

Perception of physiological visual illusions by individuals with schizophrenia

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Summary

Visual perception by individuals with schizophrenia has not been extensively researched. The focus of this review is the perception of physiological visual illusions by patients with schizophrenia, differences of perception reported in a small number of studies. Increased or decreased susceptibility of these patients to various illusions seems to be unconnected to the location of origin in the visual apparatus, which also takes place in illusions connected to other modalities. The susceptibility of patients with schizophrenia to haptic illusions has not yet been investigated, although the need for such investigation is clear. The emerging picture is that some individuals with schizophrenia are “resistant” to some of the illusions and are able to assess visual phenomena more “rationally”, yet certain illusions (ex. Müller-Lyer’s) are perceived more intensely. Disturbances in the perception of visual illusions have neither been classified as possible diagnostic indicators of a dangerous mental condition, nor included in the endophenotype of schizophrenia. Although the relevant data are sparse, the ability to replicate the results is limited, and the research model lacks a “gold standard”, some preliminary conclusions may be drawn. There are indications that disturbances in visual perception are connected to the extent of disorganization, poor initial social functioning, poor prognosis, and the types of schizophrenia described as neurodevelopmental. Patients with schizophrenia usually fail to perceive those illusions that require volitional controlled attention, and show lack of sensitivity to the contrast between shape and background.

Key words: schizophrenia, visual illusions, visual perception

Introduction

The subject of visual processing in individuals suffering from schizophrenia has been rarely examined. T. Bilikiewicz claimed that visual hallucinations did not happen in patients with schizophrenia, but their presence could be the evidence of coexisting

symptoms of delirium [1]. However, the occurrence of visual hallucinations in schizophrenia, though rare, is generally accepted by psychiatrists along with other modalities [2]. The mistake made by famous clinician could be the evidence that visual perception is somewhat neglected during a psychiatric examination. Visual illusions, which are even more difficult to assess, are even more neglected. This seems surprising since at least 25% of the cortex is involved in visual processing. It is difficult to believe that the schizophrenic process, which involves many areas of the central nervous system, could completely omit such a significant part of the brain, especially given that this course involves the same transmitters as those in other parts of the central nervous system, such as glutamate, GABA or acetylcholine.

Is it possible that history could repeat itself? For decades, the absence of cognitive disturbances, including perception (also visual perception), in schizophrenia was generally accepted as the part of traditional criteria. Any results that did not support this view were labeled *ex inactivitate mentis*, that means, “atrophy of an unused organ”, as view supported by A. Kępiński [3]. This distinguished scientist tried to explain cognitive disorders in this way. Correction of this view took a long time. Over thirty years passed between Brenda Milner’s implementation of the Wisconsin Card Sorting Test in 1964 and the acceptance of the cognitive dimension as one of the five dimensions of schizophrenia.

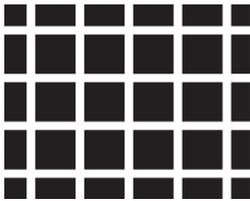
Researchers’ limited interest in visual illusions in schizophrenia stems from several circumstances:

1. Historical context. In 1903, in the 7th edition of his psychiatry textbook, E. Kraepelin reported that patients with schizophrenia had an incomplete perception of visual stimuli displayed for short periods of time. E. Bleuler tried to replicate this experiment without success, and eight years later in a famous book that defined the concept of schizophrenia, strongly denied the existence of visual perception disorders in this condition. This halted research in the field for at least half a century [4].
2. Difficulty in detecting the problem. While attention disorders, disorganized speech, and hallucinations reported by the patients are easy to recognize, visual process require an experienced observer equipped with adequate research tools. For example, it is difficult to exclude the possibility that a patient’s reading problems may stem from visual disorders, rather than problems with attention or memory, as suggested by Revhaim et al. [5], but till now this is not explained.
3. Limited research tools. Multiple types of physiological visual illusions exist. In the case of working memory, researchers use a handful of validated tests, with emphasis on one in particular as the most common. Tests used to examination of visual perception allow for a great deal of freedom as to the test form and presentation (drawn, computerized, with various object size, various backgrounds). The psychometric properties of the majority of these tests have not been fully explained and the tests have not been standardized on larger populations. This makes comparison of new findings with the existing data challenging.
4. Ambiguity as to the brain region in which illusions arise, often with unknown or not completely recognized pathomechanism. Potentially, visual illusions can arise in any part of the visual tract, from retina (e. g. Hermann grid) to the higher-order

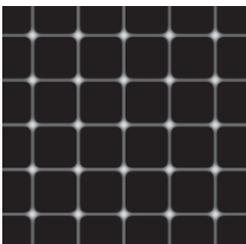
centers that are responsible for making associations (e. g. ambiguous pictures). One example of a visual illusion of which the origin in the brain is unknown is the so-called Illusion of the Moon. In this illusion, this celestial body (the moon is the largest body possible to are responsible for making associations (e. g. ambiguous pictures). One example of a observe directly with the naked eye) appears larger when it appears directly above the horizon than when it is seen higher in the sky, although the angular width is necessarily the same. Despite many attempts to explain this phenomenon, what we have thus far is several different hypotheses attempting to explain this incorrect human perception.

5. Favouring dopamine and prefrontal dysfunction concepts in the research on etiology of schizophrenia. In December 2010, Silverstein and Keane conducted a search in PubMed with the search terms: schizophrenia and specific lobes and brain structure. Co-occurrences with visual cortex exceeded 4000, while the number for occipital lobes with their optic centers was less than 500 [4]. Thus, the disruption of visual perception, including the illusions of this modality, simply does not fit some of the conceptions of the disorder.

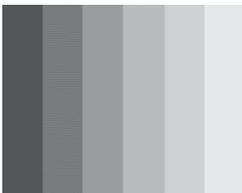
Illusions probably arising in the retina



Do you see dots at the junctures between the white lines?



Do black dots appear scintillate in the white boxes?



The contrast between adjacent stripes with only slightly differing shades of gray seems more exaggerated than it actually is.

Figure 1. **Hermann grid, Bergen's illusion, Mach bands**

Selected physiological illusions and their perception in patients with schizophrenia

Illusions – the Hermann grid and Bergen’s illusion and Mach bands, similar in concept and origin – are known to arise in retina. They are based on the phenomenon of lateral inhibition, discovery of which was awarded with the Nobel Prize in 1967 (H. K. Hertline). The Hermann grid consists of black squares arranged next to each other at regular intervals with white lines running between them on all sides. The illusion that appears in this grid are black dots seen at the white junctures between the evenly spaced black squares. Photoreceptor cell (cone) is stopped by two adjoining inhibitory interneurons in the line course, while by four in the cross line, which results in dark stains. Because the illusion is most clearly seen at a viewing angle of about two degrees, which corresponds to the density of the retina’s photosensitive elements, the retina seems to be the area where the illusion originates [6]. However, this illusion

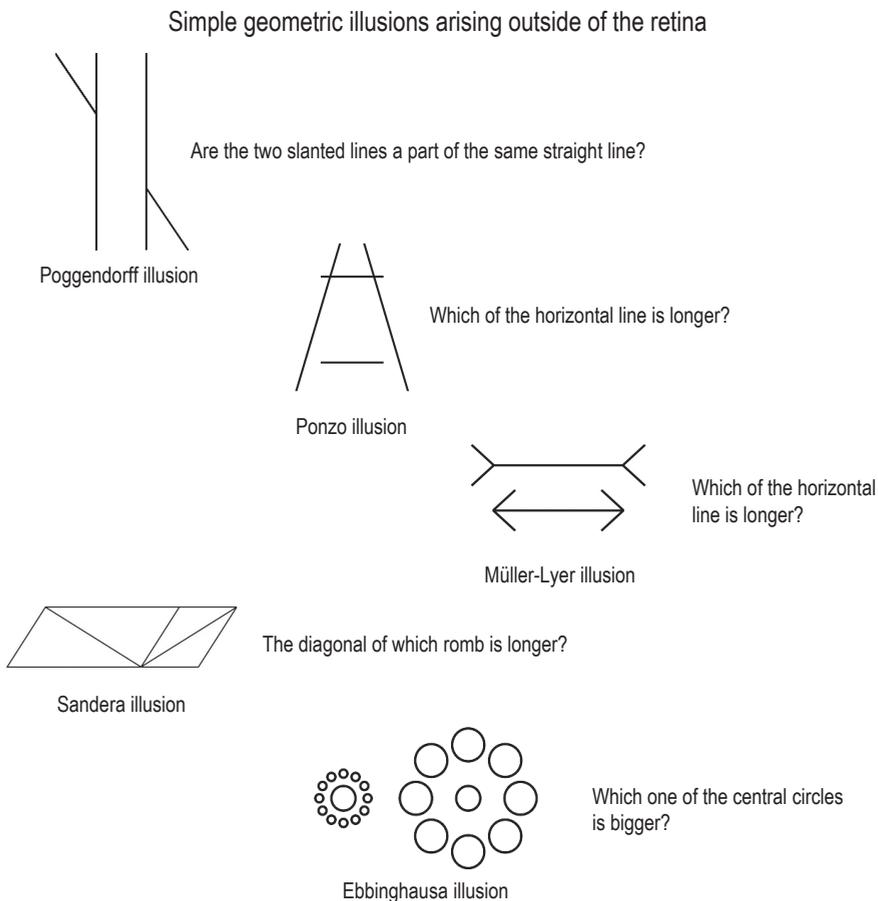


Figure 2. **Simple visual illusions**

does not disappear with different viewing angles, and many investigators now favour a theory that the illusion arises in another part of the visual tract, perhaps even in the primary visual cortex [7, 8]. These types of illusions become stronger when the contrast between the dark and light elements becomes greater [9].

It is striking that the illusions based on lateral inhibition in the retina have been tested on patients with schizophrenia only once (!). Kantrowitz et al., in their study comparing 38 individuals suffering from schizophrenia with 28 healthy individuals, included the Hermann grid among a series of tests they conducted; at the same time, they investigated how the perception of the illusion changed if the color contrast changed. They found that this illusion was not as strongly perceived by patients with schizophrenia as it was by healthy adults, and that this disproportion became greatest with the strongest color contrast [10].

Because the lateral inhibition is connected with NMDA receptors [11], its decrease is consistent with the glutamate theories of schizophrenia. Poorer lateral inhibition at the higher levels of the visual tract was confirmed with a more sophisticated procedure – the so-called contrast-contrast effect. In this illusion, a circular patch is removed from a large image of a circle filled with dots, and is placed next to that image along with a few more circles of the same type but with varying degrees of contrast. Then the subjects have to select the circle with the color contrast that best completes the larger image. Healthy adults usually choose elements with lower contrast, while patients with schizophrenia solve this test correctly [12].

Simple geometric illusions arising outside of the retina:

a) Poggendorff illusion

In Poggendorff illusion, a straight line at an angle of 45 degrees passes behind two vertical lines and is obscured by the space between those lines. The two ends of the transverse line seem offset, but in fact they are not. Changes in contrast do not impact the perception of this illusion [13].

This illusion was one of the first illusions examined in patients with schizophrenia, as ill persons are usually more prone to illusions. It was confirmed as early as the 1960s by Pressey et al. [14]. However, the study was later criticized for problems with its methodology which included comparison of often uneducated schizophrenic adults with a control group of students. Later, a study by Letoureneau and Lavoie [15] compared a group of patients with paranoid (7 persons) or simple schizophrenia (6) with a group of healthy individuals (15 persons), controlling for age and IQ. This experiment showed that both groups of patients with schizophrenia are more prone to Poggendorff illusion than the control group, and individuals with simple schizophrenia are more prone to it than those with the paranoid form of the disorder. In contrast, the study by Kantorowitz et al. [10] did not find an increased susceptibility to this illusion in patients with schizophrenia.

b) Müller-Lyer illusion

Müller-Lyer illusion presents two vertical lines of the same length; one of those lines has arrows pointing inward on both ends while the other has arrows pointing outward. The line with arrows directed outward appears shorter.

Most studies on healthy volunteers show that their susceptibility to this illusion decreases with changes in color and with increased contrast between the arrows and the line [16, 17]; however, opposite results have also been reported [18]. Over the last few decades, a few studies on susceptibility of patients with schizophrenia to Müller-Lyer illusions have been published. All of them reported a significant increase in the susceptibility of patients with schizophrenia to this illusion [10, 19, 20], which makes Müller-Lyer illusion, along with Poggendorff illusion, a prominent one in the field. It seems that sensitivity to this illusion decreases with the duration of the i [19]. The well-established position of the Müller-Lyer illusion has led to a suggestion that it may be used in the creation of models of schizophrenia in primates as a tool suggesting the illness [20].

c) Ponzo illusion

Ponzo illusion, like Müller-Lyer illusion, involves an incorrect visual assessment of the length of two lines which are drawn across two long converging lines. The characteristics of the Ponzo illusion, such as sensitivity to color and contrast, were examined in only two volunteers [21]; however, this illusion is suspected not to intensify with an increase in contrast. Kantrowitz et al. reported that the reduced susceptibility of patients with schizophrenia to this illusion was statistically significant [10]. On the other hand, Russian investigators have recently found that sensitivity to this illusion is low in the early stages of the illness but increases with the length of the illness [22].

d) Sander illusion

Sander illusion is another illusion that involves an incorrect visual assessment of the length of lines. To date, there have been no studies on the influence of the contrast or color on susceptibility to this illusion. Susceptibility of patients with schizophrenia to this illusion was reported only in one publication [10].

Complex illusions

a) Hollow-mask illusion

Hollow-mask illusion involves an incorrect interpretation of the concave side of a face mask as a normal convex face. This illusion can be viewed on multiple websites (e. g. a hollow mask with a Charlie Chaplin's face¹); it is also the basis of a test entitled: "Check if you suffer from schizophrenia." This illusion was first described by Gregory [23]; however, similar illusions must have been known earlier. Some paintings from previous centuries had e.g. shoes directed always in the viewer independently on his position, which was based on a similar phenomenon. In the 1990s, it was found that persons with schizophrenia did not experience this illusion, and perceived the hollow (concave) side of the mask, correctly, as hollow. There was an attempt to connect this perception to the dysfunction of the endogenous cannabinoid

¹ http://www.youtube.com/watch?v=QbKw0_v2clo

system [24]. By means of functional magnetic resonance, a German-British team made an attempt to explain the mechanism of this illusion by exploring visual attention. They discovered a strengthening of the bottom-up and weakening of the top-down attention process by patients with schizophrenia, which provides a potential explanation [25]. We will return to the concept of visual attention in the last part of the review.

b) Stereoscopic vision

Poorer stereoscopic vision is also characteristic in individuals suffering from schizophrenia. In a study conducted by Schechter et al., schizophrenic adults showed less precision in three-dimensional vision than did the control group [26]. Kantorovitz et al. reported similar results, which have been frequently cited [10]. Disturbances of stereoscopic vision were found in subjects with schizotypal personality attributes (to a much lesser extent) [27], however, not in those in prodromal phases of schizophrenia [28].

Illusions combined with other modalities

Illusion of mass assessment based on the size of an object

The statement: a kilogram of nails is heavier than a kilogram of feather is a common symbol of stupidity. However, beyond the physical reality of the equivalence of each kilogram, there is also a psychological reality, that the weight of two objects with the same mass but different sizes is often incorrectly assessed by a person who is holding them. Typically, the smaller object seems to be heavier. It was known as early as in 1896 and designated the height-weight illusion, also called Charpentier illusion after the person who discovered it [29]. Research has shown that many factors influence this illusion, such as: sensorimotor [30], perceptual [31] and cognitive [32]. It is assumed that this illusion results from the disruption of a two-way system: information transfer to the brain and its reference. In other words, “the brain prepares itself” for a certain weight based on the size of the object to be lifted, which may then be corrected in either direction [33]. Previously, researchers [34, 35] proposed a model in which symptoms of schizophrenia could be explained through disorders in this system, specifically in the signal strength of efferent copy or in the comparator in central nervous system. Williams et al. [36] compared the susceptibility to the height-weight illusion of twenty patients with schizophrenia and twenty healthy individuals. Their experiment showed that patients with schizophrenia were less prone to this illusion – the object’s size does not influence their assessment of the object’s weight. It concerns both patients with positive or negative symptoms.

Tasks combining the visual perception with motor activity

These kinds of tasks require the activation in the central nervous system of the so-called dorsal system of information transmission from the visual cortex (the so-called “vision for action”) [37]. One example of such investigation is a study by Chen

et al., which focused on the perception of the Roelofs illusion (effect), which also has an auditory equivalent. Moving the rectangular frame around an object in one direction causes an illusion that the object has moved in the opposite direction. The researchers chose this object to be a point. The subjects in the study were to use their index finger to indicate the central position of that point on a screen before and after the rectangular frame was moved. The experiment showed that subjects with schizophrenia had a poorer ability to do so accurately (33 vs. 34 volunteers) [38]. Other studies also confirmed the dysfunction of the “vision for action” system [39]. However, methods used to investigate perception and activity at the same time examine the whole system, without precisely identifying the location of the dysfunction.

Haptic illusions –an unexplored area

Haptic illusions refer to a distorted perception of size, proportion etc. while exploring an object through touch. G. Révész is considered to be a pioneer in investigating haptic types of simple physiological visual geometric illusions. In his publication from 1934 he suggested that all 29 simple physiological visual geometric illusions known to him also existed in the haptic version [40]. Half a century later, his conclusions were being called into question. For example, Poggendorff illusion is not a haptic illusion in healthy volunteers, Müller-Lyer illusion is, and in the Delbeouf illusion (in its Ebbinghaus version, in which one circle is inside another one), the incorrect assessment of size is only reported for the circle placed inside another one, never the external one [41].

Use of the sense of touch to examine objects may be experimental, but it is also a standard method of exploring one’s surroundings that is used by blind people. Although visual cognition of an object is usually a single all-inclusive event, use of the sense of touch to perceive an object is sequential. Visual perception of an object is different in individuals blind from birth who are unable to visualize the task, and in those who are healthy or with acquired visually impairment.

To date, there have been no publications on the haptic versions of common geometric illusions in patients with schizophrenia; such investigation is needed [20, 42].

Lack of susceptibility to illusions – interpretation attempt

Persons with schizophrenia display a heightened perception of only some physiological visual illusions (e. g. Müller-Lyer). For most of those illusions, according to the available research, patients with schizophrenia show “resistance” to some of them (Ponzo, Ebbinghaus, hollow-mask, height-weight, decreased lateral inhibition, and sensitivity to contrast), and often make a “more accurate” assessment of the visual phenomenon. Could this be the sign of some positive properties of the brain of these patients, at least in some aspects of visual perception? The answer is No: insensitivity to these illusions is only another example of dissimilarity of people with schizophrenia. O. Sacks analyzed the problem of brain susceptibility to illusions as an aspect of its maturity. He cited J. W. Goethe, who was fascinated by color and illusion: “The optical illusion is the optical truth” and next his own travesty “The visual illusion is the

neurological truth” ([43] p. 40). We know that people who grow up in the bush where visibility is reduced to 1–2 meters do not know perspective (which is, after all, a type of illusion). Tribesmen from Torres Strait in New Guinea, who live in round houses and rarely see right angles, do not experience the Müller-Lyer illusion, whereas patients with schizophrenia perceive this illusion strongly. Thus, the ability to experience physiological visual illusions is a characteristic of a mature and a completely developed nervous system. From this point of view, the inability to perceive an illusion should be considered a deficit.

The perception of Ebbinghaus illusion may provide evidence for this claim. Horton and Silverstein [44] found in 2011 that this illusion is perceived only by those patients with schizophrenia who are deaf. The improved perception of this illusion in this group was likely caused by the reorganization of brain structures in people with sensory deficits, which led to a better visual perception in general in deaf people with schizophrenia and a formation of the ability to perceive this illusion.

Potential clinical importance of lack of the visual illusions in patients with schizophrenia

The title issue of involves several questions which are still opened. Despite the fragmentary data, sometimes poor replication of the results, and the lack of a „gold standard”, some preliminary conclusions to fundamental problems have been drawn [45, 46]:

1. Is the insensitivity to some illusions a general feature of all people with schizophrenia, or is it only one of the symptom connected to a specific type of schizophrenia? Research suggests that this phenomenon is related to the degree of disorganization, poor initial social functioning, poor prognosis, and types of schizophrenia that are described as neurodevelopmental. The length of time that the patient has been affected by the illness may also influence the perception of some illusions, but it has never been correlated with the positive symptoms;
2. Is this dysfunction a primary characteristic of the condition, or is it a secondary result of attention deficits, disorders of cognitive functions, or pharmacotherapy? Data seem to confirm the “primary nature” hypothesis; nevertheless, e.g. the evidence that pharmacotherapy is not influential in this dysfunction is limited to only two studies [47, 48];
3. Are these problems typical for patients with schizophrenia, or do they affect patients with similar disorders? Six of the eight papers that focused on individuals on the spectrum of schizophrenia (mainly with schizotypic disorders) suggested the latter.
4. Can visual illusions be categorized according to their “insensitivity in schizophrenia”? Although this seems possible, it requires some reference to physiology of attention in visual perception. As early as in the nineteenth century, W. James discovered two methods of selecting visual information through attention:
 - bottom-up attention that works in whole area of perception continuously, which is not volitional and reacts to objects or phenomena that stand out (salience);

- top-down concentration, also known as task-dependent or volitional, which is controlled and requires effort [37].

There is some indication that in patients with schizophrenia only the second one of these functions is disrupted and usually the volitionally-controlled illusions, which are also insensitive to figure/background contrast, are not perceived by patients with schizophrenia. The “hollow mask” illusion discussed earlier is one of such tasks. The first type of attention is probably not disturbed, and tasks involving it, where time background/figure contrast is important, are performed at least correctly (e. g. Poggendorff or Müller-Lyer). But exceptions (e. g. Hermann grid) are present.

Disruptions in the perception of physiological visual illusions are neither classified as indicators for the diagnosis of the at-risk mental state, nor are included in the endophenotype of schizophrenia [49]. Visual perception is still on the sidelines of schizophrenia research. It may be surprising that after the Brain Decade and in times of sophisticated functional neuroimaging techniques, the simple question of how a person with schizophrenia perceives the world remains unclear.

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