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Motion and Color Cognition

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Synonyms

Achromatopsia; Color from motion; Dynamic color spreading; Neon color spreading

Definition

Motion and color cognition is a branch of cognitive neuroscience devoted to using brain imaging, psychophysical experiments, and computational modeling to understand the interactions between motion and color processing in the human visual system.

Overview

The relationships between the perceptions of color and visual motion are complex and intriguing. Evidence from patients with certain rare forms of damage to the cerebral cortex indicates that color and motion are to some extent processed separately within the visual system. This conclusion is buttressed by physiological evidence for separate neural pathways for the processing of color and motion and psychophysical evidence that the perception of motion in color displays is greatly reduced when the colors are isoluminant. However, experiments and demonstrations reveal that the perceptions of color and motion can interact. Motion can trigger the perception of color in achromatic stimuli and in uncolored regions of space. Color can determine the perceived direction of motion, and changes in color can trigger the perception of apparent motion. This article briefly reviews the evidence for separate processing of color and visual motion and for the ways they interact.

Evidence for Separate Processing of Color and Motion

Patients with the rare condition of *cerebral achromatopsia* cannot perceive colors, due to damage of cortex in the inferior temporal lobe of both cerebral hemispheres [1, 2]. Cerebral achromatopsia differs from the more common condition of color blindness, in which one or more of the normal three cone systems in the retinas are missing. A color-blind person missing the long-wavelength cone system, for instance, can still perceive many colors but has a range of color perceptions more limited than that of a normal trichromat, who has all three cone systems. Cerebral achromatopsics can have all three cones systems intact in their retinas but are still unable to perceive any colors because of damage to visual cortex. Yet many cerebral achromatopsics have no difficulty perceiving visual motion, indicating that the processing of color within the human visual system can be

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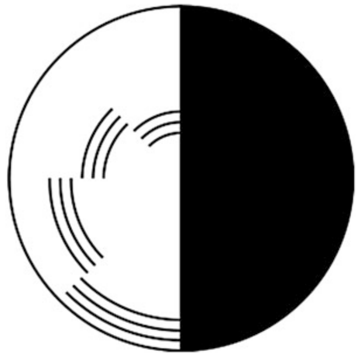

Fig. 1 Benham's top. Spinning this achromatic pattern leads to perceived colors

damaged without also damaging the processing of visual motion. (See also the Encyclopedia of Color Science and Technology entry on color naming and categorization in inherited color deficiencies and the entry on color perception and environmental impairments.)

Conversely, patients with the rare condition of *cerebral akinetopsia* cannot perceive motion, due to damage of cortex in the middle temporal area of both cerebral hemispheres [2, 3]. According to Josef Zihl and his colleagues, one such patient "...had difficulty, for example, in pouring tea or coffee into a cup because the fluid appeared to be frozen, like a glacier. In addition, she could not stop pouring at the right time since she was unable to perceive the movement in the cup (or a pot) when the fluid rose" [2, 4]. Yet this patient was able to perceive color, indicating that the processing of motion within the human visual system can be damaged without also damaging the processing of color.

Cerebral achromatopsia and cerebral akinetopsia indicate that color and motion are to some extent processed separately within the visual system. Further evidence for their separate processing comes from neuroanatomical and neurophysiological studies revealing that the visual system has a parvocellular pathway that processes color and detailed form information and a magnocellular pathway that processes motion, depth, and coarse form information [5]. These pathways are clearly segregated in the lateral geniculate nucleus of the thalamus, a relay station for visual information traveling from the eyes to visual cortex. One psychophysical correlate of this separate processing is the observation that perceived motion in color displays is greatly reduced when the displays are made isoluminant, an effect first discovered in 1911 by Pleikart Stumpf [6].

Evidence for Interactions in the Processing of Color and Motion

However, despite the anatomical, neuropsychological, and psychophysical evidence for the separate processing of motion and color, there are several intriguing visual phenomena which clearly demonstrate that the perception of motion and color can interact. An early example was discovered by the French monk Benedict Prevost in 1826, when he noticed that if he waved his hands in the dim light of the cloisters, then colors appeared near his moving fingers [7].

Charles Benham marketed a top in 1895 with a pattern similar to that shown in Fig. 1 [8]. Spinning the top leads to the perception of the colors of an artificial spectrum, again demonstrating an interaction between color and motion. (See also the Encyclopedia of Color Science and Technology entry on illusory colors.)

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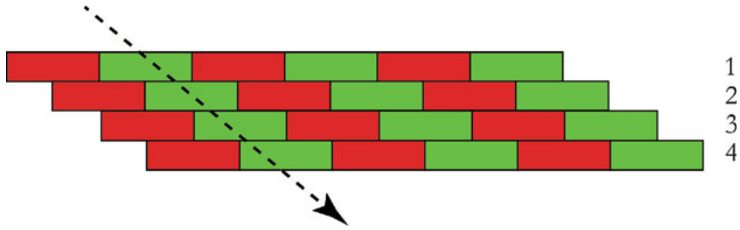

Fig. 2 Color and motion correspondence. This figure depicts four frames of a movie in which the colored blocks could, in principle, be perceived either as moving to the left or as moving to the right. Color information, even at isoluminance, biases us to see movement to the right

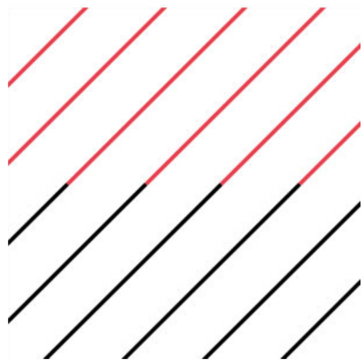

Fig. 3 Wallach's display. The *red neon* color spreading seen in the upper half of the *square* becomes more pronounced when the *lines* are moved *horizontally*, but appear to be moving *vertically*

Karen Dobkins and Tom Albright discovered in 1993 that color can influence the perceived direction of motion [2]. They showed subjects a movie in which a row of red and green blocks appeared to move horizontally. Four frames from such a movie are shown schematically in Fig. 2. From one frame to the next, the blocks moved exactly one half of a block width, so that the movie is compatible, in principle, with being seen as blocks moving to the left or to the right. However, if the brightness of the green blocks differs from that of the red blocks, then the visual system sees a direction of motion consistent with this, i.e., such that the brightness of each block does not appear to change as it moves. However, if all the blocks are equal in perceived brightness, the visual system sees a direction of motion consistent with the colors, i.e., such that the color of each block does not appear to change as it moves. Thus, color information by itself, apart from luminance information, can influence the perceived direction of motion. Similar evidence for the interaction of color and motion comes from experiments showing that color can affect the perceived direction of discrete apparent motion stimuli [9] and of sine-wave gratings [10, 11].

Conversely, V.S. Ramachandran discovered in 1987 that motion can "capture" color borders. If an illusory contour or a group of random dots are moved in the vicinity of a color border, then that border appears to move in the same direction as the illusory contour or random dots [12].

Hans Wallach in 1935 created a display similar to that shown in Fig. 3 [13]. As can be seen in the figure, the oblique lines are red in the upper half of the display and black in the lower half. The red color of the lines in the upper half appears to spread faintly through the white regions, a phenomenon known as neon color spreading.

Wallach then put the oblique lines in motion, translating them sideways underneath a rectangular window, indicated in Fig. 3 by a gray frame. This leads to a bistable perception of the motion of the

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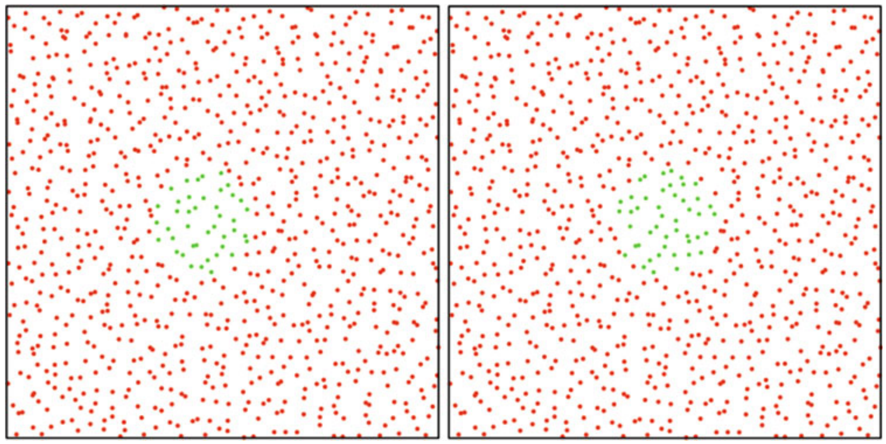

Fig. 4 Two frames from a movie display of dynamic color spreading. These frames can be stereo fused to get an impression of a glowing *green* disk hovering over a field of *red dots*

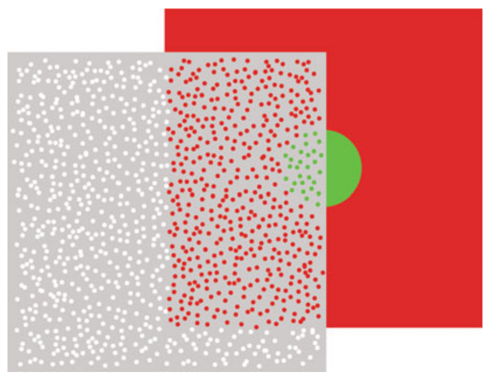

Fig. 5 Dynamic color spreading seen amodally. The *red dots* appear to be holes in a sheet of paper, and through the holes one sees a *green* disk moving over a *red* background

lines. Sometimes observers see them translating horizontally, as in fact they are. But sometimes, due to the ambiguities of motion seen through small apertures, observers see the lines translating vertically. In this latter case, observers report that the red neon color spreading is greatly enhanced. Thus motion can interact with color by enhancing neon color spreading.

A similar interaction between color and motion can be seen in displays of dynamic color spreading [2, 14]. Two frames from such a display are shown in Fig. 4. Each frame has a few hundred dots, which do not change position from frame to frame. Some of the dots are colored red and others, within a circular region, are colored green. The circular region in which dots are colored green moves slightly from frame to frame. This leads to the perception of a glowing green disk that moves over a field of static red dots. One can get feel for the perception of the glowing disk by using Fig. 4 as a stereo display, and cross fusing the two images. One sees a glowing green disk floating in front of the field of red dots.

Sometimes the green disk does not appear to float in front of a field of red dots. Instead, the red dots appear to be holes in a white sheet of paper, and through the holes one sees a solid green disk moving over a uniformly colored red background. This "amodal" perception of dynamic color spreading is illustrated in Fig. 5. One can get a feel for this amodal perception by again treating Fig. 4

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as a stereo display, but this time fusing the two images by diverging the eyes rather than crossing them.

Displays of dynamic color spreading demonstrate that apparent motion can trigger the creation of illusory objects and the spreading of color over the surfaces of such illusory objects. The surface color can have a neon quality if the object is seen floating in front of the dots or a paint quality if the object is seen amodally.

Summary

Evidence from neuropsychology, neurophysiology, and psychophysics indicates that color and motion are to some extent processed in separate pathways of the visual system, but that these visual pathways interact in a sophisticated fashion, and that together they can create the appearance of objects in motion with colored surfaces.

Cross-References

► Benham Disk
► Color Phenomenology
► Color Processing, Cortical
► Color Psychology
► Colors, Subjective

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