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The Enigma of Op Art

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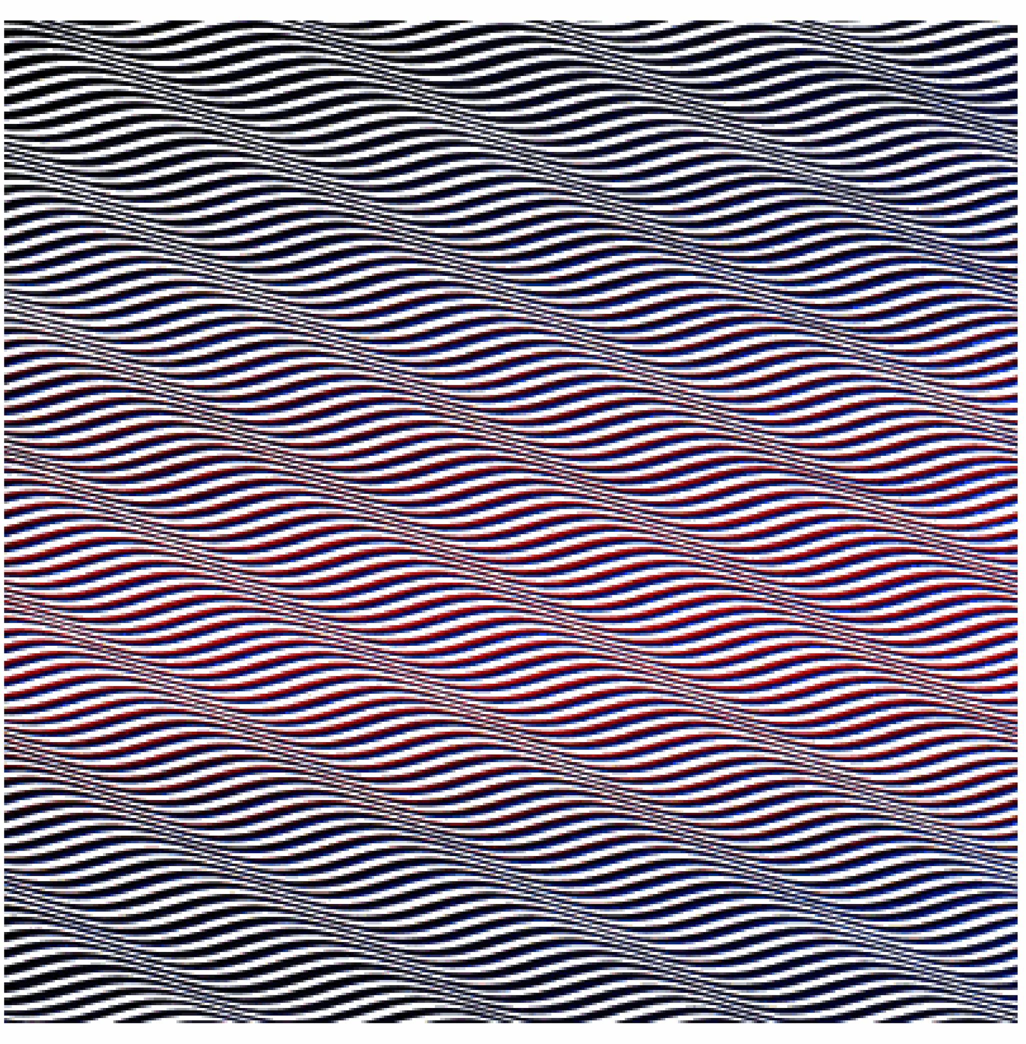


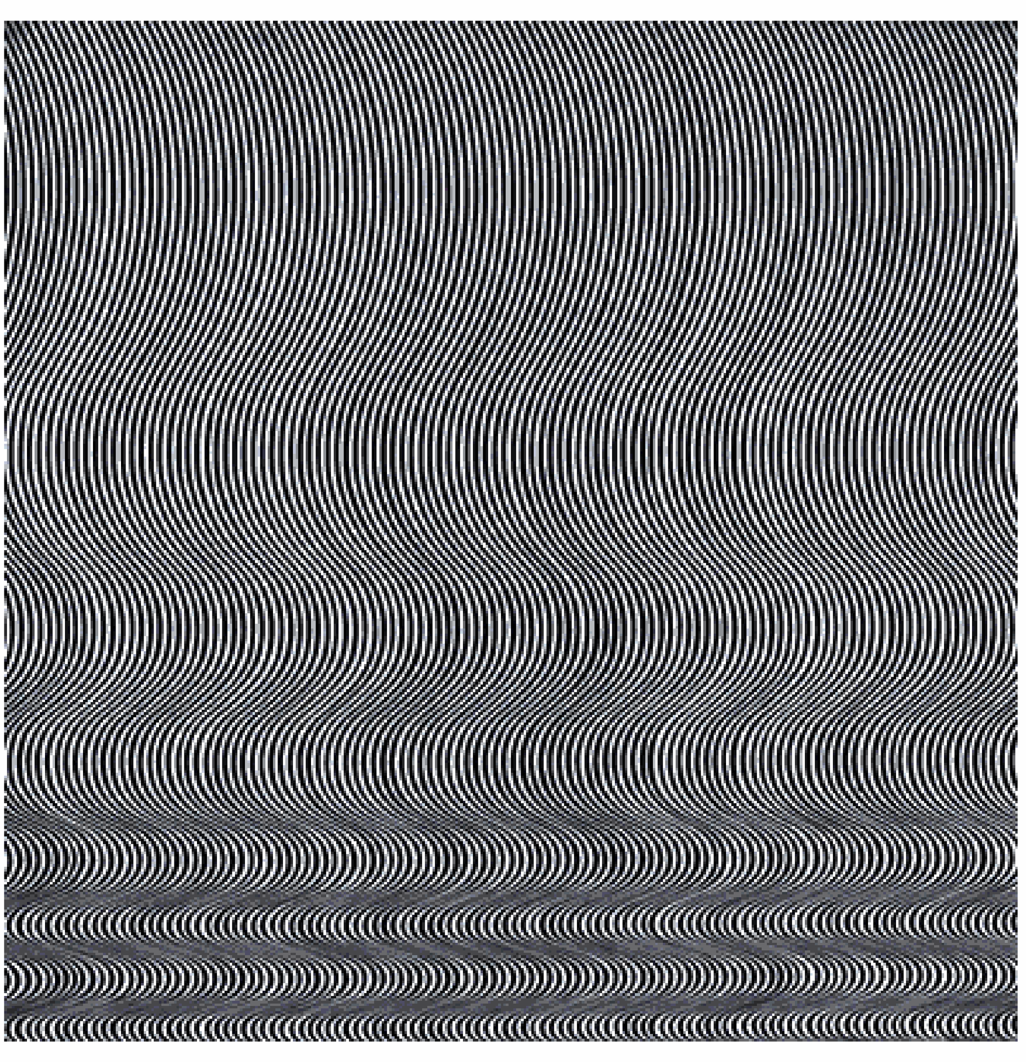
Cataract 3, Bridget Riley, 1967.

In the 1960s, the British artist Bridget Riley began to develop a distinctive style characterised by simple and repetitive geometric patterns which create vivid illusions of movement and sometimes colour and often have a disorientating effect usually described by observers as "shimmering" or "flickering". With her explorations of the dynamic nature of optical phenomena, Riley became one of the most prominent exponents of what came to be known as Op Art.

Many optical illusions are generated by the brain, and studying them has provided us with a better understanding of the workings of the visual system. For example, the illusions known as hybrid images, which consist of visual stimuli that can be interpreted in more than one way, are thought to occur because the large-scale and fine-grained features of an image are processed at different speeds through parallel streams.

The physiological basis of how illusions such as those seen in Riley's paintings occur has long been the subject of debate. In the past few years, however, studies which use of a combination of experimental psychophysics and computational techniques suggest that these illusions are produced not in the brain but primarily because of miniscule and involuntary eye movements called microsaccades.

Johan Zanker, a professor of neuroscience at Royal Holloway, University of London, has been investigating the possible mechanisms underlying these phenomena using various stimuli generated from Riley's *Fall* (below). This painting is usually described as a pattern of horizontal bands and often produces the illusion that the gratings are moving in changing directions. The initial experiments showed that the intensity of the illusion produced by the stimuli varied according to the distance between the lines - the greater the distance, the more intense was the strength of the illusion.



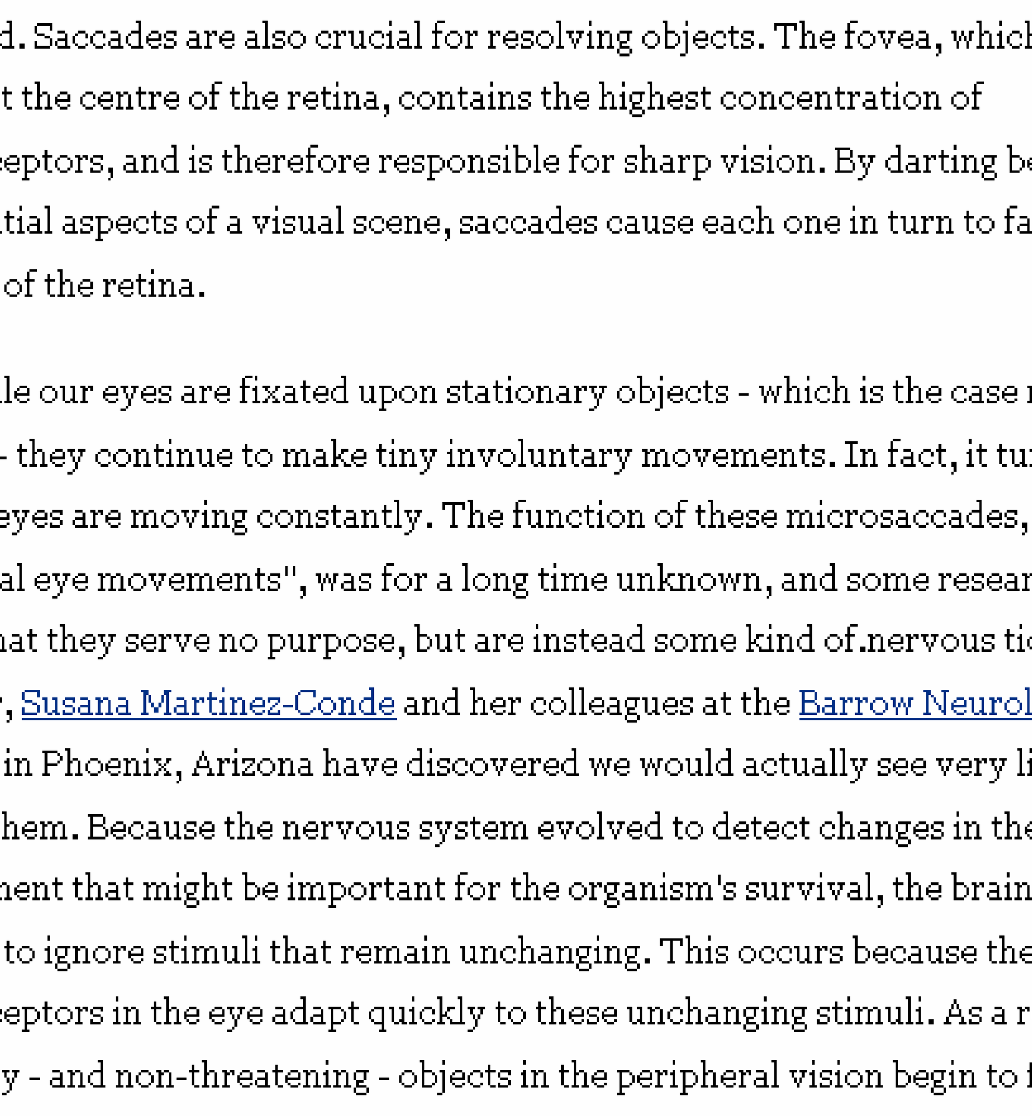
Fall, Bridget Riley, 1963.

Zanker then stabilized the images observed by his participants using a photographic flash to illuminate the stimuli for very short periods of time, so that they impinge on the retina only briefly. Under these conditions, the illusion almost disappeared completely. Furthermore, when the participants viewed the same stimuli through a small pinhole, which stablizes the image to a lesser extent, the strength of the illusion was diminished. By contrast, when the stimuli were viewed normally, even for very short periods of time, the illusion persisted. These findings suggest that eye movements are essential for experiencing the illusion. They were confirmed by another experiment in which participiants were presented with the painting itself, whilst a video-based eye-tracker was used to monitor their eye movements.

Zanker explains the illusion created by *Fall* as follows. Although the patterns in it are not homogenous, it contains no prominent visual features on which the observer can focus their attention. When the eyes move back and forth across the painting, there is nothing to which the brain's motion detection mechanisms can refer and so the gaze remains unstabilized. As a result, the observer experiences "motion without displacement" - she has a vivid impression of mixed movements with incoherent directions, which are not accompanied by a change in position.

The eye movements which Zanker uses to explain the illusion are called saccades. These are rapid and voluntary movements which cause the eyes to simultaneously jump from one aspect of an object to another. When looking at a face, for instance, the eyes momentarily fixate upon one feature, such as the mouth, and then move to fixate upon the nose, then the eyes, and so on. In this way, essential features are extracted from the visual scene so that a mental representation of that scene can be generated. Saccades are also crucial for resolving objects. The fovea, which is located at the centre of the retina, contains the highest concentration of photoreceptors, and is therefore responsible for sharp vision. By darting between the essential aspects of a visual scene, saccades cause each one in turn to fall upon that part of the retina.

Even while our eyes are fixated upon stationary objects - which is the case most of the time - they continue to make tiny involuntary movements. In fact, it turns out that our eyes are moving constantly. The function of these microsaccades, or "fixational eye movements", was for a long time unknown, and some researchers argued that they serve no purpose, but are instead some kind of.nervous tic. However, Susana Martinez-Conde and her colleagues at the Barrow Neurological Institute in Phoenix, Arizona have discovered we would actually see very little without them. Because the nervous system evolved to detect changes in the environment that might be important for the organism's survival, the brain quickly learns to to ignore stimuli that remain unchanging. This occurs because the photoreceptors in the eye adapt quickly to these unchanging stimuli. As a result, stationary - and non-threatening - objects in the peripheral vision begin to fade and then eventually disappear from visual awareness. Microsaccades counteract the adaptation of the photoreceptors and so prevent this visual fading.



Enigma, Isia Leviant, 1981.

New work from Martinez-Conde's laboratory supports Zanker's conclusion that these illusions are generated by eye movements. In a study due to be published in the *Proceedings of the National Academy of Sciences*, they provide strong evidence that microsaccades are essential for the illusion produced by Isia Leviant's painting *Enigma* (above). This consists of several concentric circles of the same colour superimposed on a pattern of radiating black and white lines, and creates an intereference effect known as the moiré sensation, a shimmering effect and a sensation of circular motion.

In the study, 3 participants were presented with Leviant's painting. They were asked to press a button each time they perceived a slowing down of the circular movements and to release the button when it appeared to speed up again. As they did this, their eye movements were recorded 500 times per second with a camera. A strong correlation was found between the intensity of the illusion and the frequency of the eye movements - the more frequent the microsaccades, the more intense the illusion wsa perceived to be. Martinez-Conde says that this is a likely explanation for other illusions, such as that in Riley's *Fall*.

Exactly how the brain generates microsaccades is, however, still unclear, as is whether or not they are generated at random. How these movements are linked to the brain mechanisms underlying the illusions, and why they do not produce similar illusions when we view other patterns such as straight gratings or checkerboards, is also poorly understood. What is clear though, is that while these eye movements are essential for the maintenance of proper vision, they are also at least partly responsible for producing perceptions that are inconsistent with the image being viewed.

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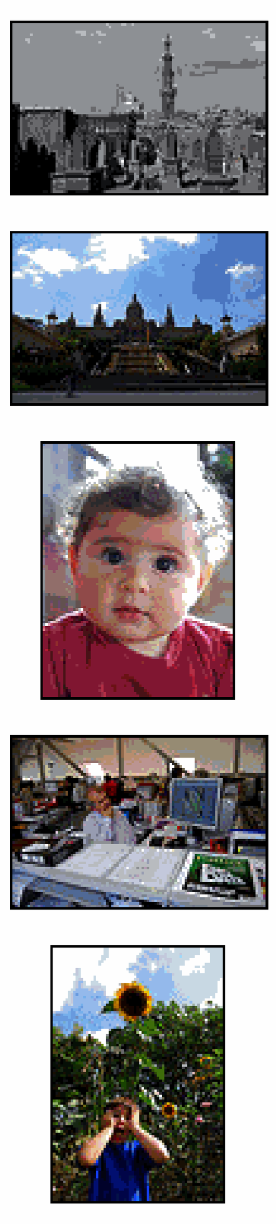

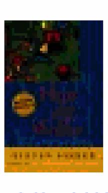

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