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Perceptual belongingness determines the direction of lightness induction depending on grouping stability and intentionality

Mauro Murgia [a], Valter Prpic [a], Ilaria Santoro [a], Fabrizio Sors [a], Tiziano Agostini [a], Alessandra Galmonte [b,*]

[a] Department of Life Sciences, University of Trieste, Italy
[b] Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Italy

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ABSTRACT

Contrast and assimilation are two opposite perceptual phenomena deriving from the relationships among perceptual elements in a visual field. In contrast, perceptual differences are enhanced; while, in assimilation, they are decreased. Indeed, if contrast or assimilation occurs depends on various factors. Interestingly, Gestalt scientists explained both phenomena as the result of perceptual belongingness, giving rise to an intriguing paradox. Benary suggested that belongingness determines contrast; conversely, Fuchs suggested that it determines assimilation. This paradox can be related both to the grouping stability (stable/multi-stable) and to the grouping intentionality (intentional/non-intentional). In the present work we ran four experiments to test whether the contrast/assimilation outcomes depend on the above-mentioned variables. We found that, intentionality and multi-stability elicit assimilation; while, non-intentionality and stability elicit contrast.

1. Introduction

In vision research, it is well established that the perceptual characteristics of an object are induced by the context in which that object is perceived. In particular, two different phenomena can be observed: The first one is called "contrast effect" and consists in an increase of the perceived differences between the object and its surround; the second one is called "assimilation effect" and consists in a decrease of their perceived differences.

Historically, in the lightness domain, the study of contrast and assimilation effects has followed two different approaches. On the one hand, the lightness contrast effect has been the core of several theories, mainly focused on the classical simultaneous lightness contrast display (for a review of the main theories of lightness contrast see Gilchrist, 2006; Gilchrist et al., 1999). On the other hand, the lightness assimilation effect has been studied by individuating the factors responsible for it (e.g., Beck, 1966; Burnham, 1953; Helson, 1963; Helson, 1964; Musatti, 1953; Soranzo, Galmonte, & Agostini, 2010; von Bezold, 1862), rather than searching for a general theory able to explain the effect.

Perceptual belongingness in the domain of lightness has been defined as follows: "A field part x is determined in its appearance by its 'appurtenance' to other field parts. The more x belongs to the field part y, the more will its whiteness be determined by the gradient xy, and the less it belongs to the part z, the less will its whiteness depend on the gradient xz." (Koffka, 1935, p.246). Belongingness (Gestaltzugehörigkeit) has been found to affect different colour phenomena like contrast, constancy, and assimilation (e.g., Agostini & Galmonte, 1999; Agostini & Galmonte, 2002; Agostini & Proffitt, 1993; Benary, 1924; Fuchs, 1923; Soranzo & Agostini, 2004; Soranzo & Agostini, 2006).

A "belongingness paradox" arises from the fact that, in the literature, different Gestalt scientists used the perceptual belongingness concept to explain both contrast and assimilation (Agostini & Galmonte, 2000).

1.1. Contrast effects explained by belongingness

Benary (1924) first proposed that the perceptual belongingness produces lightness contrast (Fig. 1). The grey triangle target lying between the arms of the black cross appears darker than the physically identical grey triangle target placed inside the black triangle. However, the local induction on both targets should make appear them equal; in fact, in both targets the catheti border with a low reflectance area (black), and the hypotenuses border with a high reflectance area (white). According to Benary, this happens because of belongingness: the grey target superimposed to the black triangle stably and spontaneously belongs to it, and from it,

* Corresponding author at: Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Via Casorati 43, 37131 Verona, Italy.
E-mail address: alessandra.galmonte@univr.it (A. Galmonte).

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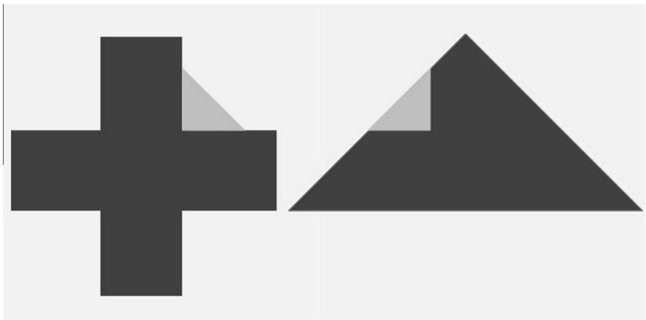

Fig. 1. Benary's display. The grey triangle on the left (belonging to the white background) appears darker than the one on the right (belonging to the black triangle), even if they have identical reflectance and they are surrounded by the same quantity of black and white area.

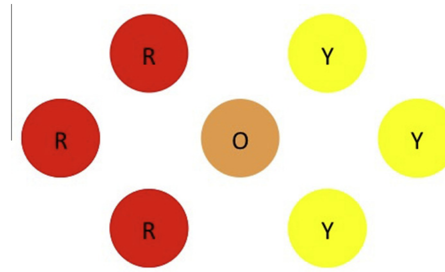

Fig. 2. Fuchs' display. When the orange disk (O) is intentionally grouped with (belongs to) the red disks (R) it appears as reddish, while when it is intentionally grouped with (belongs to) the yellow disks (Y), it appears as yellowish.

it is contrasted, so being perceived as lighter. On the other hand, the physically identical target placed between the arms of the black cross actually lies on the white background, to which it stably and spontaneously belongs and from which it is therefore contrasted, thus appearing as darker.

Agostini and Proffitt (1993) demonstrated how the lightness contrast can be evoked by perceived grouping, even in absence of edge proximity between induced and inducing regions. Authors demonstrated that the principle of belongingness, emerging by Gestalt laws of grouping, can be generalized to other situations and that the contrast effect takes place also without adjacency.

Successively, Agostini and Galmonte (2002) showed that, when higher-level and lower-level factors act contemporaneously, the contrast effect induced by the global organisation principle of perceptual belongingness overcomes the effect due to retinal lateral inhibition.

Bressan (2001) and Gilchrist and Annan (2002) reported two lightness contrast displays in which grouping factors make a grey target totally surrounded by black appear darker than an equal grey target surrounded by white, reversing the classical contrast effect. Agostini, Murgia, and Galmonte (2014) demonstrated that when the global grouping factors are removed, the Agostini & Galmonte effect (2002) is reversed. Conversely, in a number of variations of Bressan's and Gilchrist & Annan's displays, the elimination of the global grouping factors does not change the direction of the effect. These results indicate that the factors determining the Agostini & Galmonte effect are different from those acting on the other two configurations, in which the lightness change is due also to factors other than belongingness.

1.2. Assimilation effects explained by belongingness

Fuchs (1923) showed that when a chromatic disk can be organised with either one of two different groups, the colour of the disk is assimilated to the colour of the group to which it is forced to belong to. Indeed, in Fuchs' multi-stable display, when a central orange disk (O) is made to belong to a group of yellow disks (Y), it appears yellowish; while when it is intentionally made to belong to a group of red disks (R), it is perceived as reddish (Fig. 2). Fuchs first proposed that belongingness produces chromatic assimilation.

An assimilation configuration similar to the Fuchs' one has been created by Musatti (1953). Similarly to Fuchs' display, in Musatti's display a central orange octagon can be made to belong to either a group of yellow or red trapezia. As a result, it appears respectively as yellowish or as reddish.

To sum up, there are several examples in which belongingness seems to be responsible for opposite perceptual outcomes. Indeed, in some cases the perceptual result is a contrast effect (i.e., Benary); whereas in other cases the perceptual result is an assimilation effect (i.e., Fuchs), giving rise to the belongingness paradox.

1.3. The new approach

To account for the belongingness paradox, we will focus on the research of two eminent Gestalt psychologists, Fuchs and Benary. Let's try to identify the main differences between their displays.

A first difference that has to be noted concerns the grouping stability, that is, whether a visual element can belong to: (a) more than one group, one at a time, or (b) always one single group. In Fuchs display, the target can be grouped together with the other dots in at least two different ways, that is, with either the yellow dots or the red dots. For this reason, the target belongingness is multi-stable. On the other hand, in Benary's display, the target belongingness is stable, because there are always two grey targets, and each of them is perceived to be stably grouped with only one region. We define these two situations multi-stability (M) vs. stability (S) of grouping, respectively.

A second difference regards grouping intentionality, elicited by different task instructions. In Fuchs' experiment, the task instructions were to fixate the central disk and to alternatively see it grouped with the yellow/red disks intentionally forming a diamond and to report the colour of the central disk. Benary, instead, using a fixation point, asked to compare the lightness of the two target triangles and to report which of them was darker/lighter. In this case, task instructions did not require to intentionally group elements of the configuration. It must be noted that the task instructions used by Fuchs imply that observers had to focus their attention to concentrate upon one of the two possible figural solutions (Fuchs, 1923); while Benary's task instructions imply that observers had to distribute their attention (Benary, 1924). We define these two situations intentionality (I) vs. non-intentionality (N) of grouping, respectively.

Grouping stability and grouping intentionality are closely related. Indeed, in the Fuchs experiment to make the judgment participants had to intentionally allocate their attention focusing on a local part of the display to obtain a temporarily stable perceptual grouping; while, in the Benary experiment participants had to fixate the centre of the display to globally distribute their attention on the whole display, and, in this case, a non-intentional permanently stable perceptual grouping arises (i.e., according to the Gestalt laws of perceptual organisation).

How we have just seen, Fuchs and Benary configurations are very different in many aspects. To try to better understand which are the causes of the belongingness paradox, we built a set of Fuchs- and Benary-like displays that can be considered comparable in terms of chromaticity and spatial articulation (Agostini & Galmonte, 1999), manipulating both grouping stability and intentionality: (1) grouping intentionality: intentional (I) and non-intentional (N); (2) grouping stability: stable (S) and multi-stable (M).