Optical Illusions

Optical illusions fascinate us, challenging our default notion that what we see is real. They demonstrate that all our perception is illusion, in a sense – incoming sensory information is interpreted, yielding the internal representation of the world. Therefore, after our eyes have filtered the visual input we need sound judgement of information in order to create our inner reality: "Your senses then you'll have to trust, / They'll let you see what's true and just, / Should reason keep your mind awake".[8]

What is an optical illusion? "I know it when I see one" could not be farther off the track – as the best illusions are the ones where a discrepancy from reality is not 'seen' until one uses other modalities (eg. touch) or instruments (rulers, light metres). And even when we know that we are subject to an optical illusion, most illusory percepts still persist – a phenomenon called cognitive impenetrability.[15] As Gregory[9] aptly stated it "it is surprisingly hard to define 'illusion' in a satisfactory way". According to the Merriam-Webster Online Collegiate Dictionary, an illusion is 1. something that deceives or misleads intellectually; 2. perception of something objectively existing in such a way as to cause misinterpretation of its actual nature.

Why study illusions?

Is it only the playful child in scientists that drives them to study optical illusions? To some degree, yes, but illusions can also decide major sport events: referee judgements probably are affected by the 'flash lag effect', eg. when judging the spot where a tennis ball touched the ground.[2] However, there are professional reasons as well: Optical illusions are particularly good adaptations of our visual system to standard viewing situations. These adaptations are 'hardwired' into our brains, and thus can cause inappropriate interpretations of the visual scene. Hence illusions can reveal mechanisms of perception.

There are also some clinical conditions in which optical illusions play a major role, eg. organic psychoses, epileptic aura and migraine. Another often overlooked[21] disorder is the Charles Bonnet syndrome:[4] patients with a normal cognitive status but reduced afferent sensory input due to visual system pathology (eg. age-related macular degeneration) or with brainstem pathology[6] experience visual hallucinations of various sorts. Finally, from a visual scientist's point of view the Rorschach test[17] is based on optical illusions or more precisely on the phenomenon that our brain is constantly looking for known patterns in random structures with low information content, called pareidolia.

What is old, what is new?

Some illusions are long known to mankind, eg. the waterfall illusion was mentioned by Aristotle: after staring at a waterfall for a couple of minutes neighbouring objects seem to be shifting upwards. This was followed up by Lucretius, Purkinje and Addams who coined the term 'waterfall illusion'. Recent evidence suggests that this motion aftereffect is not due to 'fatigue' but rather due to a gain adjustment, an optimal adaptation to prevailing conditions.[18] The description of numerous illusions, in particular geometric illusions, in the 19th century was followed by striking new ones, many of which rely on computer animation, in the last decade.

Classification

This abundance of illusions is hard to categorise, especially since many still lack a successful explanation. We will use the following six phenomenological groups:

- Luminance and contrast
- Motion
- Geometric or angle illusions
- 3D interpretation: size constancy and impossible figures
- Cognitive/Gestalt effects
- Colour

and show examples of the first four. Many more examples of illusions can be found at <http://www.michaelbach.de/ot>.

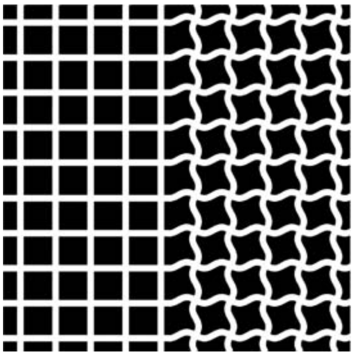

Figure 1: The Hermann grid on the left with grey patches at the intersections, and a new variant on the right[7] removing the illusionary patches.

Luminance & Contrast

The 'Hermann grid' was discovered in 1870 by the physiologist Ludimar Hermann.[11] If you examine the left part of Figure 1, you will notice faint grey patches at the intersections of the white 'streets'. These patches are not visible when directly fixated.

For half a century this illusion was explained on the basis of lateral inhibition;[3] this assumes that we see the world as our retinal ganglion cells encode and thereby compress it. However, in most situations our visual cortex undoes the retinal encoding by spatial integration to approach a veridical luminance perception. A complete explanation of the Hermann grid would have to include why this mechanism fails here. Recently János Geier showed that just a slight torsion of the grid lines abolishes the appearance of the grey patches (Figure 1, right part), highlighting the additional role of cortical processing, ie. orientation selective neurons.[7]

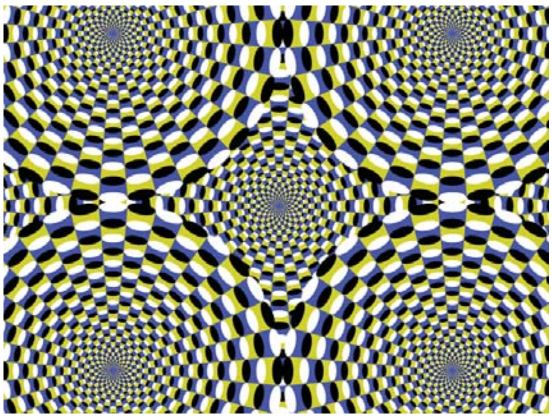

Figure 2: Kitaoka's 'Throwing cast nets'.

Motion

In Figure 2[12] the disks appear to expand slowly. It may take a few seconds and exploring eye movements to appreciate the effect – still, not everyone perceives this illusion.

The complete explanation of this illusion is not fully established in spite of promising recent efforts.[1,5,12] Prerequisites are: asymmetric luminance steps, eg. from dark to dark-grey and white to light-grey and eye movements. When they suddenly appear (= temporal modula-

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tion), the asymmetric luminance steps drive motion detectors.[10,16] The eye movements affect temporal modulation with the help of either adaptation[1] or possibly saccadic suppression. A grouping arrangement enhances the effect, but colour is not necessary.

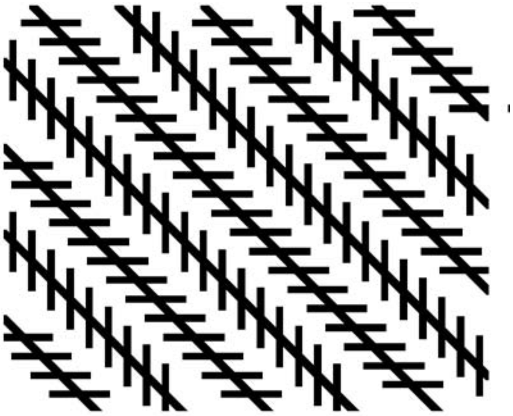


Figure 3: The Zöllner illusion. The oblique lines are all parallel.

Geometric or angle illusions

The German astrophysicist J Zöllner discovered in 1860 that parallel lines intersected by short lines at an acute angle appear to diverge (Figure 3): The crossings of the short lines evoke a depth perception so that one end of the long lines appears to be closer to the observer than the other. This class also comprises Fraser's Spiral, the Poggendorff and Hering illusions. Common to all of them is that small angles are overestimated, but the precise underlying mechanisms remain to be clarified.

Size Constancy

A large class of illusions is probably caused by size constancy. This is an important mechanism where our visual system multiplies retinal (or angular) size with assumed distance, enabling us to estimate size independent of geometrical perspective. Partially already present at birth,[20] we take size constancy for granted, only reminded of its ever-present action when it fails. The latter can happen when distance information is not available and our visual system resorts to 'default settings' – eg. in the moon illusion that lets the moon appear larger when it is near the horizon than when seen high in the sky – or when the 3-dimensional image interpretation is not appropriate – eg. the Ponzo illusion, or Shepard's 'Turning the Tables':[19]

If we had one table cloth, would it exactly cover both table tops in Figure 4, top? Certainly not. If we were to cut out one table top from the paper, would it cover the other one? Indeed yes, they are identical parallelograms, as shown in the bottom of Figure 4. This example demonstrates that one cannot deduce from optical illusions that our eyes 'deceive' us. Both answers above are correct. The observer's irritation stems from our automatic interpretation of line drawings as renderings of 3-dimensional objects, a very good strategy for most of our life. This automatic 3D interpretation is so strong that it is hard, if possible at all, to envisage the table tops as flat parallelograms.

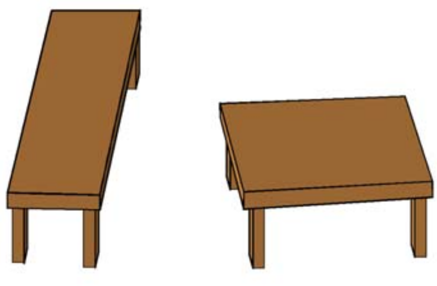
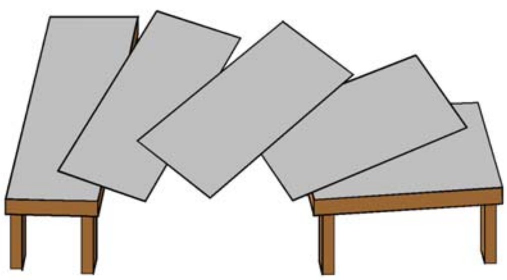


Figure 4: Shepard's 'Turning the Tables'. Are the two table tops identical?



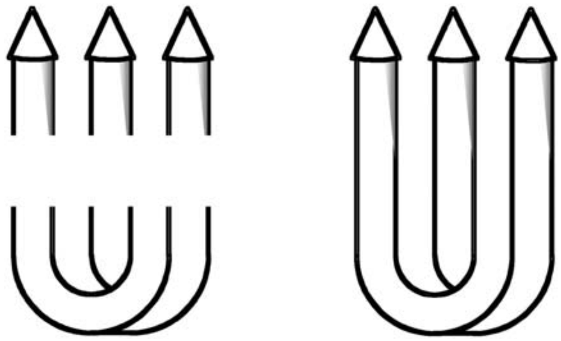


Figure 5: The impossible trident, also known as blivet or devil's fork.

Impossible Figures

Consider Figure 5 (left) above. The upper part is easily conceived as three towers, the bottom catches our eyes as a rod bent into a U-shape. Both interpretations are perfectly valid. If, however, the lines are connected as seen in the right part, an 'impossible object' emerges. The line continuations are not appropriate, because they turn the empty background between the towers into surfaces of the U at the bottom. The observer is left with an uncanny percept, and both art and science are linked here: Mauritius Escher drew his "Ascending and Descending" only two years after Penrose[13] published the 'impossible staircase' drawing.

Future

Plato[14] already alerted us to the discrepancy between perception and reality in his "Allegory of the Cave". In all likelihood we will never be able to turn around and see the true reality, but we can do our best to understand it. Many illusions remain unsolved to date, and there will be more to come. In the meantime, we can enjoy their viability as a research tool, and also to introduce the next generation to the fascination of science.

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