The Cheshire Cat Illusion

*The Cheshire Cat ‘vanished quite slowly, beginning with the end of the tail, and ending with the grin, which remained some time after the rest of it had gone’.*

- Alice’s Adventures in Wonderland, Lewis Carroll

It is said that the pursuit of science is a humbling endeavour. Science has the power to shock us out of our habitual familiarity with the natural world, and subvert every notion we hold to be ‘common-sense’. In the words of the psychologist William James, it takes ‘a mind debauched by learning to carry the process of making the natural seem strange’. Perhaps the most extraordinary phenomenon, however, is also one to which we are uniquely blind - consciousness. Though we may operate on the assumption that we see the world as it is, ‘reality’ as we experience it is in fact an elaborate internal model constructed by our brain.

Described by Francis Crick as the ‘Astonishing Hypothesis’, this fact is one we are rarely made aware of, as the vast majority of our cognition occurs below the surface level of consciousness (Freud offered the analogy of an iceberg, in which the conscious mind comprises only the small exposed tip). Visual illusions are of great interest to us here at Grand Illusions because, as well as being entertaining and curious, they can offer small but fascinating windows into the complex hidden machinery of consciousness.

The ‘iceberg of consciousness’
The Cheshire Cat effect, first discovered by Sally Duensing and Bob Miller in 1978, is a particularly powerful and compelling illusion, but one which neuroscience has yet to fully understand. Though definite conclusions are thus difficult, we hope in this article to offer you some interesting potential explanations drawn from modern research, and invite you to explore further!

As we begin to untangle this illusion, it is worth noting that, of our five senses, vision is undoubtedly the most important. This is reflected in our neuroanatomy, with around one quarter of the human brain believed to be devoted to understanding our visual environment. Unsurprisingly, the nature of visual perception has long been the subject of research.

You may already be familiar with such visual illusions as the candle with one or two faces, and the old/young woman: these are examples of how the brain is able to switch between different interpretations of the same image when presented with an ambiguous stimulus. Most people see only one interpretation at any one time, a form of ‘perceptual rivalry’, and can consciously switch between the interpretations.
A slightly more complex set-up, first described around the turn of the 19th century, may help us in starting to explain the Cheshire Cat illusion. If one image (say, a face) is shown just to a person’s right eye, and a sufficiently different image (say, a house) to the same area of the left eye, a fascinating phenomenon occurs. You might expect that the person would see the two images on top of one another, but instead the person will have the conscious perception of seeing just one image for a few moments, then the other, in a randomly alternating fashion (you can see this for yourself with some demonstrations here). One image is dominant whilst the other is suppressed. This strange visual transitioning, termed ‘binocular rivalry’ has been the subject of much research, although its exact neural underpinnings are still debated.

Although the two images remain stationary in the visual field, it is as though each is competing for exclusive access to the person’s consciousness - in other words, when an image moves from being suppressed to being dominant, it moves from being unconsciously processed to consciously perceived. The competition between the images must occur somewhere in the brain - but where? Research indicates that it most likely happens on multiple levels of the visual system (a series of nerve cells and specialised brain areas which connect the retinas of the eyes to the cerebral cortex, shown in the diagram below).

![Diagram of the brain showing the thalamus and visual system](image)
Importantly, scientists have increasingly learnt that vision is not a single process, but a complex aggregation of many distinct capacities - such as the ability to detect colour, or motion, or faces - and that these abilities are located (at least to some extent) in separate areas of the brain.

One model of how different aspects of a visual stimulus are represented in the brain describes two routes of connected nerve cells, the **‘what’ pathway** and the **‘where’ pathway**. The ‘what’ pathway, extending from the primary visual cortex at the back of the brain around to the temporal lobes at the sides of the brain, deals with recognising shapes, sizes, objects, faces and text in the external environment, and placing them in the context of our memories and emotions. The ‘where’ pathway, connecting the primary visual cortex with the parietal lobes at the top of the brain, specialises in the layout of the external world: location, distance, position in space, and motion, and uses this information for planning physical actions made by the body.

In this diagram, the ‘what’ pathway is shown in purple, and the ‘where’ pathway in green.

Whilst the ‘what’ pathway is generally linked to conscious visual perception, the ‘where’
pathway can process incoming visual information in a way that leads to appropriate physical actions even if the person is not consciously aware of the information. During binocular rivalry, activity in the ‘what’ pathway of each hemisphere of the brain is alternately suppressed as one image fluctuates in and out of conscious perception - perhaps partially explaining in the Cheshire Cat illusion how the stimulus of the moving hand in one eye can suppress the stimulus of the face in the other.

There are several other visual phenomena where stimuli are not registered by conscious perception, and become invisible. One such example is motion-induced blindness, a demonstration of which you can see here. In this illusion, small stationary objects appear to disappear and reappear when surrounded by a global moving pattern: again, an example of an unvarying visual stimulus which nevertheless leads to fluctuations in perception. There are several theories of the underlying neural basis of this illusion, but one explanation is that the constant stimulus of the stationary object is akin to a small defect in the moving visual field (like our blind spots, which we are not normally aware of) and the brain simply ‘fills in’ the space where the stationary object should be with the global moving pattern and removes it from awareness. Another possibility to explain the disappearance and reappearance of the stationary object is an oscillation in attention or awareness between the ‘what’ stream (representing the static object) and ‘where’ stream (responding to the global motion). Perhaps we are primed to pay more attention to moving objects than static ones in our visual field: hence why the moving hand in the Cheshire Cat illusion is able to successfully remove the image of the face from our awareness.

Though the psychological phenomena described above help us to explain the Cheshire cat illusion, what is so interesting is that they only appear to account for part of the effect. In contrast to most other cases of motion-induced blindness, in which the stationary object entirely disappears, looking at a human face normally results in just the eyes and mouth remaining visible (thus appearing to be eerily disembodied and suspended in the air). Why should this be?
"Well! I've often seen a cat without a grin," thought Alice; "but a grin without a cat! It's the most curious thing I ever saw in all my life."

The answer, it would appear, rests in the importance of faces. As *Homo sapiens*, we are a hypersocial species, and perhaps the single most crucial aspect of the environment we need to concentrate on, and respond appropriately to, is other people. Indeed, within evolutionary biology the ‘social brain’ hypothesis (or ‘Machiavellian intelligence’ hypothesis) posits that much of the expansion in brain size during the emergence of modern humans was due to selection for improved social cognition. ‘Folk psychology’ capacities, such as theory of mind, allow us to conceptualise the mental states of others, to which we can then attribute beliefs, desire and intentions. This capacity to interpret and explain the behaviours of others according to underlying mental states evolved to help us better understand and predict other humans, and thus to more successfully navigate (and manipulate!) our way through a complex social world.

Crucial to these abilities is facial recognition. In order to identify friends and foes, and then internally model their beliefs and emotional states, requires the recognition of faces and facial expressions. As the neurobiologist Margaret Livingstone points out, ‘Faces are among the most informative stimuli we ever perceive: Even a split-second glimpse of a person’s face tells us their identity, sex, mood, race, and direction of attention’.

There is now a strong, and growing, body of evidence from evolutionary, cognitive and developmental psychology that, in the human brain, faces constitute a ‘special’ category of stimuli, and are treated differently from perceptions of general objects. Furthermore, facial recognition also appears to be processed by discrete and specialised neural structures.

Compelling evidence comes from a particular neuropathology known as *prosopagnosia*. Caused by damage to parts of the inferior temporal cortex, it is a highly specific impairment in an individual’s ability to recognise faces. Patients exhibit great difficulty recognising previously familiar faces, but may be entirely fine at identifying other objects. In order to identify a friend, patients may have to rely on other distinguishing features, such as jewelry or clothes.
Interestingly, a corroborative, but converse, case comes from a patient known as C.K., who exhibited the reverse condition: impaired object recognition, but functional facial recognition. These cases strongly suggest that facial recognition is indeed distinct from normal object perception.

Further evidence of this functional specialisation, and neurological localisation, has come from studies of the brain using positron-emission tomography (PET) and functional magnetic resonance imaging (fMRI). These techniques, which emerged in the 1990s, allow scientists to measure blood flow and oxygen consumption in the brain. This can then indicate which areas of the brain are being activated during different tasks. Experiments using these scans have found that faces elicit activation in both hemispheres of the lateral fusiform gyrus, for example, and in particular, resulted in the identification of a particular region - the **fusiform face area** (FFA). The FFA is consistently activated when a person is looking at a face, or indeed even just imagining a face, but doesn’t light up in response to other objects.

It is still possible of course that such activation is simply correlated with facial recognition, rather than actually being responsible for it. It turns out that this question of cause-and-effect was directly tested, however, in a fascinating study carried out by the neurologist Josef Parvizi at Stanford University. In an attempt to locate the source of seizures in a 47 year old male patient, Parvizi used electrodes to stimulate different parts of his temporal lobe, resulting in various experiences of colours and memories. When the electrodes stimulated the fusiform gyrus, however, the patient said to Parvizi: ‘You just turned into somebody else. Your whole face just sort of metamorphosed’. On ceasing stimulation, he reported that the face had returned to normal. This effect did not alter recognition of any other objects, and appeared to be unique to faces.

All the findings above suggest that the primacy and salience given to facial information by the brain may help to explain why vision of the face is not entirely suppressed in the Cheshire Cat effect. A question remains however: why doesn’t the entire face remain? Why is it only the eyes and mouth that appear to linger on?
Studies in neurobiology suggest this may be linked to the fact that human faces are processed by the brain as Gestalt percepts, in that our brain perceives them as unified wholes. Rather than processing them as discrete groupings of patterns, our brains use a template-matching approach that concentrates primarily on the eyes and mouth for identification. Our reliance on the configurational relationship between features, rather than simply details, is powerfully illustrated in the Thatcher effect, in which it is much harder to detect expressions in inverted faces. The importance of eyes and mouths in recognition is further exhibited in our strong tendency to project these facial features onto random patterns, a phenomenon known as pareidolia (seeing faces on the moon’s surface, or in clouds, are common examples). It would thus appear that, within facial recognition, eyes and mouths are given special status, which may explain why they remain in the illusion.

To conclude, the Cheshire Cat illusion may appear at first to be a mere curiosity, but dig a little deeper and we find that attempts to explain it must draw on our understanding of human consciousness itself. This article has attempted to offer some explanatory ideas behind the effect, but we still lack a full understanding of exactly what is happening in the brain, and many questions remain. How exactly does the brain decide what visual stimuli are salient? How do certain visual processes enter our consciousness? What exactly is the neural difference between conscious and non-conscious sensory data? What governs the interaction between our What and Where pathways in cases of motion-induced blindness? Though we cannot yet know what answers neuroscientists will find to these questions, as they continue to explore ‘backstage in the private theater of the mind’ (Kandel, 2012), the truth is likely to be prove only curioser and curioser.

Matthew Ball

September 2013
References

William James, evolutionary psychology and ‘debauching the mind’
- http://www.cep.ucsb.edu/primer.html


http://www.perceptionweb.com/abstract.cgi?id=p080269

http://visionlab.harvard.edu/Members/Olivia/tutorialsDemos/Binocular%20Rivalry%20Tutorial.pdf


Eric Kandel (2012) The Age of Insight

Image: https://stanley.gatech.edu/research_topics_vision.html