Simultaneous color contrast

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27. Simultaneous Color Contrast

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Simultaneous color contrast is the condition whereby two surfaces with the same spectral composition are perceived to have a different color when they are placed against different backgrounds with different chromaticity (see Figure 1).

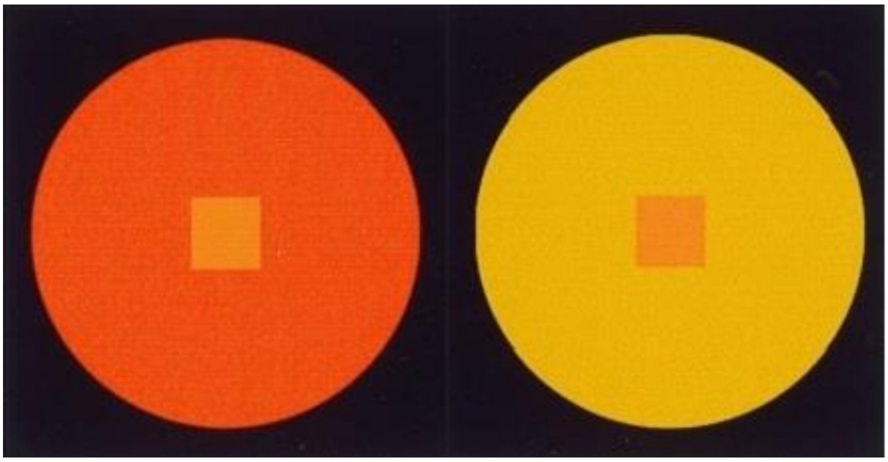

Figure 1. The spectral components of the squares in the centers of the red and yellow surrounds are identical. The appearance of the color is different, however. The two squares appear to acquire the opposite spectral component of their surrounds.

The term 'simultaneous' was introduced by Chevreul to "distinguish this phenomenon to the 'successive' contrast, where two colors appear in succession upon the same retinal area" [1, p. 264].

The term 'contrast' indicates that the perceived color of the surfaces is 'contrasted' by the color of the surround. As this term is also used in the literature to specify the relative intensity of the stimulation, some authors prefer the term "induction" over contrast.

When the squares and the backgrounds are achromatic, this phenomenon is named Simultaneous Brightness (or Lightness) Contrast (see Figure 2).

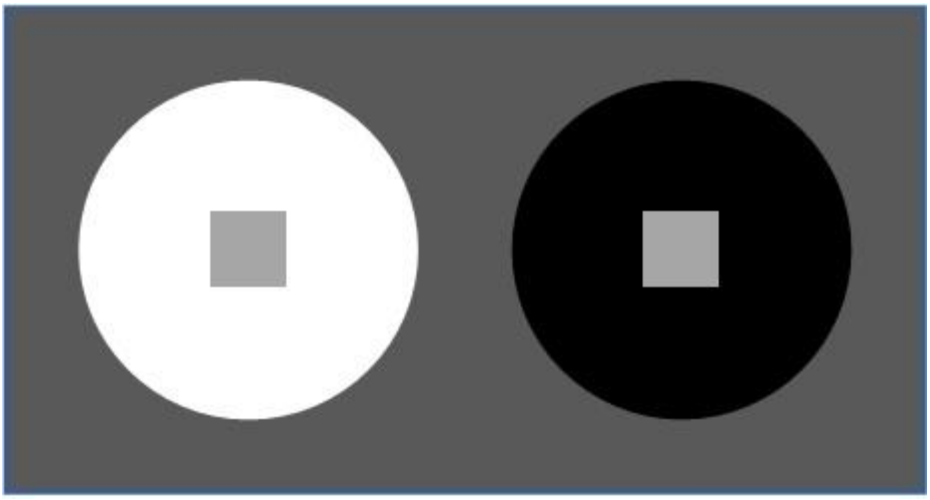

Figure 2. The grey squares in the centers of the white and black surrounds are the same. The appearance is different, however: the square to the left appears darker than the square to the right.

This is one of the most studied phenomena in visual perception and has been the focus of centuries of debate that has interested scientists and philosophers since Aristotle's time [2]. In the 19th century controversy raged between Hering [3], who supported an explanation based on retinal neuron interaction processes, and Helmholtz [1], who was in favor of an explanation based on higher level processes, involving assumptions about the configuration as a whole.

The retinal-based interpretation (also referred to as the 'low-level' interpretation) was particularly in vogue during the 1960s mainly because of the physiological discovery of the lateral inhibition process in the limulus retina [4]. To explain the contrast phenomenon the retinal-based interpretation focuses on the notion that the receptors that are stimulated by the background then send inhibition to the receptors that are stimulated by the surrounded area. According to this view, the simultaneous color contrast shown in Figure 1 occurs because the receptors stimulated by the red background inhibit the red sensitive receptors stimulated by the orange square, leading to a yellowish appearance. Conversely, the receptors stimulated by the yellow background inhibit the yellow sensitive receptors stimulated by the orange square, leading to a reddish appearance.

A similar explanation is provided for the contrast phenomenon seen in Figure 2. The receptors stimulated by the light background send inhibition to the receptors stimulated by the patch that the background surrounds, causing perceptual darkening. On the other hand, the receptors stimulated by the dark background send little inhibition to nearby receptors and, therefore, there is no darkening effect [5].

During the last few decades, however, the balance has been shifted towards more high-levels theories. This is because a series of phenomena have been presented that are difficult to explain on the basis of retinal interactions. One of the best-known demonstrations is the Benary cross (see Figure 3), discovered by Max Wertheimer and studied further by Benary [6].

Figure 3. The Benary cross. The two grey triangles are the same. Although they are surrounded by the same amount of white and black area the left triangle appears lighter than the right triangle.

Although both grey triangles are surrounded by the same amount of black and white, the left triangle appears lighter than the right triangle. Even more interesting is the contrast phenomenon found by Agostini and Galmonte [7]. In this case, a grey region surrounded by a dark area appears darker than an identical grey region surrounded by a light area (see Figure 4).

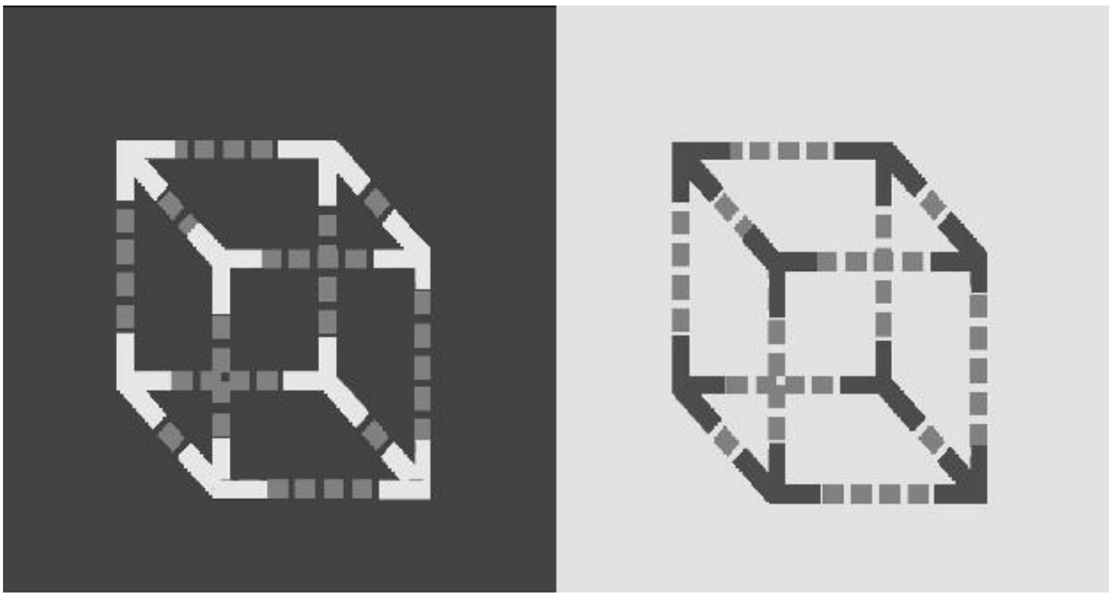

Figure 4. The dashed elements of the cubes are the same grey but those to the left appear darker than those to the right despite of the fact that they are surrounded by a darker area.

The interested reader can find more of these effects elsewhere [8-12]. As these examples are difficult to be explained on the basis of retinal interactions, they have been interpreted according to the principles of perceptual organization [13,14]; that is, the perceived color of a surface is determined primarily by the global contrast between the surface and the color of the surfaces to which it perceptually belongs (where perceptual belongingness refers to the grouping of a set of apparent elements into a perceived whole).

The low-level explanation has not, however, been completely abandoned as some contrast phenomena seem to involve retinal interactions such as those that generated by gradual luminance transitions (for example, [15-18]). Figure 5 shows a paradoxical contrast effect generated by luminance transitions. The luminance surrounding the two little squares to the left side is the same, but the top square looks darker. Similarly, the luminance surrounding the two little squares to the right side of figure 5 is the same, but the top one looks lighter. Authors named this phenomenon the "phantom illusion" [19] because it is generated by imperceptible luminance gradients, which profile is represented next to each display.

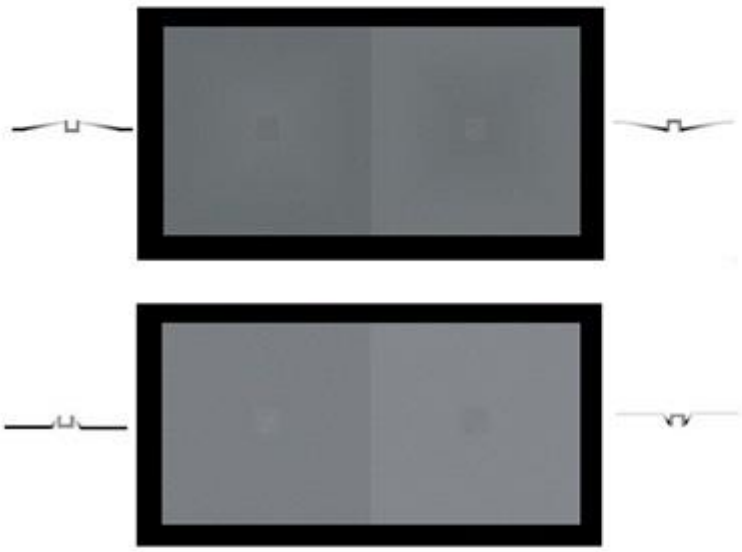

Fig. 5. The phantom illusion. Wide unnoticeable luminance transitions generate contrast effects on the surrounded targets (top). Narrow unnoticeable luminance transitions generate assimilation (bottom).

Besides the debate between low- and high-level supporters, a vivid debate exist amongst scientists asserting that the retinal image is decomposed by high level mechanisms. This is the debate between the *framework* and the *layer* types of decomposition models.

The framework model maintains that the visual system, in agreement with the belongingness principles, processes the light reflected by surfaces that reaches the eyes by grouping it into a set of contiguous frameworks. According to this model, contrast effects are generated by the geometric and photometric relationships among the surfaces within the same perceptual group, i.e. within the same framework [14, 20].

Conversely, the *layer* model claims that the visual system operates by splitting the light reaching the eyes into separate overlapping layers which correspond to separate physical contributions (illumination, reflectance, transparency, etc.). According to this model, contrast effects are generated when the light reaching the eyes is misattributed to the surface color and illumination. In other words, part of the light that the visual system should attribute to the surface color is instead attributed to the illumination or vice-versa [21-28].

To disentangle these two models Soranzo, Lugrin and Wilson [29] studied the contrast phenomenon in the Virtual Reality Cave. This apparatus permitted the manipulation of the geometrical relationships between the surfaces while maintaining the same photometric relationships (i.e. the amount of light reaching the observers' eyes remained constant). However, findings indicated that both of the decomposition processes which the framework and the layer models advocate are *jointly* accountable for the color contrast phenomenon. The color contrast phenomenon may therefore be attributed to the summative effect of the framework and the layer processes.

Cross References

Anchoring Theory of Lightness
Aristotele
Chevreul, Michel-Eugène
Color Contrast
Perceptual Grouping, and Color

References

1. Helmholtz H. V. (1866/1964). *Helmholtz's treatise on physiological optics*. New York: Optical Society of America

2. Wade, N. J. (1996). Descriptions of visual phenomena from Aristotle to Wheatstone *Perception, 25,* 1137-1175.

3. Hering E. (1874/1964). *Outlines of a Theory of the Light Sense. (*translated by L. M. Hurvich), D. Jameson. Cambridge, MA: Harvard University Press.

4. Hartline H. K., Wagner, H. G. & Ratliff, F. (1956). Inhibition in the eye of Limulus. *Journal of General Physiology, 39*, 651-673.

5. Cornsweet, T. N. (1970). *Visual Perception*. New York: Academic Press.

6. Benary, W. (1924). Beobachtungen zu einem Experiment uber Helligkeitskontrast. *Psychologische Forschung, 5,* 131-142.

7. Agostini, T. & Galmonte, A. (2002). Perceptual organization overcomes the effects of local surround in determining simultaneous lightness contrast. *Psychological science, 13***,** 88-92.

8. White, M. (1979). A new effect of pattern on perceived lightness. *Perception, 8*(4), 413-416.

9. Knill, D. C. & Kersten, D. (1991). Apparent surface curvature affects lightness perception. *Nature, 351,* 228–230.

10. Adelson, E. H. (1993). Perceptual organization and the judgment of brightness. *Science, 262*, 2042–2044.

11. Agostini, T. & Proffit, D. R. (1993). Perceptual organization evokes simultaneous lightness contrast. *Perception, 22*(3), 263-272.

12. Lotto, R.B. & Purves, D. (1999). The effects of color on brightness. *Nature Neuroscience*, *2* (1), 1010-1014.

13. Wertheimer, M. (1923). Untersuchungen zur lehre von der Gestalt. *Psychologische Forshung, 4,* 301-350.

14. Gilchrist A., Kossyfidis C., Bonato F., Agostini T., Cataliotti J., Li X., Spehar B., Annan V., Economou E. (1999). An anchoring theory of lightness perception. *Psychological Review, 106*, 795-834.

15 Kingdom, F., & Moulden, B. (1992). A multi-channel approach to brightness coding. *Vision Research, 32*, 1565–1582.

16. Blakeslee, B, & McCourt, M.E. (2004). A unified theory of brightness contrast and assimilation incorporating oriented multiscale spatial filtering and contrast normalization. *Vision Research, 44*, 2483–2503.

17. Todorovic´, D. (2006). Lightness, illumination, and gradients. *Spatial Vision*, *19*(2–4), 219–261.

18. Robinson, A. E., Hammonb P.S, & de Sa, V.R. (2007). Explaining brightness illusions using spatial filtering and local response normalization. *Vision Research*, *47*(12), 1631-1644.

19. Galmonte, A., Soranzo, A., Rudd, M. E., & Agostini, T. (2015). The phantom illusion. Vision research, 117, 49-58.

20. Gilchrist, A. (2006). *Seeing black and White*. Oxford Psychology series. Oxford University press.

21. Eagleman, D. M., Jacobson, J. E., & Sejnowski, T. J. (2004). Perceived luminance depends on temporal context. *Nature, 428*, 854–856.

22. Gilchrist, A. (1979). The perception of surface blacks and whites. *Scientific American, 24*(3), 88–97.

23. Gilchrist, A. L. (1988). Lightness contrast and failures of lightness constancy: A common explanation. *Perception & Psychophysics, 43*(5), 415–424.

24. Schirillo, J. (1999a). Surround articulation. I. Brightness judgments. *Journal of the Optical Society of America A, 16*, 793–803.

25. Soranzo, A. & Agostini, T. (2006). Does perceptual belongingness affect lightness constancy? *Perception*, *35*, 185–192.

26. Soranzo, A. & Agostini, T. (2006). Photometric, geometric and perceptual factors in Illumination-independent lightness constancy. *Perception and Psychophysics*, *68* (1), 102-113.

27. Soranzo, A., Galmonte A. & Agostini T. (2009). Lightness constancy: Ratio invariance and luminance profile. *Attention*, *Perception, & Psychophysics*, *71*(3), p. 463-470.

28. Soranzo, A., Galmonte A. & Agostini T. (2010). The luminance misattribution in lightness perception. *Psihologija*, *43* (1), 33-45.

29. Soranzo A., Lugrin J-L. & Wilson C. (2013). The effects of belongingness on the SLC phenomenon: a VR study. *Vision research*, *86*, 97–106.