Encyclopedia of Color Science and Technology
DOI 10.1007/978-3-642-27851-8_65-2

Fechner's Colors and Behnam's Top

John H. Krantz*
Natural Sciences, Department of Psychology, Hanover College, Hanover, IN, USA

Synonyms

Behnam's disk; Fechner-Behnam subjective color; Illusory colors; Pattern-induced flicker colors; Subjective colors

Definitions

Fechner colors refer to the illusory colors that result from the repeated flashing of black and white patterns. These colors are often referred to as Fechner colors after their discoverer. *Behnam's top* is a pattern of spinning patterns developed for a spinning disk to create these illusory colors that have become a standard.

Basic Phenomenon and History

Fechner colors refer to the creation of illusory or subjective colors through an alternating pattern of black and white stimulus. Fechner reported the discovery of this illusion in an 1838 paper, and his name has been given to these illusory colors. The discovery was accidental as Fechner at the time was involved in the creation of disks to create different shades of gray [1]. From the beginning, a spinning disk was the means for creating these illusory colors. There were several studies throughout the nineteenth century of this phenomenon with spinning disks including studies by such a luminary as Helmholtz. Helmholtz even proposed one of the early explanations for these colors. Each of the early studies had used individually designed disks to create the illusory colors. In 1894, Behnam developed what has become the near-standard disk pattern of producing these illusory colors that he called the "artificial spectrum top" and has come to bear his name [2]. This disk is called usually either Behnam's top or Behnam's disk. Figure 1 shows some examples of a Behnam's top. Variations in the disk include having thicker single lines or thinner three parallel lines.

To generate these illusory colors, it is important that the flicker rate of the stimulus is not too slow or too fast. The flicker is noticeable and the stimulus is well short of the critical fusion frequency. The rate of alternation of the black and white areas is not terribly fast with effective stimuli frequencies going from 3 Hz on up with optimal rotational frequencies for the spinning disk of about 4–6 Hz [3, 4]. The direction of the spinning seems to affect the colors experienced [10].

*Email: krantzj@hanover.edu

DOI 10.1007/978-3-642-27851-8_65-2

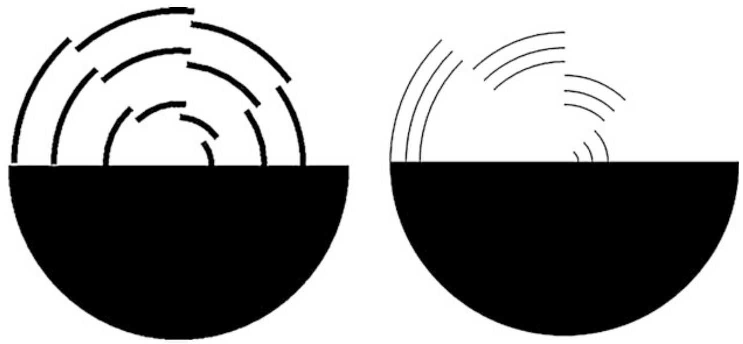

Fig. 1 Common versions of Behnam's top or disk

Creating and Measuring Fechner Colors

To create Fechner colors, the disk is usually spun in the frequencies reported above. Colors are experienced in bands located where the black lines will be flickering [5]. While Behnam's top represents a traditional means of creating the colors, researchers have developed many alternatives in trying to understand how these illusory colors occur [4, 7, 9, 10]. It is also not necessary that a spinning disk or top be used. A stationary flickering stimulus can be used [7] though there is some evidence that the colors are not as easily seen [9]. To see an online example that uses a flickering stimulus, the reader is referred to Krantz [8].

Measuring Behnam's top has been approached several ways over the years. The most common methods use some form of color matching to determine the color experienced by the participant. Schramme [10] used a color matching paradigm where a mirror was used to overlay the color patch onto the spinning disk. Then participants tried to match this patch to the illusory colors they were seeing. Rosenblum, Anderson, and Purple [9] used Munsell color chips to make the color matches which served them well as they were interested if the illusory colors show some of the features of color matching errors seen in dichromats. Jarvis [7] used a binocular matching method where the illusory colors were presented in one eye and the matching color was presented in another eye. In all of these methods, the attempt was to try to determine the color perceived by the observer.

Results from various studies over the years have revealed several interesting features of Fechner colors. First, the colors experienced are always desaturated, that is, somewhat washed out [7]. These colors can vary in their vibrancy in ways that depend upon the method of generation, but natural colors can much more easily be made to be highly saturated. Many reports indicate a wide range of individual differences in the colors experienced [6]. While most visual phenomena have some individual variation, there is a remarkable degree of agreement across observers. If there were not this agreement, then technologies such as color reproduction would not be feasible. This agreement is not seen in Fechner colors. Other researchers have observed that both illumination level and adaptation state alter the colors experienced, making the adaptation state of observers important to control in any experiment on Fechner colors [3, 4]. Perhaps one of the most interesting findings is that Fechner colors can be obtained with monochromatic, single-wavelength illumination as well as in full-spectrum neutral illumination [3].

Encyclopedia of Color Science and Technology
DOI 10.1007/978-3-642-27851-8_65-2

Explanations and Future Directions

There have been many different types of explanations offered for the existence of Fechner colors in the almost 200 years since its discovery [1]. The challenge for any theoretical explanation is twofold: how does a monochromatic or neutral color stimulation lead to the perception of colors and what is the role of the flickering rate? Another important factor to consider, often ignored in most theoretical attempts, is the individual differences in the colors reported by observers. Older explanations have involved fatigue in receptors, the role of complementary colors, and even factors related to Hering's original theory of color perception. Most of these explanations have been ruled out by directly examining fatigue, contrast, and limitations of the complementarity of the colors experienced [1]. As more information about cone functioning developed, explanations developed that used ideas about differences in the speed with which different wavelengths of light are processed [3] and information about the relative speed with which the blue or short-wavelength cone responding to flickering stimuli compared to the speed of the other cones responding to the same flickering stimuli have been developed. The hypothesis is that it is the relative slowness of the short-wavelength cone in responding to flickering stimuli that is responsible for Fechner colors. The idea is that with slowly flickering stimuli, the short wavelength cone responds too slowly to pick up the flicker adequately, while the middle- and long-wavelength cones, red and green cones, respectively, still can respond. Thus, these cones do not adequately cancel each other out in the blue-yellow color opponent channel leading to the perception of colors. Shramme [10] found, using color matches, Fechner colors that fell along the blue-yellow axis of the 1931 CIE diagram that matched these expectations. Despite the sophistication and intuitive plausibility of this explanation, it is still safe to say that there is no generally accepted explanation for these illusory colors. Campenhausen et al. [4] propose a two-step model for Fechner colors that involves both summing of cone inputs in a noncolor opponent pathway and lateral interactions at the level of the horizontal cells. The support for this hypothesis comes from many lines of evidence but includes that Fechner color in areas that do not receive modulated light and that achromatic effects similar to Fechner colors can be produced in rod vision. Shramme [10], whose results seemed to support the possibility that Fechner colors were due to the slowness of the short-wavelength cone, proposed that Fechner colors actually arise in the blue-yellow ganglion cells. The argument here depended upon the ability to manipulate the perceived Fechner color along the blue-yellow axis of the CIE diagram in a manner which would have been hard to predict from the action of the short-wavelength cone alone. Using these two explanations as examples, it can be seen that even the level of the visual system involved is not agreed upon, though all theories do seem to argue that Fechner colors arise in the retina.

While these explanations are intriguing, future developments will be needed to combine, modify, or seek a new direction of explanation for Fechner colors. One feature of the findings that is rarely explained and needs to be is individual variation in the colors experienced. The actual mechanism of the temporal response needs to be further uncovered as this finding increases the evidence for multiple ways that the eye responds to temporally moving or flickering stimuli. It is possible that it is in the variations in temporal response that the individual differences of Fechner colors lie.

Cross-References

► CIE Diagram
► Color Opponent Cells
► Color Phenomenology

DOI 10.1007/978-3-642-27851-8_65-2

- ► Cones
- ► Motion and Color Cognition
- ► Munsell Color System
- ► Psychological Color Space and Color Terms

References

1. Bagley, F.W.: An investigation of Fechner's colors. Am. J. Psychol. **13**(4), 488–525 (1902)
2. Behnam, C.E.: The artificial spectrum top. Nature **51**, 200 (1894)
3. Brown, J.L.: Flicker and intermittent stimulation. In: Graham, C.H. (ed.) Vision and Visual Perception, pp. 251–320. Wiley, New York (1965)
4. Campenhausen, C.V., Hostetter, K., Schramme, J., Tritsch, M.F.: Color induction vs non-opponent lateral interactions in the human retina. Vis. Res. **32**(5), 913–923 (1992)
5. Falk, D., Brill, D., Stork, D.: Seeing the Light. Harper & Row, New York (1986)
6. Gerjuoy, H., Clarke, F.R.: Fechner colors on television. Am. J. Psychol. **71**(3), 606–607 (1958)
7. Jarvis, J.R.: On Fechner-Benham subjective color. Vis. Res. **17**, 445–471 (1977)
8. Krantz, J. H.: Behnam's top and Fechner colors. http://psych.hanover.edu/krantz/BenhamTop/ (1999). Accessed 6 Jun 2012
9. Rosenblum, K., Anderson, M.L., Purple, R.L.: Normal and color defective perceptions of Fechner-Benham colors: implications for color vision theory. Vis. Res. **21**, 1483–1490 (1981)
10. Schramme, J.: Changes in pattern induced flicker colors are mediated by the blue-yellow opponent process. Vis. Res. **32**(11), 2129–2134 (1992)