illusion could give providers insight into possible risk of a patient developing schizophrenia. Furthermore, while many consider people with schizophrenia to misinterpret their surroundings due to the connotations of hallucinations, delusions and other visual discrepancies that come with the disorder, the actuality is that people with schizophrenia may often perceive reality with better accuracy than those without schizophrenia. As a result, greater understanding of optical illusions, visual perception and schizophrenia in relation to perceptual differences could have a beneficial societal impact as well. Seldom do people realize how much of our own reality is constructed by top-down processing and filtering of sensory information; However, education on even just this one phenomenon regarding visual construction of reality holds significant power to change the perspective of those who are unfamiliar with disorders like schizophrenia and other psychosis-related disorders.
CHAPTER VI

BIBLIOGRAPHY


Figure 1: Pathway of visual sensory information from eye to the lateral geniculate nucleus to the primary visual cortex.

Figure 2: Visual sensory information being processed by specialized cells in the eye that relay information to the brain via changes in electrical activity known as action potentials.

Figure 3: Normal composition of the Adelson’s Checker-Shadow Illusion
Image sourced from: Shadow Optical Illusion. Business Balls,

Figure 4: Composition of the Adelson’s Checker-Shadow Illusion including bars
Image sourced from: Shadow Optical Illusion. Business Balls,
Figure 5: A: Straight-on view of a physical example of the HMI. B: Angled view of a physical example of the HMI.

Figure 6: A: Straight-on view of a physical example of the LPI. B. Angled view of a physical example of the LPI.

Figure 7: A: Stereoscopic pictures of a female face; B: Graphic representation of binocular depth and binocular depth inversion

Figure 8: Locations of regions of interest in the brain from experiment by Dima et. al.
Figure 9: Models 1 and 2 from experiment by Dima et. al.

Figure 10: A: Normal composition of Müller-Lyer Illusion; B: Müller-Lyer with the center lines highlighted in red and ends of the lines clearly defined with dotted line

Figure 11: The Ebbinghaus Illusion
Figure 12: Pathways of ventral and dorsal streams for processing visual information in the brain.

CHAPTER VIII

AUTHOR’S BIOGRAPHY

Kathryn Stanislaski was born in Framingham, Massachusetts in 2000 and grew up in the city of Somerville, Massachusetts with her parents, younger brother and many well-loved pets. Graduating from Saint Joseph Preparatory High School in 2018, Kathryn later attended the University of Maine in Orono, ME and graduated in 2022 with a Bachelor of Science in Zoology, minors in Neuroscience and Psychology, and a concentration in Pre-Health Studies with Honors. While at the University of Maine, Kathryn worked for the University Volunteer Ambulance Service for four years, as both an EMT and officer at the organization. Along with responding to 911 calls, staffing sports games and providing emergency medical treatment, transport and standby for the University and its surrounding towns, Kathryn also worked at UVAC hiring, training and instructing new members. Along with her passion for medicine and the sciences, Kathryn is an avid artist and enjoys drawing, painting and many other forms of visual arts. As for future endeavors, Kathryn hopes to continue to work in the medical field and combine her interests through additional arts and science graduate degrees, with plans to pursue a career as a medical illustrator or visual specialist.