Quick guide

Binocular rivalry

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What is binocular rivalry? In humans and animals with forward facing eyes, the two eyes provide views of the world that are only subtly different from one another. In each eye, the lens focuses light into a two-dimensional image on the retina. In normal vision, the disparity between the retinal images provides a stereoscopic cue to the third spatial dimension, depth. But when the eyes are presented with a pair of images that cannot be fused into a coherent percept, binocular co-operation gives way to competition. Perception then alternates between the two eyes' images as they rival for perceptual dominance (Figure 1).

How can I experience binocular rivalry for myself? All you need to experience binocular rivalry is two eyes and a rolled up piece of paper. Place your hand about 25 cm in front of one eye, far enough that it does not appear blurry, and use the rolled up paper as a viewing tube to look through with the other eye. Angle the viewing tube such that it points slightly behind the hand that the other eye is viewing. You should now be able to see what is at the far end of the viewing tube through a hole in your hand! This is because disparate images from the two eyes are rivaling for perceptual dominance. Typically, the view through the tube tends to dominate and the corresponding part of the image of your hand is suppressed, hence the hole. With a little care, however, you should be able to experience rivalry alternations in which the hole disappears and reappears over time. High-contrast images in sharp focus tend to dominate over low-contrast, blurry ones, so it helps to aim the viewing tube at an untextured region of wall or carpet. Moving the hand you are viewing backwards and forwards slightly can also help to bring the whole hand into perceptual dominance and suppress the view through the tube. Once rivalry has begun, alternations should continue to occur spontaneously every few seconds.

What can binocular rivalry tell us about how vision works? In almost every action we rely on our perceptual processing of sensory input providing a faithful representation of the visual environment. In normal vision, the extent to which we all see the world similarly depends largely on similarities in the incoming sensory information: the environment determines the sensory input and this in turn constrains perception. During binocular rivalry, however, the close coupling between sensory input and perceptual interpretation breaks down: while the visual stimulus remains constant, perception alternates between two very different interpretations of the sensory input. When different observers view the same binocular rivalry stimulus, the alternations they experience occur independently of one another. This dissociation between sensation and perception means that when a subject monitors their percept during binocular rivalry they are offering us a glimpse into the otherwise private world of their subjective perceptual awareness.

Most researchers agree that binocular rivalry is a laboratory phenomenon that rarely if ever occurs in our normal visual environment. But its very existence is diagnostic of the mechanisms underlying normal visual perception. According to the prevalent Bayesian view, our perceptual systems are constantly evaluating their sensory input and selecting the interpretation of the pattern of sensory signals that is most probable on the basis of prior experience. We are normally completely unaware of the operation of the mechanisms mediating this selection. But during binocular rivalry we experience alternations in our perception that directly reflect the characteristic dynamics of the endogenous selection processes. Thus, the phenomenon of binocular rivalry affords an ingenious experimenter a means of investigating not only the content of subjective perceptual awareness dissociated from the sensory input, but also the mechanisms of selection between competing perceptual interpretations of the sensory input.

What is going on in our brains when we experience binocular rivalry? Because binocular rivalry offers a means of dissociating perceptual state from sensory input, it is of particular interest to neuroscientists concerned with identifying those brain processes that give rise to perceptual awareness. By simultaneous monitoring of neural activity and the observer's perceptual state, patterns of neural activity can be identified that correlate with endogenous perceptual alternations. Pioneering studies used monkeys trained to give a continuous manual report of their perception while the experimenters simultaneously recorded the activity of single neurons in visual cortex. The results of these studies indicate that the proportion of neurons showing activity correlated with the monkey's percept tends to increase as the cortical visual processing hierarchy is ascended. However, subsequent functional neuroimaging studies in humans have revealed neural activity

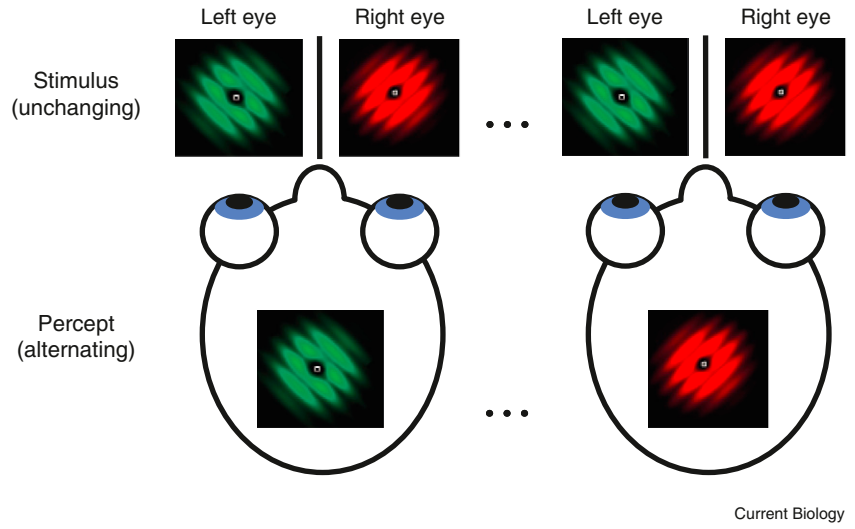

Figure 1. Schematic illustration of binocular rivalry.

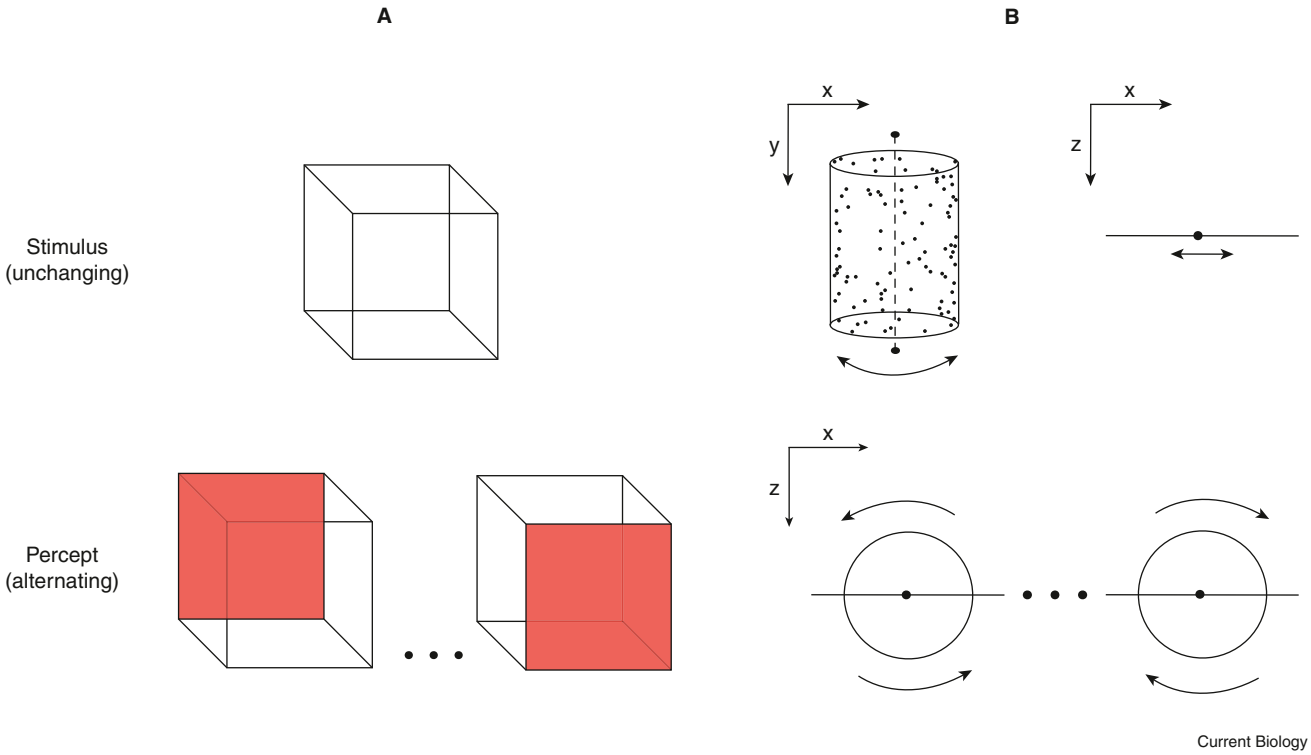

Figure 2. Other bistable visual phenomena: the Necker cube and ambiguous structure-from-motion.

Both of these stimuli afford three-dimensional interpretations that are bistable. (A) The Necker cube stimulus is a two-dimensional line drawing that is typically perceived as a cube in which the top-left and bottom-right faces are alternately experienced as foremost. (B) The stimulus for ambiguous structure-from-motion is a set of dots each performing simple harmonic motion in a fronto-parallel plane. The compelling percept is of a three-dimensional shape rotating in depth. The direction of this rotation is ambiguous, with the front surface of appearing to move either rightwards or leftwards and the back surface appearing to move in the opposite direction.

correlated with perception, not only in early visual cortex, but even in the sub-cortical lateral geniculate nucleus (LGN). The LGN relays signals separately from each eye to the cortex, so it is likely that activity correlated with perception reflects feedback of signals from visual cortex. The results of these and other studies paint a somewhat complex picture of the mechanisms underlying binocular rivalry. There can be little doubt, however, that binocular rivalry is not mediated at a single locus in the brain, but instead involves neuronal interactions at multiple levels of the visual processing hierarchy.

Does everyone experience binocular rivalry? Although there can be large inter-individual differences in dynamics, it seems that everyone with normal binocular vision can experience binocular rivalry. But the rate of rivalry alternation can depend strongly on an individual's mental state. Patients with clinical psychosis, for example, have been reported to exhibit abnormally slow rates of perceptual alternation during binocular rivalry. Experimentally, mental state can be manipulated by the administration of a psychoactive drug such as psilocybin, or by the use of experienced meditators as subjects. Psilocybin has been found to slow the rate of rivalry alternations and increase the preponderance of perceptual mixtures of the two stimuli, while some Tibetan monks have reported sustained perceptual dominance of a single stimulus during and after meditation, corresponding to an almost complete cessation of rivalry alternations.

Are there any related phenomena? Binocular rivalry is an example of bistable perception. Other such visual phenomena include the Necker cube and ambiguous structure-from-motion (Figure 2). In all cases, perceptual alternations between the two interpretations of the stimulus show similar characteristic dynamics, although the underlying neural mechanisms are likely somewhat different.

Where can I find out more?

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