Review of Psychology
2000, Vol. 7, No. 1-2, 3-7 UDC 159.9

Contrast and assimilation: the belongingness paradox

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Contrast and assimilation phenomena have a central role in the theories on the appearance of surface color. It is well known that principles of perceptual organization affect color perception. Paradoxically, the belongingness principle has been used to explain contrast as well as assimilation. In this paper, we try to solve this paradox by arguing that assimilation occurs earlier during the formation of perceptual groups, whereas contrast occurs after the formation of perceptual groups.

In the visual world, the perceptual features of an object are affected by the context in which that object is perceived. An increase in perceived similarities between the object and its surround is called an assimilation effect whereas an increase in perceived differences is referred to as a contrast effect.

In the psychological literature, two displays have become dominant exemplars of these phenomena in the domain of color perception. One is the so-called simultaneous contrast display, and the other is von Bezold assimilation display (1862). In the simultaneous contrast display, the gray square surrounded by the black background appears lighter than the gray square surrounded by the white one, even though their color is physically identical (see Figure 1).

On the other hand, in von Bezold assimilation display, the gray background containing the small black elements appears darker than the same gray background containing the small white elements (see Figure 2).

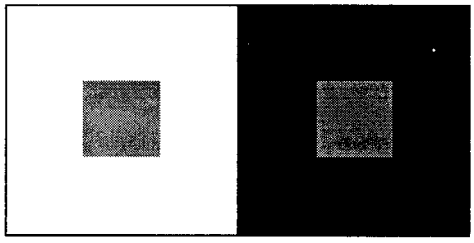

Figure 1. The gray square on the left appears darker than that on the right even though they have the same luminance.

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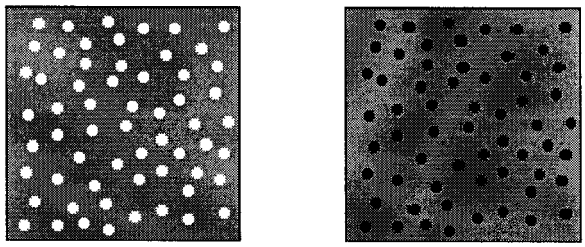

Figure 2. Even though the two backgrounds have the same luminance, the gray background on the right appears darker than the other.

Several theories of contrast have been developed in the domain of color perception. These accounts were principally focused on the classical simultaneous contrast display; for a review of the main theories of lightness contrast see Agostini & Proffitt (1993).

As concerns the assimilation phenomena, the research has been developed to delimit the factors that cause them. Several factors seem to cooperate in producing the effect. Von Bezold argued that such configural factors as shape, size, and position are responsible for assimilation phenomena. For example, in his display, assimilation can be reversed to a contrast simply by increasing the size of the black and white elements scattered on the backgrounds (see Figure 3).

Helson (1964) argued that assimilation is the result of a process that is opposite to that producing contrast. His hypothesis appealed to the physiological mechanisms of receptor summation and lateral inhibition. According to Helson, small differences in the intensity of stimulation in adjacent areas on the retina would summate, and thereby would produce assimilation, whereas large differences reaching some common synapses would give rise to an inhibi-

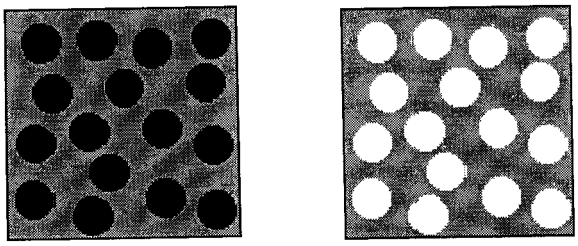

Figure 3. By increasing the size of the scattered elements of Fi- g- ure 2, the direction of the effect is inverted. The gray background on the left is perceived lighter than that on the right.

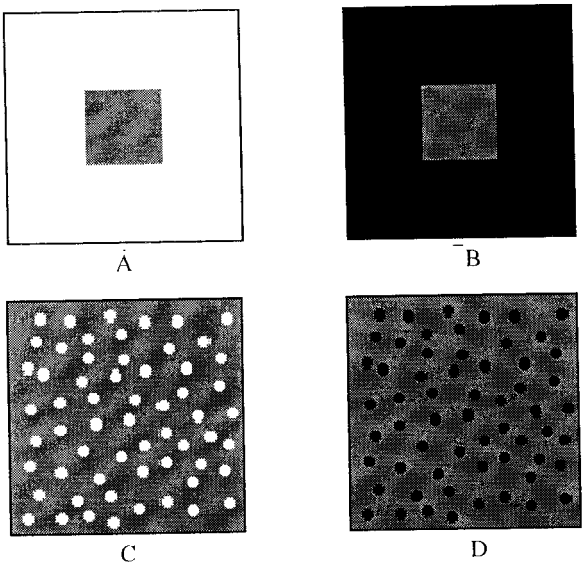

Figure 4. When the gray areas of the pair A-B are compared the gray on the left appears darker than the other (contrast effect), while the comparison between the gray areas of the pair C-D gives rise to assimilation, that is the gray background on the left is perceived lighter than that on the right. However, when all the four configurations are simultaneously present, the gray of A seems more similar to that of C and the gray of B to that of D.

tion effect which would produce contrast. He assumed that, within certain limits, area acts like luminance: increases in area have the same effect as increases in luminance. As the size of the inducing elements increase relative to the gray background, assimilation is replaced by contrast.

Kanizsa (1988) argued that, in the von Bezold assimilation display, the scattered elements are perceived as the texture of the large gray area, that is, there is no figure-background stratification but rather the display is seen as a textured surface. Contrast is observed when the elements start to be perceived as figures lying on a homogeneous gray background.

Kanizsa's paradox

Kanizsa (1980) showed that when the gray areas of the pair A-B (see Figure 4) are compared, a contrast effect is observed, while the comparison between the gray areas of the pair C-D gives rise to assimilation. However, when all the four configurations are simultaneously present, the gray of A seems more similar to that of C and the gray of B to that of D.

From these results, Kanizsa concluded that chromatic phenomena are extremely sensitive to structural changes of the context in which they are perceived. The paradox can be solved by assuming that the perceptual system "does not interpret" the relations of equality based on the formal logic but rather on those of perceptual organization.

Perceptual organization

One of the most studied problems in vision concerns the principles governing perceptual organization. Gestalt psychology studied perceived grouping and formulated the laws of proximity (see Figure 5a), similarity (see Figure 5b), good continuation, (see Figure 5c) common fate, closure, and prägnanz to explain the tendency of the visual system to aggregate discrete elements within larger wholes (Wertheimer, 1923; Koffka, 1935).

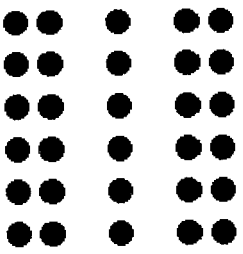

Figure 5a

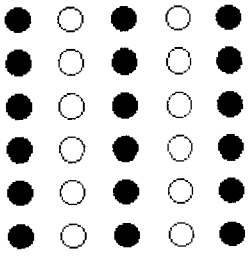

Figure 5b

Figure 5c

Figure 5. In these figures are depicted three principles of perceptual grouping: proximity (5a), similarity (5b), and good continuation (5c).

It has been shown how phenomenal objects organize themselves according to autonomous laws. At this point, the questions are: does perceived belongingness modify color appearance? Moreover, if there is any change of color appearance as a function of perceptual belongingness[1], in which dimension does it occur? In that of contrast or in that of assimilation? Benary (1924) and Fuchs (1923) tried to give an answer to these questions and, based on empirical observations, they reached different conclusions. In fact, Benary concluded that perceived belongingness produces contrast, while Fuchs maintained that it produces assimilation.

Benary started from a Wertheimer's observation (1923). In the Benary display, two identical middle gray triangles are arranged like in Figure 6. Although the gray triangle outside the cross, but belonging to the white background, is surrounded by more black than that inside the black triangle, its color appears darker. From these results, Benary concluded that perceptual belongingness produces contrast phenomena.

Following Benary's proposal that perceptual belongingness produces contrast, Agostini and Proffitt (1993) have shown that contrast can be evoked by perceived grouping in absence of edge proximity between induced and inducing regions. When belongingness was evoked by figural alignment (see Figure 7), the gray dot belonging to the black inducing dots was perceived lighter that the gray dot belonging to the white inducing dots.

On the other hand, Fuchs (1923) showed that when a chromatic disk can be organized with either one of two different groups, the color of the disk is assimilated to the color of the group to which it is intentionally organized.

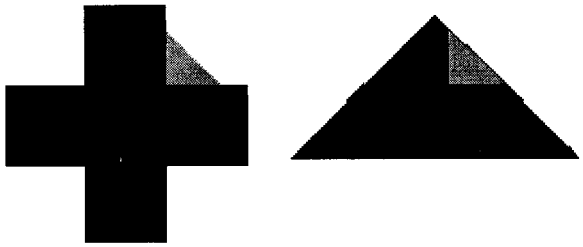

Figure 6. The gray triangle placed between the arms of the cross is perceived darker than the same gray triangle placed on the big triangle even though they border with the very same colors.

[1] A satisfactory definition of perceptual belongingness has never been offered. Agostini & Galmonte (1999) tried to operationalize the concept. If an element in the visual field is necessary to complete a perceptual unit than that element belongs to that unit. The features (color, size, orientation, etc.) of that element are affected by the features (color, size, orientation, etc.) of the unit to which it belongs.

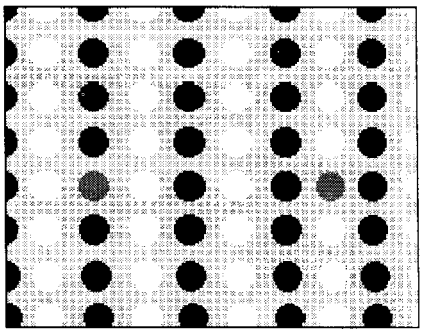

Figure 7. Two gray dots having the same luminance are perceived different if they are aligned with a black or a white column of dots: that one belonging to the black appears lighter than the other does.

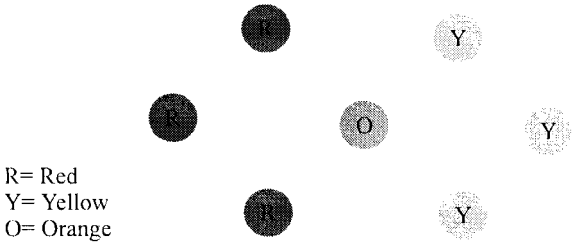

Figure 8. When the central orange disk is intentionally organized with the red elements, it appears more reddish than when it is intentionally organized with the yellow ones.

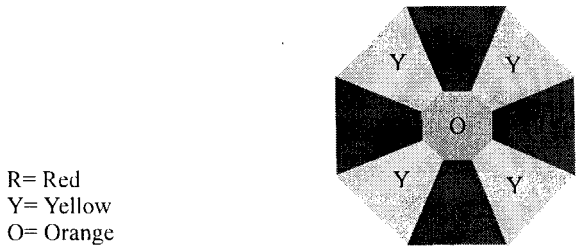

Figure 9. When the central orange octagon is intentionally organized with the red arms of a Maltese cross, it appears more reddish than when it is intentionally organized with the yellow ones.

Figure 8 depicts the Fuchs display. An orange disk was the common vertex of two diamonds. One diamond was composed of red disks and the other of yellow ones. The task of the participants was to organize the orange disk with each diamond. When the target was organized with the red diamond, it appeared more reddish than when it was intentionally organized with the yellow one. From these results, Fuchs concluded that belongingness produces chromatic assimilation.

Musatti (1953) proposed another example of intentional perceptual grouping and chromatic assimilation with adjacent surfaces (see Figure 9).

"Belongingness paradox"

On the basis of the previous experimental results, Agostini & Proffitt (1992) formulated what they called the "Belongingness paradox", which can be expressed in this way: When two elements belong to different perceptual groups, their colors are contrasted with the color of the group to which they belong; however, when an element is intentionally organized into one or the other of two groups, its color is assimilated to the color of the group to which it belongs.

In order to resolve this paradox, it is important to identify the similarities as well as the differences between Fuchs display and that of Agostini and Proffitt. The first similarity between these displays concerns the absence of proximity between the targets and the inducing elements. In both displays the very same background surrounds induced and inducing regions. Moreover, in both displays the effect (contrast or assimilation) occurs for elements that are always part of the figure. In the Agostini and Proffitt display (see Figure 7), each one of the two gray disks is an element of a black or white column. In Fuchs display (see Figure 8), the orange disk can be either one element of the red diamond or one element of the yellow one. On the contrary, in the classical displays the effect (contrast or assimilation) is always the results of an interaction between figure and background: either the two gray targets are contrasted by the color of the backgrounds (see Figure 1) or the backgrounds are assimilated to the color of the scattered elements (see Figure 2).

Although there are similarities, there are also some important differences. These differences can be responsible for the diverging results. The first difference concerns the *group belongingness status* of the target in each type of display. In Fuchs display, the central dot can be grouped together with the other dots in at least three different ways. It can be grouped together with all the other dots according to principles of perceptual organization like symmetry, shape similarity, and size similarity. It can be grouped together with only the yellow dots, or with only the red dots. The last two groupings are possible because the central dot has a chromaticity that is half way from that of the red and that of the yellow elements and it is the common vertex of two symmetrical configurations. For these reasons, the group belongingness status of the orange dot is ambiguous. In Agostini and Proffitt display, there is no such ambiguity, because there are always two gray dots, and each is perceived to belong to only one group. The second difference derives from the previous one and concerns the task of the participants (intentional *vs.* perceptual organization). In Fuchs' experiments, the participants were asked to *intentionally organize* the orange target with either the red diamond or the yellow one and then to report in which one of the two conditions the orange target appeared more reddish. In Agostini and Proffitt's experiments, the participants were asked to compare the color of the two gray target that were *perceptually organized* (according to Gestalt's laws of perceptual organization) into one or the other of two different groups.

The group belongingness status of the target and the task performed by the participants can have crucial influence on whether contrast or assimilation will occur in a specific display. When the group belongingness status of the target is ambiguous like in Fuchs display, the participants must necessarily be instructed to intentionally organize the target with either one or the other of the two groups. On the other hand, in Agostini and Proffitt display, the elements forming these groups are organized by symmetry and shape/size similarity and each one of the two gray targets belongs to a different group; therefore, their group belongingness status is unambiguous.

In general, it seems that when intentional organization is required in order to form a group that does not spontaneously exist, the visual system reduces the perceived differences between the visual features of the ambiguous element and the corresponding features of the group to which it is intentionally organized. Assimilation serves the function of strengthening the intentionally formed group. On the contrary, when the groups are formed according to principles of perceptual organization, the visual system increases the perceived differences between the visual features of the unambiguous element and the corresponding features of the group to which it is perceptually organized. Contrast serves the function of exaggerating differences between the elements in a well-organized group.

In everyday experience, it is essential for us to notice how things are similar as well as how they are different. Assimilation serves the first of these functions, whereas contrast serves the latter. What might seem paradoxical at first can be resolved by assuming that assimilation and contrast are produced at different stages of perceptual processing. Assimilation occurs earlier during the formation of perceptual groups whereas contrast occurs after the formation of perceptual groups.

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Received May 2000
Accepted October 2000