Vision

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Ambiguous perception from bottom to top

Visual information is inherently ambiguous. For example, a circular disc rotated 45 degrees away in depth elicits the same retinal activation as an elliptical disc presented head-on. However, human minds have the remarkable capacity to resolve this ambiguity, leading to a stable and coherent perceptual world. One way in which this stability is achieved is through 'top-down' factors. Expectations, beliefs and goals bias perception toward one interpretation or another. These and other top-down factors have been explored using bistable stimuli, including the Necker cube, duck–rabbit and face–vase illusions and countless other demonstrations that populate perception textbooks. These stimuli are bistable, such that the same retinal image can spontaneously elicit two different perceptual experiences.

However, top-down factors are not the whole story. Low-level sensory properties such as stimulus contrast also guide perception in surprisingly powerful ways. The so-called aperture problem is a profound demonstration of the interplay between top-down and bottom-up properties. When a moving grating (periodic set of parallel lines) appears behind a small window (an 'aperture'), it is ambiguous as to which direction the lines are moving. Almost any oriented grating, moving in almost any direction at any speed, can elicit identical responses in motion-sensitive neurons, leading to perfectly ambiguous perceptual experiences. However, when two moving gratings are superimposed at right angles, the ambiguity disappears. Instead, the stimulus is perceived either as two separately moving gratings or as a single 'plaid' pattern moving coherently in a single direction.

In their 1982 article, Adelson and Movshon combined psychophysics and computational modelling techniques to investigate the contributions of low-level visual properties to this phenomenon. They systematically varied the relative contrast, speed and spatial frequency (density of the lines comprising the grating) of the two superimposed gratings.

Adelson and Movshon found that each of these low-level properties — which might seem largely irrelevant to determining motion — altered the likelihood of perceiving coherent motion. For example, the perception of coherent motion decreases as the relative contrast decreases, the relative speed increases, the angle between motion directions increases and the difference in spatial frequency between the two gratings increases.

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Adelson and Movshon's work underscores the importance of early feature-specific mechanisms in resolving perceptual ambiguity. When one sees a moving object, many features contribute to the determination of its motion direction. The perception of the world is of complete, unambiguous representations, which discounts the inferential nature of sensory experience. Visual perception is the final product of a chain of processing stages that combine low-level sensory inputs with higher-order components to arrive at a 'best guess' as to what one is looking at.

Adelson and Movshon's findings continue to influence research into how mechanisms across the visual hierarchy resolve perceptual ambiguity. Although ambiguous stimuli (such as superimposed gratings moving behind an aperture) and bistable stimuli (such as the Necker cube) are powerful tools for investigating differences in top-down processing, much of this work treats low-level stimulus differences as irrelevant. Adelson and Movshon flipped the script by highlighting the importance of low-level features and the early mechanisms that encode them. In this way, their work exemplifies the importance of low-level mechanisms in generating a coherent perceptual experience of the world.

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Competing interests
The author declares no competing interests.