Visual deception: The historical connection between illusions and hallucinations from a Gestalt theoretical and cognitive neuroscience perspective

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Abstract
This article describes illusions and hallucinations from a Gestalt psychological and cognitive neuroscientific point of view. Filling in the missing gaps, researchers hypothesize about the attempt of the brain to predict what has been seen as it compensates for the small delay between ocular and cortical processing. Whereas illusions are the result of the brain filling in wrong information and results in misperception of external stimuli, hallucinations arise independently of external stimuli and are therefore labeled as "false perceptions". Gestalt psychology held that illusions are the result of the brain's interference with what we actually see, offers several laws that describe certain principles. Cognitive neuroscience focusses more on explaining these principles, made possible due to brain imaging and the knowledge of the corresponding brain areas. The underlying mechanisms during hallucinations have not yet been completely clarified. Different theories assume they are caused by damage in specific areas of the brain and abnormal levels of neurotransmitters.

Keywords: *false perception, wrong perception, optical illusions, hallucinations, Gestalt psychology, cognitive neuroscience*

Introduction

A lot has changed during the last century when it comes to knowledge about the human brain and the way abnormal behavior has been interpreted.This behavior, in previous centuries attributable to demonic possession, witches' curses, or simply viewed as mysterious and inexplicable, can now be explained in terms of brain dysfunctions or disorders, resulting in better understanding of the human brain (Appollionio, 2013). The human brain can manipulate what we see and create images that don't correspond to actual reality, an experience that is known as visual deception. Optical illusions are visual deceptions that appear real but are in fact a misinterpretation of what is being perceived (Kalat, 2007). This kind of deception, also known as "wrong perception", occur for a number of reasons that were described by Gestalt psychologists. Certain painting techniques can also provoke an illusion, something that has been known since the Renaissance (14^{th}-17^{th} century) and is considered to have been portrayed in art beginning in about 500 BCE (Leeman, Elffers & Schuyt, 1976). Known as *trompe l'oeil* ("optical illusion"), these paintings on walls or ceilings create the impression of depth and greater space for the viewer. Such illusions were shared by many people and were considered to be art.

Another form of perception that does not correspond to reality is referred to as "hallucinating". During hallucinations, there is no external stimuli that causes the perception reported by the person who is hallucinating. Hallucinations can be visual, auditory, tactile or olfactory (Kalat, 2007). People who experience a visual hallucination may become aware of the fact that it isn't real, but most people believe that what they are perceiving during their hallucinations is real (Kalat, 2007). Even though a clear distinction can be made between illusions and hallucinations, for many years researchers did not clearly understand why and

how the latter can be interpreted. In the 1930s, Gestalt psychology became very popular because of its descriptions of how the brain processed visual information (Koffka, 1935). Gestalt psychology merely speculated about how the brain processes visual information, but in recent years brain imaging has made it possible to directly examine specific brain functions. These developments have spawned a new research domain called cognitive neuroscience, elements of both cognitive psychology and neuroscience. Within cognitive neuroscience there has already been extensive research on the distinction between illusions and visual hallucinations. This raises the question as to what the differences are between illusions and visual hallucinations as we understand them today, and if this understanding is substantially different from the point of view of the Gestalt psychologists of the early 20th century. Another question that arises is whether the shift to cognitive neuroscience has changed our understanding of visual deception. The goal of this article is to provide insight into how the views on visual deception have changed as part of the shift from a Gestalt paradigm to a cognitive neuroscience perspective.

This article describes the principles of Gestalt psychology and other associated principles for explaining optical illusions and hallucinations using theoretical approaches and case studies. Subsequently, the brain mechanisms of the human visual system in the brain are explained in order to provide a foundation for understanding different ways of processing visual information during optical illusions and visual hallucinations from a cognitive neuroscience point of view.

Visual deception from a Gestalt psychology point of view

One of the first inferences made about visual deception originates from 1856 and was translated from German to English in 1920. It was a handbook for physiological optics, written by Hermann von Helmholtz, who wrote about the effects of visual perception from a psychological point of view and how these effects are processed in the brain (Cahan, 1993). Wilhelm Wundt, often referred to as the founding father of modern psychology, was also interested in how humans experience the world around them. However, where Wundt believed that psychology should concentrate on *introspection*, a method focusing on conscious thoughts and feelings (Cahan, 1993). Helmholtz studied the unconscious influences of the brain as well (Wozniak, 1992). Helmholtz and Edward Hering, among other researchers, speculated in global terms on the phenomenon of vision (Turner, 1993). In 1861, Hering published the Hering Illusion (Figure 1), sometimes referred to in the literature as the Hering-Helmholtz Illusion, which two parallel lines superimposed upon mirroring radiating lines projecting outward from a single axis in the center of the visual field appear to be curved.

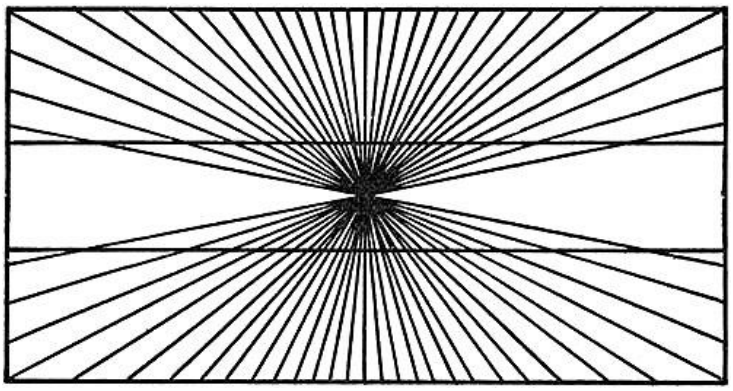

Figure 1. Reprinted from "*The Project Gutenberg EBook of Visual Illusions*", by M. Luckiesh. 2013, Retrieved from http://www.gutenberg.org. Copyright 2011 by Project Gutenberg. Reprinted with permission.

As the Hering Illusion illustrates, our brain is fooling us by perceiving something that isn't actually there. From this point of view, the human brain creates an image under the influence of other processes without consciousness, which became the main principle of a theory called Gestalt psychology. This school of thought held that the human brain works in a holistic way (the German term *Gestalt*, roughly translated, means "perceived whole") and humans see an object as a whole before they see the details which make it possible to understand the world (Koffka, 1935). One of the founders of Gestalt psychology in 1912 was Max Wertheimer, who rejected the view of Structuralism, a theory that claimed that every process could be understood by identifying its component parts (Bruce, 2003). Gestalt psychology also emphasized, processing within the brain affect perceptual outcomes. Wertheimer believed that the visual system in the brain contained a grouping mechanism which automatically combines individual parts into a whole, resulting in a complete image. The phenomenon of optical illusions can be explained as the brain filling in gaps in which visual stimuli are absent in order to create a whole image. Gestalt psychology described this process in terms of grouping mechanisms that reflected a number of Gestalt "laws" (see Figure 2)(Bruce, 2003). The first of these, called "Proximity", causes people to see objects in close proximity to one another as comprising a single group, simply because they are close to each other. The second of these laws is "Similarity", which makes people perceive objects sharing a certain similarity (i.e., in contrast to other objects) as together. "Closure" explains the principle of seeing a complete recognizable geometric figure when only parts of the lines of that figure are visible. The final image, "Good continuation", abeles the perception of an object that is obscured or intersected by another object.

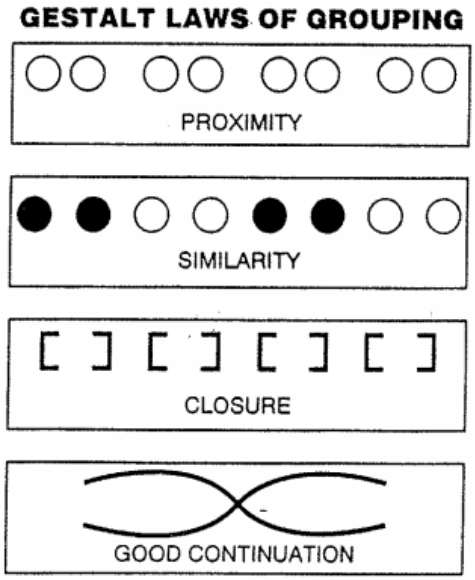

Figure 2: Reprinted from "The legacy of Gestalt psychology", by I. Rock and S. Palmer, *Scientific American, 263,* p. 89. Copyright 1990 by Scientific American.

The processing of visual information combines these laws with certain objects that are seen and results in a coherent image. On the other hand, it is also possible to see something without actual input from the outside world. Such a phenomenon is called a visual hallucination. From a Gestalt psychological perspective, a visual hallucination can be explained as an illusion, because the Gestalt principles are the foundation of psychological functioning. Therefore, K. Conrad (1953) attempted to apply the Gestalt principles/laws to explain mental disorders (Fish, Forrest & Macpherson, 1960). In the case of mental disorders,

the ability to integrate new experiences and the differentiation of individual parts from a total field seem compromised, resulting in a disordered perception of the world. Conrad describes a case study of a patient who perceived scratches on the wall as moving words. Another patient saw written words moving around during a test (Fish, Forrest & Macpherson, 1960). Gestalt principles state that new experiences are integrated into existing memory constructs and that these stored constructs help create perceptions that make sense to the individual. In the case of mental disorders, the integration of new memories and the retrieving of stored constructs that create sensible perception are both impaired (Fish, Forrest & Macpherson, 1960). The impairments of these "Gestalt" functions result in the inability to combine details of a certain field in order to understand the whole and leads to misinterpretation of visual perception, a phenomenon called illusions.

Cognitive neuroscience on illusions and hallucinations

Since the understanding that what we see is influenced by the brain, it is important to know more about the underlying mechanisms of the visual system. The brain area responsible for visual perception is called the visual cortex (comprising the regions V1-V5) which is in contact with our eyes. Both eyes have an area called the retina that processes visual information through the optic nerve and dorsal lateral geniculate nucleus to the primary visual cortex (V1) in the occipital lobes (Purves et al., 2013). The primary visual cortex is responsible for processing and sending it to the other brain areas. When humans look at an image, the construction of that image is seen by the retina and transferred via the optic nerve to the primary visual cortex. The visual cortex contains certain groups of neurons called columns, which correspond to receptive fields in the retina containing information about specific movement and shapes orientations in the visual field. The brain combines the information that is perceived from different parts of each eye to create a complete image, and then sends information out to other areas in the brain. This processing of visual information within the brain is called "higher visual processing" and comprises two specific paths (Purves et al, 2013). The first path, referred to as the "where" path is connected to V5, leading to the parietal lobes, provides us with spatial information referring to analysis of motion and the location of an object. The second path, known as the "what" path is connected to V4, which leads to the temporal lobes. It is responsible for higher-level analytical processing and object recognition (Purves et al, 2013).

Because higher processing takes place during perception, it seems plausible that if information is shared with other brain areas, these areas influence what we see. In fact, the higher the order of brain processing, the less dependence there is on visual input from the retina (Purves et al, 2013). Sometimes a scene or object is perceived incorrectly due to a misapplication and the "rules" that determine how we interpret what we see, resulting in an illusion. Modern science distinguishes two kinds of illusions. The first one has a physical cause while the second results from wrongly applying one's knowledge (Gregory, 1997). Physical causes include illusions due to flaws in perceiving the correct light on an object, occur when sensory signals reaching the eye are disturbed, and are known as ambiguities and distortions. "Cognitive illusions" occur when knowledge is wrongly applied and sensory signals are misinterpreted (Gregory, 1997). In 2008 Mark Changizi stated that the human visual system tries to predict the future in order to compensate for the small delay (slightly less than one-tenth of a second) between when light reaches our retina and when this information arrives in the visual cortex. According to this theory, geometric optical illusions that contain certain shapes, are translated by our brain in the wrong way because of a wrong interpretation (Changizi, 2008). For instance, the Hering Illusion looks like a wheel on a bike, a shape stored in our memory. Research on primates found similar effects of the brain's predictions in this respect. For instance, in viewing the Kanizsa square (Figure 3), humans

typically see a square between four three-quarter circles that are equidistant from one another, each with inner perpendicular lines that create the perception of the square. Because research on animals is more accessible than that on humans, Cox et al. (2013) looked at the brain of monkey's who looked at the Kanizsa square. He found that columns of neurons in V4 started firing in a pattern that mirrored the specific shape of the perceived square in the middle, although there really was no "square". This research suggests that V4 may be responsible for this illusion and provides us with knowledge which can possibly be applied to the human brain as well.

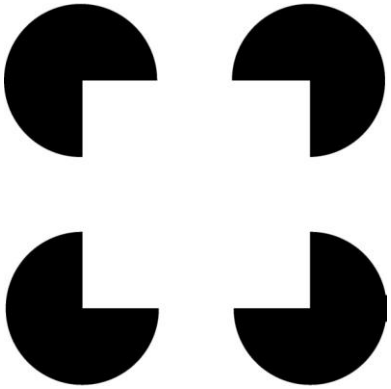

Figure 3: Reprinted from "*Perception Preattentive and Phenomenal*", by Austin Clark. 2013, Retrieved from http://selfpace.uconn.edu/paper/ClarkAusHppp_html _m14cd758a.jpg. Copyright 2006 by University of Connecticut.

The end result of what we eventually see can be explained in term of two different sorts of processing. "Bottom-up" processing refers to the processing of stimuli that are perceived in the environment without interference of cognitive processes in the brain. Sensory stimuli are more likely to be processed "top-down"-fashion, which does contain interference from the brain, which completes what we see, making this form of processing knowledge based (Frith & Dolan, 1997). The Gestalt laws are a good example of the top-down processing principle. During a hallucination there are no external visual stimuli misinterpreted. Instead, hallucinations are generated by the brain itself, resulting in difficulty in discriminating between between real and imagined events. It is not yet clear how visual hallucinations originate in the brain. Manford and Andermann (1998) reported that brain defects in the primary visual cortex (i.e. seizures) can cause visual hallucinations. The same is said about lesions (i.e. tissue abnormalities) due to disease or an accident (trauma) that can result in slight changes in this part of the cortex and result in hallucinations. Damage in this brain area may result in distorted visual processing, yet this subjects requires further research. Other, more recent, research shows that the basis of hallucinations may be top-down processing, where higher cognitive processes determine perception (Aleman et al., 2003). When researchers (Ku et al., 2008) showed visual illusory stimuli to participants in order to mimic hallucinations during brains scans, several brain areas responded to these stimuli. In the first phase of perception, the amygdala, responsible for emotional regulation, was pre-dominantly active (Ku et al., 2008). The second phase showed an increase of activity in the medial frontal cortex, an area that is thought to be responsible for decision-making (Botvinck, Cohen & Carter, 2004) and/or retrieval of long term memory (Euston,

Gruber & McNaughton, 2012). The occipitotemporal areas that are associated with visual recognition were also found to be active. In the later phase, the thalamus was predominantly active, which means that sensory signals were relayed to the corresponding brain areas. During the last phase, participants reported hallucinations, indicating that the previous phases were an emotional response mediated by perception.

Hallucinations can result from a number of different causes. People who suffer from schizophrenia are known to experience hallucinations (mostly auditory), a mental disorder that was first described by Emil Kraepelin in 1891 (Aderibigbe, Theodoridis & Vieweg, 1999). The phenomenon of dreaming is often compared to hallucinating because of the similar experience of having a "real perception" in the absence of external stimuli (Chiu, 1989). But there is an important distinction between the two phenomena in terms of level of alertness. Dreaming only occurs during sleep and is considered to be healthy whereas hallucinating may be a sign of mental illness and can occur when someone is awake. However, a sleeping disorder called narcolepsy that causes extreme sleep attacks during the day can induce hallucinations during states of both sleep and wakefulness (Kalat, 2007). The underlying cause of narcolepsy is presumed to an imbalance in levels of neurotransmitters (i.e. chemicals in the brain that are used for communication between neurons) (Kalat, 2007). Besides dreaming or mental illness, hallucinations can also occur during psychoactive drug abuse due to subjective changes in perception. As with narcolepsy, neurotransmitters has often been associated with hallucinating (mainly the neurotransmitters dopamine and serotonin, responsible for reward-directed behavior and the overall feeling of well-being) (Purves et al, 2013). For example, hallucinogens are class of drugs that can cause hallucinations because they create an imbalance in neurotransmitter levels. One hallucinogenic drug, LSD, is known to cause powerful hallucinations, partly due to interaction with the serotonin system (Kenemans, 2011). Dopamine has been associated with hallucinations since the first treatment of Parkinson patients with L-dopa, which can induce dopamine levels in the brain that may lead to hallucinations (Jenkins & Groh, 1970). The same effect holds for people using recreational drugs which cause an overproduction of dopamine in the brain, like amphetamines, cocaine or crystal meth (Kish, 2008).

Conclusion

In describing the phenomena of optical illusions, Gestalt psychology focuses more on describing the principles whereas cognitive neuroscience also tries to explain the underlying mechanisms. Brain imaging techniques have made it possible to confirm the important role of higher level brain processing during visual deception, a role first suggested by Helmholtz in 1890. The Gestalt principles described by Koffka and Wertheimer show that during perception, the component parts of an image do not determine what is seen. Mechanisms in the brain combine these parts into a whole image. This notion is still shared today. Cognitive neuroscience expanded upon these findings. It has shown that during visual perception, brain processing in higher regions is less dependent on input from the retina. The interference of the brain prevents people from perceiving visual stimuli as they are, which is called top-down processing and can help understand why optical illusions can occur. Another cause of illusions can be due to an inaccurate perception of light, that distorts the perceived image. These explanations show that Gestalt principles are not completely outdated or wrong, but instead have provided researchers with a descriptive framework. Cognitive neuroscience has concentrated on discovering the underlying mechanisms of brain functioning. These mechanisms of brain functioning have been partly mapped during the last decade, and have made clear that the eyes convey information through the optical nerve to the primary visual cortex. Research on animals even shows that columns of neurons in the visual cortex

actually respond to specific shapes and are grouped together, roughly resembling the grouping principles described by Gestalt psychologists nearly 100 years ago. Researchers hypothesize about the attempt of the brain to predict what has been seen, in order to compensate for the short delay in transmission of visual information from the eye to the cortex.

Gestalt psychology stated that illusions occur when the Gestalt principles cannot be applied to a certain visual stimuli, whereas hallucinations happen due to impairments in the Gestalt functions stored in the brain. An interesting fact is that while Conrad (1953) tried to explain misperception of visual stimuli reported by a patient from a Gestalt point of view, and referred to them as illusions, today these symptoms are described as hallucinations because of the lack of external visual input. New research shows that the hallucinations may also occur as a result of "top-down" expectations, (a form of processing also assumed responsible for perceiving illusions) and that defects in the primary visual cortex can cause visual hallucinations. Mimicking hallucinations during research revealed a so-called monitoring phase in the brain during which participants reported seeing a hallucination, which could be interpreted as a checking mechanism. Dreaming was described as a healthy form of hallucinating during sleep, while those who suffer from narcolepsy, may experience hallucinations while awake, due to imbalance of neurotransmitter levels. Hallucinations can also result from the use of hallucinogenic drugs and from elevated levels of the neurotransmitter dopamine.

In conclusion, the shift from Gestalt psychology to cognitive neuroscience shifted the understanding of illusions and hallucinations from theoretical to the empirical domain. Because of brain imaging researchers can now identify the brain areas which are active during visual processing, and therefore have the potential to explain illusions.

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