Von Bezold assimilation effect reverses in stereoscopic conditions

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“Von Bezhold assimilation effect reverses in stroboscopic conditions

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Abstract

Lightness contrast and assimilation are opposite phenomenon: in the contrast grey targets appear darker when bordering bright surfaces (inducers) rather than dark ones; in the assimilation the opposite occurs. The question is: which is visual process favours the occurrence of one phenomenon over the other? According to the level of the visual process they refer to, researchers provided three answers to this question. The first asserts that both the phenomena are caused by peripheral processes; the second attributes their occurrence to central processes, and the third claims that contrast involves central processes whilst assimilation involves peripheral ones.

The present research was aimed at testing these hypotheses. An experiment on an IT system equipped with goggles for the stereo vision was run. Observers were asked to evaluate the lightness of a grey target, and two variables were systematically manipulated: i) Inducers' apparent distance; ii) Inducers' intensity. In all the conditions, the retinal stimulation was kept constant, so that peripheral processes were the same.

Results show that the lightness of the target depends on both the variables. As the retinal stimulation was kept constant, we conclude that central mechanisms are involved in both the phenomena.

Introduction

One of the most compelling features of visual perception is the relationship between lightness contrast and lightness assimilation. Lightness contrast is the condition whereby grey surfaces (targets) appear *darker* when bordering bright, rather than dark, surfaces (inducers); whereas in lightness assimilation, targets appear *lighter* when bordering bright, rather than dark, inducers.

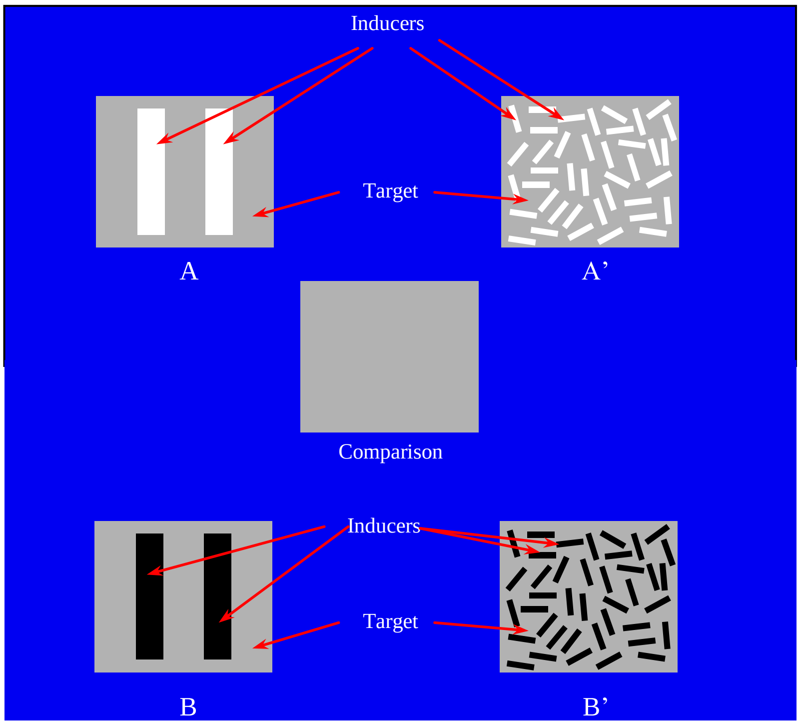

Figure 1. The five target squares share the same luminance; however, A and B’ appear darker rather than the comparison, whilst A’ and B appear lighter. The amount of the target area covered by the inducers is the same.

In figure 1, the grey targets in displays A and B look, respectively, darker and lighter rather than the grey square in the middle of the figure (comparison) in spite of the fact that all of them share the same luminance. On the contrary, in displays A’ and B’ the targets look, respectively, lighter and darker rather than the comparison. These latter displays can be referred as von Bezholt type of displays as they resemble the configuration ideated by von Bezholt in 1874. In these displays the amount of the target area covered by the inducers is the same as that one in displays A and B; nevertheless, the effect of the inducers on the target lightness is the opposite. It seems that reducing the inducers size and augmenting their number (i.e. increasing their spatial frequency) produces a shift from contrast to assimilation. Hence, from a *physical* perspective, this shift is generated by the manipulation of the inducers’ spatial frequency. However, the question is: what factor, from a *psychological* perspective, causes the occurrence of one phenomenon over the other?

Researchers have provided three different answers to this question in accordance to the level of the visual process they refer to.

One proposal is that the shift from contrast to assimilation is caused by a bottom-up, peripheral, mechanism of visual processing. According to this view, assimilation effects are based on local averaging of luminance within large neurons' receptive fields. Specifically, it has been proposed that a neuronal spatial integration (Helson, 1964; DeValois & DeValois, 1975; Hurvich & Jameson, 1966; 1974; Jameson & Hurvich, 1975) or weighted averages across distance (Reid & Shapley, 1988) occurs within receptive field centres.

The second interpretation suggests that this shift is generated by more central mechanisms of visual processing, such as figure/ground segmentation (Musatti, 1931; 1953; Festinger, Coren & Rivers, 1970; de Weert and Van Kruysbergen 1997) and observer expertise (Kanizsa, 1979).

For example, to explain the lightness difference between the targets in displays A and A' on one side, and the difference between displays B and B', on the other side, peripheral explanations suggest that the inducers in A' and B' are so small that the receptive field of each retinal neuron includes part of the target and part of one inducer simultaneously. As the neuron activity depends on the local average between the luminance of the target and the luminance of one inducer, the net result is an assimilation effect. This is not happening in displays A and B because in these conditions there are some neurons which receptive field includes one inducer only, or part of one inducer, whilst others' receptive fields includes the grey target only. In this case, those neurons stimulated by one inducer inhibit those stimulated by the target, resulting in a contrast effect.

Central mechanisms advocates, on the other hand, underline that figure/ground segregation is stronger in displays A and B rather than in A' and B'. Because of this, whilst in displays A and B white or black figures, on a grey background, are perceived, in A' and B' a single, mosaic like, figure is seen. As there is only one perceptual unit in the latter, the target lightness tends to homogenise with that one of the inducers, leading to an assimilation effect; whilst in the former the lightness of the two different perceptual units tend to contrast, leading to a contrast effect.

Finally, the third position, sustained by Gilchrist et al. (1999) attributes the two phenomena to different levels of the visual process. Authors attribute the contrast phenomenon to central processes, such as perceptual belongingness; and assimilation to more peripheral processes. ("[…] von Bezold effect may involve a relatively low-level kind of space averaged luminance" (Gilchrist et al. 1999; page 802).

Although these different points of view, there are evidences in literature that central processes are involved in the assimilation phenomenon. De Weert and van Kruysbergen (1987) found that the strength of assimilation reduces when spatial noise is added to an assimilation-eliciting display (i.e. to a display in which the inducers spatial frequency is high). However, this happens only when the spatial noise is perceived to be coplanar with the rest of the display; when instead the spatial noise appears to be non-coplanar, assimilation persists. Authors noticed that the retinal stimulation in the two conditions (spatial noise coplanar vs. non-coplanar) was practically the same; this persuaded them to conclude that central mechanisms are involved in assimilation.

Besides these experimental evidences, de Weert and van Kruysbergen reported also an observation that inspired our own research. By means of a stereo display to stratify the figure elements, authors observed that – after stratification - when some red and green disc-shaped-inducers are painted on a homogeneous white target, the latter appears reddish if the green inducers are perceived at a different plane, closer to the observer. Vice-versa, the same white target appears greenish when the red discs are those appearing closer to the observer (figure 2).

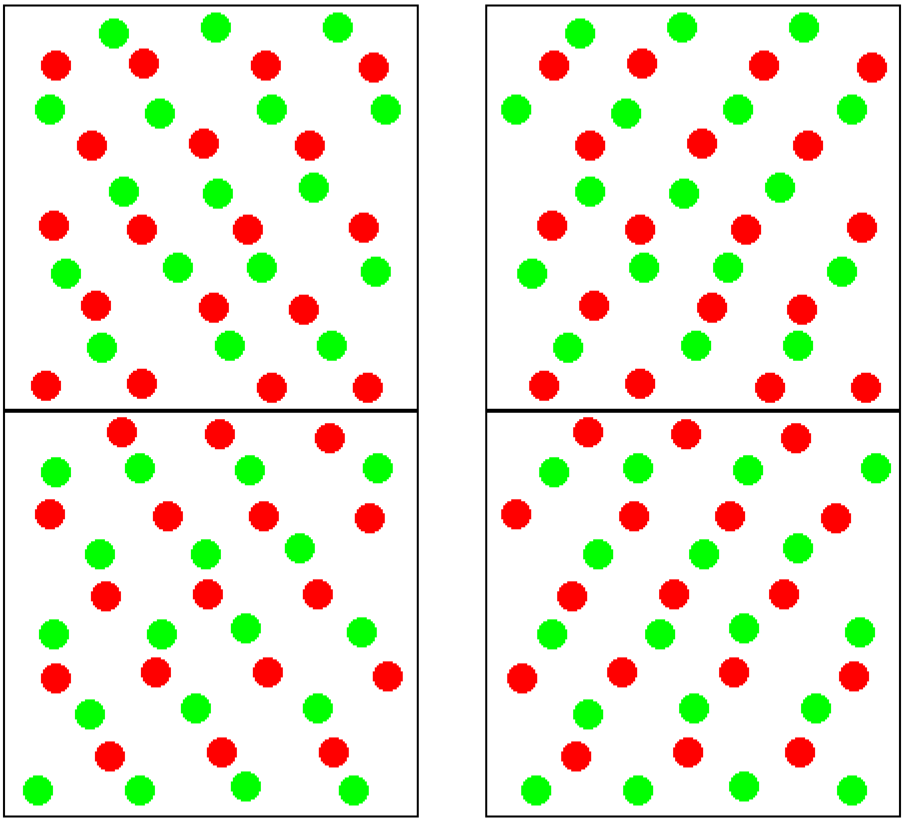

Figure 2: The display analyzed by de Weert and van Kruysbergen (1997). See text for explanation. Reprinted with permission.

Authors proposed that stratification between inducers and target may affect assimilation.

The aim of the present study is to further investigate this observation and to extend it in the achromatic domain with some important modifications. In authors' displays, both the green and red inducers where superposed to the target-background at the same time. Because of this, it may be argued that the greenish and reddish appearance of the white target could be caused by a contrast effect of the segregated discs instead of an assimilation effect of the coplanar ones. In other words, in those conditions it was not possible to attribute the reddish and greenish appearance of the white target to an assimilation effect of the apparent coplanar discs or to a contrast effect of the segregated ones. To control for this variable, we have measured separately the effects on the target lightness of inducers having different luminance.

Furthermore, de Weert and van Kruysbergen (1997) generated the apparent depth by means of two stereo figures. That is that the 3D appearance was obtained by flanking two figures that were identical in all aspects but some of the corresponding items were relatively shifted. When looking into the distance, past the page, after 20-30 seconds – because of the disparity between the corresponding items - the images fuse in one single 3D image. This method may not be appropriate for a psychophysics experiment because it cannot be controlled when and if the observers actually get the 3D impression. To control for this variable we have used an IT system equipped with goggles for stereo vision.

To sum up, the aim of this project was to further explore a phenomenon reported by de Weert and van Kruysbergen (1997) in which assimilation is affected by the apparent distance between inducers and target. To achieve this aim, we have measured the lightness of a target and we have systematically manipulated Inducers' apparent distance from the target and the Inducers' intensity.

Method

Observers

Ten volunteer observers participated in this experiment. All had normal or corrected-to-normal acuity and were naive with regard to the experimental design.

Stimuli

The stimuli were projected on a rear projection screen (204cm x 105cm). The stereo effect was generated by means of the OpenGL technology: two images (one for each eye) were drawn, and outputting those to two projectors (NEC model LT260). Polarising filters were used to prevent light from the projectors going into both eyes. Participants wore glasses having a vertical polarising filter for the left eye, and a horizontal polarising filter for the right one. By placing a vertical filter over the left projector and a horizontal filter over the right one, only one image was projected to each eye. The software depicted each image twice, once for the left eye and again for the right eye (see figure 3).

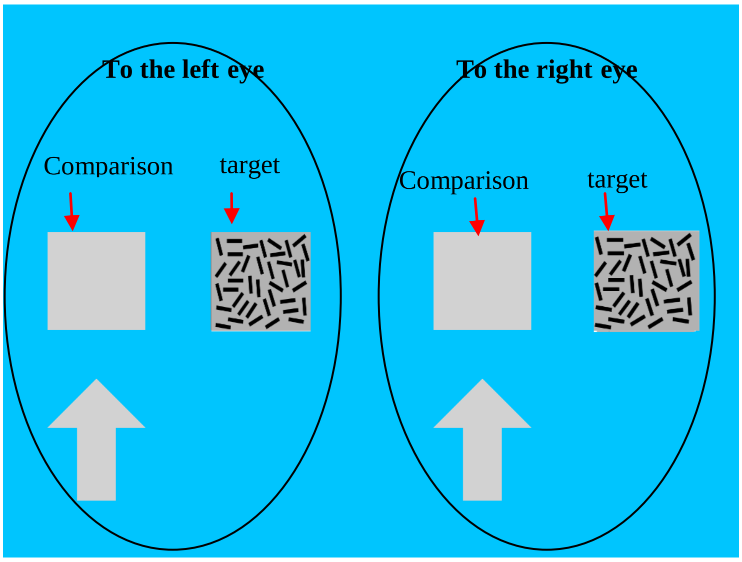

Figure 3: Example of the stimuli used in the experiment. Two images were drawn into the screen, one per each eye. The apparent distance between inducers and the target was able to be manipulated by varying the disparity between the corresponding items.

The displays were shaped as follows. The whole screen (subtending 53.67 x 35 deg of visual angle) was light-blue its luminance, measured from behind the goggles, was 20.4 cd/m^2. A grey square (10.2x10.2 deg of visual angle) served as a target; its luminance, measured from behind the goggles, was 18.2 cd/m^2.

On the top of the target, 40 small rectangles (0.2x0.95 deg) were drawn. Their luminance changed according to the level of the inducers' intensity variable. It was 72 cd/m^2 for the light level of the Inducers' intensity variable, and 4.6 cd/m^2 for the dark level (measured from behind the goggles). In this way, the absolute difference, in log units, between the target luminance and the luminance of the light inducers was the same as the difference between the target luminance and the luminance of the dark inducers. The rectangles serving as inducers were randomly oriented but their orientation was coherent through the displays. These conditions were shaped so to resemble a von Bezholt type of display.

By varying the disparity between the corresponding inducers in the two images, they could appear, in respect to the target, at three different distances, according to the level of the Distance between inducers and target variable. In the coplanar condition, there was no horizontal shift between the corresponding inducers (i.e. the two images projected to each eye were the same). In the Distance 1 condition, the corresponding inducers in the two images were shifted by 0.5 cm, whilst in the Distance 2 condition the corresponding inducers in the two images were shifted by 1 cm. Finally, there was a control condition in which the target did not have any inducers on it.

Another square having the same size as the target was presented on the screen; it did not have any inducers on it and served as a comparison patch. Its luminance was randomly assigned by the software at the beginning of each trial and it was adjustable by the participants through the provided joystick. To get a statistical control of the potential luminance non-homogeneity of the screen, the comparison patch could appear either 5 deg of visual angle on the left or 5 deg of visual angle on the right of the target. At the beginning of each trial, an arrow was presented for 2 seconds indicating which the comparison patch was.

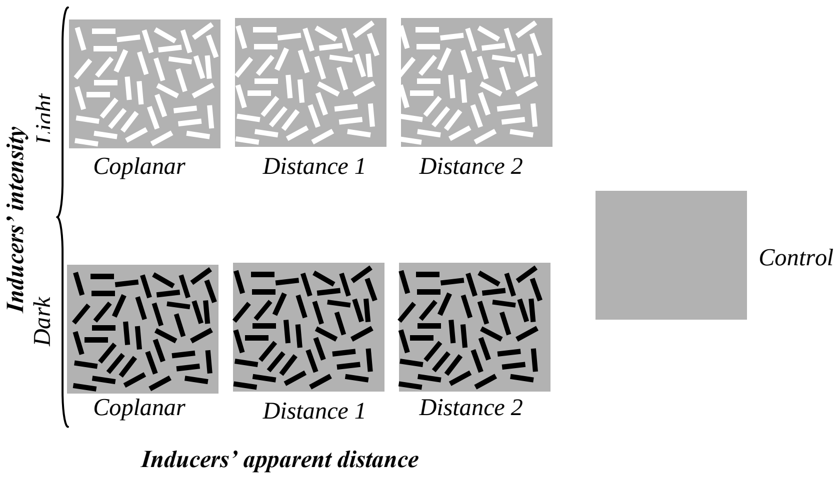

Figure 4. Experimental displays. They are arranged in two rows (according to the level of Inducers' intensity variable) and three columns (according to the level of the Distance between inducers and target variable). In addition, there was a control display in which the target patch did not have any inducers on it. To get a statistical control of the potential luminance non-homogeneity of the screen, the target could appear either on the left or on the right of the comparison patch.

To sum up, there were 6 experimental displays organized in two independent variables: 1) Inducers' intensity (Light and Dark) and 2) Inducers' apparent distance from the target (Coplanar, Distance 1 and Distance 2) plus a control condition (figure 4). These 7 displays were presented 4 times: in half of the trials the target was presented to the left of the comparison, whilst, in the other half, it was presented to the right. In total, observers did 28 adjustments.

Procedure

Observers seen the displays, presented in random order, in a darkened room from a distance of 150 centimetres from the screen. They wear goggles for the stereovision, and they were instructed to match the colour of the target patch to that one of the comparison patch by means of the provided joystick. To ensure that the observers actually get the 3D perception, prior of the beginning of the experiment, they were presented with some of the displays and were asked to describe what they were seeing. The experimented started only after they reported to get the 3D perception.

When each display appeared, an arrow was shown for 2 seconds indicating which the adjustable comparison patch was (this was done because in the control condition both the target and the comparison did not have any inducers, and were, therefore, undistinguishable). Participants adjusted the luminance of the comparison by means of the provided joystick. When observers reached a satisfactory match, they were instructed to press a button on the joystick; at that point, the target luminance was recorded and the next trial begun. The luminance of the comparison was set to a random value at the beginning of each trial. Observers performed four matches for each of the seven displays, so they provided twenty-eight adjustments. Each display was left on the screen as long as needed to produce the match. The whole session lasted about 40 minutes.

Results

A paired t-test revels that there was no difference between the two sides in which the comparison patch was presented in relation to the target. Another paired t-test revels that there was no difference between the control condition and 18.2 (the actual luminance of the target in cd/m^2). These results suggest both that participants were able to perform the task and that the luminance across the screen was sufficiently homogeneous.

Mean ratings for the successive statistical analysis were obtained by the following formula:

Transformed data = *Log [mean(Assigned luminance)/ target luminance]*

In this way, 0 was the baseline. In the Light level of the Inducers' intensity variable positive values indicate an assimilation effect, whilst negative values indicate a contrast effect. On the contrary, in the Dark level, of the same variable, positive values indicate a contrast effect, whilst negative values indicate an assimilation effect. The transformed observers' mean ratings for the experimental condition, together with the standard errors, are shown in figure 5.

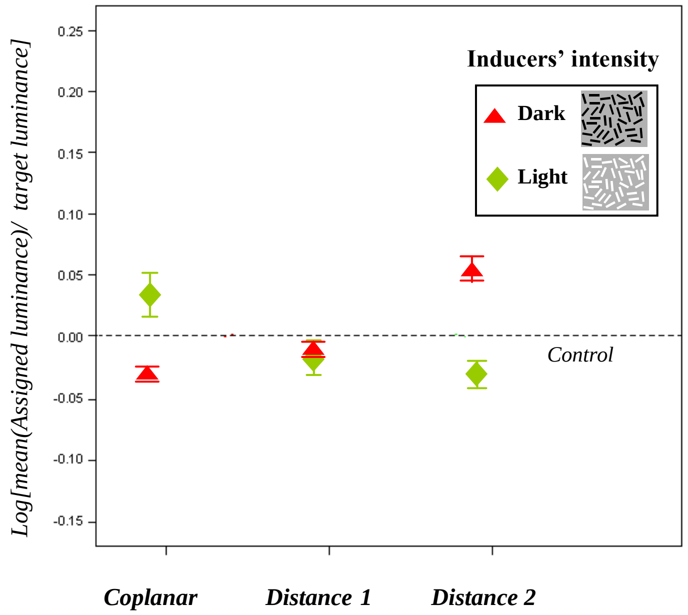

Figure 5. Results of the experiment. Mean ratings are obtained by the following formula *Log[mean(Assigned luminance)/ target luminance]*. The mean rating for the control condition is not reported, and it did not differ from 0. Bars indicate standard errors.

A two-way repeated measure ANOVA on the transformed data revealed a significant effect of the Inducers' apparent distance from the target variable [$F_{(2,9)}$= 5.11; p. < 0.05] and the Interaction between the two independent variables ($F_{(2,18)}$ = 12.96 p. < 0.05). The Inducers' intensity variable was non significant [$F_{(1,9)}$ = 1.74 p. = 0.21]. It has to be noted that by adopting this transformation, the contrast and assimilation effects of one level of the Inducers' intensity variable compensates those of the other level.

As can be seen from the graph, assimilation effects occur in the coplanar condition of the Inducers' apparent distance variable; that is, the target with light inducers appeared lighter rather than the control, whilst the target with dark inducers appeared darker rather than the control. In the Distance 1 condition of the Inducers' apparent distance variable, the target appeared darker rather than the control in both the levels of the Inducers' intensity variable. In the Distance 2 conditions of the

Inducers' apparent distance variable, contrast effects occurred in both the conditions of the Inducers intensity variable; i.e. the target with light inducers appeared darker rather than the control, whilst the target with dark inducers appeared lighter rather than the control.

DISCUSSION

The relationship between lightness contrast and lightness assimilation is one of the most interesting features of visual perception. According to the level of the visual process they refer to, researchers have provided three interpretations of this relationship. The first asserts that both the phenomena occur during the first stages of the visual process; the second attributes their occurrence to more central mechanisms, and the third claims that contrast involves central mechanisms whilst assimilation involves peripheral ones.

The present research was aimed at testing the hypothesis that central mechanisms are involved in both contrast and assimilation; and it was inspired by an observation reported by de Weert and van Kruysbergen (1997). By means of a stereo display, authors observed that when some red and green discs are painted on a white target, the latter appears greenish when the green discs are perceived at its same depth whilst the red discs stratify at a different depth plane. The same white target, however, appears reddish when the red discs appear coplanar with the target whilst the green discs are those who stratify (see again figure 2). Authors attributed this effect to assimilation between the discs and the background.

In this research, von Bezhold displays have been used as experimental stimuli and two independent variables have been systematically manipulated: Inducers' intensity and the Inducers' apparent distance from the target. These displays differ from those ideated by de Weert and van Kruysbergen (1997) in the following aspects: i) they were made by achromatic surfaces instead of chromatic ones, ii) the stratification in depth where produced by means of an IT system equipped with goggles for the stereo vision instead of using a stereo displays, iii) each inducer colour have been superposed to the target separately from the other instead of superposing inducers of different colour simultaneously.

Results show that assimilation occurs when the inducers and target were coplanar, whilst a contrast effect was found when they were non-coplanar. This effect was stronger with light rather than with dark inducers; i.e. in the light level of the

Inducers' intensity variable, this shift occurs even when the apparent distance between inducers and target was small. The next sections outline these results in more detail.

1) The assimilation/contrast shift phenomenon

The phenomenon observed here can be called the lightness contrast/ assimilation shift phenomenon. It is the condition whereby the same luminance pattern gives rise to the assimilation when inducers and target are coplanar, but it shifts toward contrast when inducers and target are not coplanar.

de Weert and van Kruysbergen (1997) attributed their observation to an assimilation effect between the discs and the background. However, the assimilation/contrast shift phenomenon emerged in our study suggests that in authors' display there might be two phenomena occurring simultaneously: an assimilation effect of the coplanar discs and, at the same time, a contrast effect of the stratified ones.

The assimilation/contrast shift phenomenon indicates that high degree of spatial frequency is not a sufficient condition to produce assimilation; but inducers need to share the same apparent depth as the target. As (virtually) equal retinal stimulations may give rise to a different perception of the target lightness, this phenomenon strongly supports the importance of central mechanisms for both contrast and assimilation.

2) Coplanarity and lightness perception

The influence of distance among surfaces on lightness perception was systematically studied by Wolff (1933). The author found that contrast reduces (or even disappears) when the inducers are perceived at a different depth plane from the target. This is not in line with our results; we found that non-coplanar inducers may still generate a contrast effect on the target. Two are the main differences between our study and Wolff's one:

1) The inducers' spatial frequency in Wolff's study was low; whilst, in our, it was high.

2) Wolff manipulated actual depth, whilst we manipulated stereoscopic depth.

This second point seems to be the crucial one. Julez (1971) and Gibbs & Lawson (1974) have found that contrast persists even when the inducers are non-coplanar with the target. As in Wolff's study, authors adopted displays in which the inducers' spatial frequency was low. However, the technique adopted to manipulate the distance between inducers and target was a stereoscopic one instead of an actual depth manipulation as in Wolff's study. At this regard, contrasting the results of Wolff on one side and those of Julez & Gibbs and Lawson on the other, Gilchrist (2006) noted that "The additional cues present in Wolff's study like accretion and deletion at target edges due to observer motion might account for the different results" (p. 278). According to this observation and to the results emerged in the present study, it may be argued that in *stereoscopic depth* experiments contrast is favoured over assimilation even when: i) inducers and target are not coplanar, ii) the inducers' spatial frequency is high.

3) Asymmetry in the assimilation/contrast shift phenomenon

Assimilation effect was found to be stronger with dark inducers rather than with light ones. In particular, it emerged that when the apparent distance between the inducers and target was small; dark inducers still generate an assimilation effect, whilst light inducers generate contrast. This asymmetry between dark and light inducers is in line with the findings of Agostini, Daris & Galmonte (2001) and de Weert and Spillman (1995).

In particular, by referring to central mechanisms such as figure/ground segregation as the main cause of assimilation, de Weert and Spillman proposed that target areas bordering dark inducers are seen primarily as ground, hence assimilation, whereas target areas bordering bright inducers are perceived predominantly as figure, hence contrast. However, authors did not explain why bright inducers favour the perception of the target as figure. Further experiments are needed to clarify this issue.

4) Belongingness and the assimilation/contrast shift phenomenon

The relationship between belongingness and lightness perception has been known from a long time. Benary (1924) showed that two equal grey targets, surrounded by the same amount of black and white, differ in lightness according to their perceptual belongingness relationships (see figure 6).

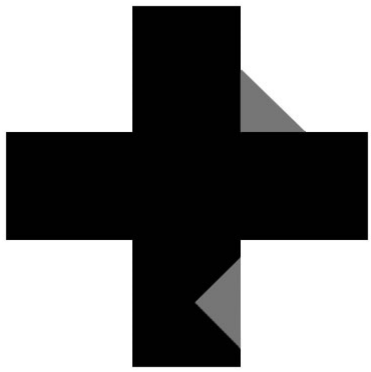

Figure 6. Benary’s figure. The two grey triangles share the same luminance and are surrounded by the same amount of white and black. However, that one on the black cross appears lighter.

As the grey triangle on the black cross appears lighter than the other, Benary (1924) suggested that belongingness induces contrast. After Benary, other scientists related lightness contrast to perceptual grouping (Munker 1970; White 1979; Agostini & Proffitt, 1993; Agostini & Galmonte, 2002 and many others).

Nevertheless, our results seem, at first glance, to contradict these findings. Indeed, by manipulating the distance between inducers and target, we have manipulated the belongingness factor of Proximity. It seems that when target and inducers strongly belong to each other so to constitute a single perceptual unit, their lightness assimilate, instead of contrast. At this regard, Fuchs (1923) proposed the perceptual whole hypothesis. The author showed that the perceived colour of a target assimilates to that one of the elements to which it belongs. Figure 7 shows that the central orange disc appears reddish if intentionally grouped with the red discs and yellowish if it is grouped with the yellow discs.

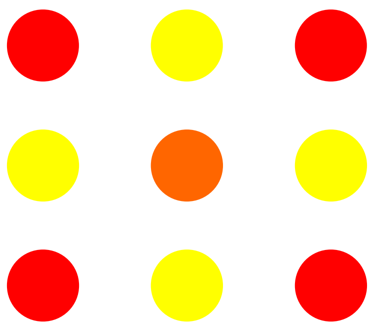

Figure 7. The figure of Fuchs (1923). The orange disc appears reddish when intentionally grouped with the red discs and yellowish when grouped with the yellow discs.

Fuchs (1923) maintained that the target tends to assume the colour of the perceptual whole to which it belongs. King (1988) holds that when belongingness produces a single perceptual unit, assimilation is favoured over contrast. When, instead, two perceptual units emerge, contrast occurs. In agreement with this proposal, it might be suggested that in von Bezholt type of displays assimilation occurs because inducers and target constitute a single perceptual unit. This was also suggested by Musatti (1953). The author holds that assimilation occurs when the inducing elements are "fragments" dispersed within the induced area. In such a case, fragments do not appear as independent units but contribute to generate the texture of a unitary whole. In fact, if the size of the fragments is increased, they become independent units, and contrast takes the place of assimilation.

In other words, it seems that when belongingness involves independent perceptual units, it generates contrast; when belongingness creates a single perceptual unit, then assimilation occurs among the sub-units of the whole.

5) The nature of the contrast phenomenon

Contrast effects have been studied extensively in recent years and have received much more attention than assimilation effects. Already in 1953 Musatti suggested that the fundamental phenomenon in the interaction effects among different surfaces in colour perception is not the contrast, like nowadays maintained (Musatti wrote), but assimilation. Not much seems to be changed since Musatti's time and contrast predominates over assimilation in most of the lightness theories (see also van Lier and Wagemans, 1997 for a discussion on this topic). We believe that the main problem is not that contrast has received so much attention, but that assimilation has been considered a minor phenomenon. In doing this, even the nature of the contrast phenomenon may have been lost.

The assimilation/contrast shift phenomenon emerged in the present study might be helpful in understanding the nature of the contrast phenomenon. As stated, since Benary' findings, most of the authors concluded that the visual system contrasts the lightness of surfaces that perceptually belong to each other. But a fundamental question arises from this conclusion: Why should the visual system enhance the lightness difference among surfaces that perceptually belong to each other?

The Anchoring Theory (Gilchrist at all; 1999) provides an answer to this question asserting that the visual system does not really enhance the lightness differences, but contrast is a sort of inevitable consequence of lightness computation. According to this theory, the visual system computes the lightness of each surface according to its luminance relation with the highest luminance (the anchor) among a set of surface luminance that perceptually belong to each other (framework). If two equal gray surfaces belong to different frameworks that one lying in the framework where the luminance of the anchor is higher will appear darker than the other.

Although this theory attempts to explain why contrast occurs, it assumes that assimilation occurs at a lower level of the visual process. However, our results (as well as the results of previous studies) show that assimilation involves central mechanisms of the visual process as well as contrast. At this regard, de Weert (1991) suggests "[…] there is no a priori reason to put assimilation in another domain than contrast (page 307)".

Therefore, a different answer to the question of why contrast occurs is needed. One possibility is to consider the *figure/ground segregation process* in conjunction with the *luminance decomposition process*.

Figure ground segregation process. It has been proposed that the visual system does not contrast the lightness of *surfaces* that perceptually belong to each other, but the lightness of the *figures* with that one of their *grounds*. If there is no figure/ground segregation, then there is no contrast effect. This way of viewing the contrast phenomenon was firstly provided by Kanizsa (1988). The author gave an original explanation of the Benary phenomenon (depicted in figure 6): "[…] to say that one of the grey triangles belongs to the cross and the other to the background is not a phenomenologically correct description. It is more correct to say that the triangles are two independent figures, each on a different background, one on the black cross, and the other on the white ground" (Kanizsa, 1988; page 291). Kanizsa underlined that the figure/ground segregation process may play an important role in the contrast phenomenon, besides perceptual belongingness. Or, better, perceptual belongingness may generate stronger contrast effects when it favours the figure/ground stratification process. More recently, Bressan (2002) proposed a lightness perception model that - although it does not include a luminance decomposition process – assumes that the figure/ground segregation process affects the contrast phenomenon.

Luminance decomposition process. It has been proposed that visual system splits the pattern of light intensities reaching the eyes into separate overlapping layers, corresponding to separate physical contributions: one layer corresponds to the reflectance and another to the illumination (Musatti, 1953; Metelli, 1974; Bergstrom, 1977; Barrow & Tenenbaum, 1978; Gilchrist, 1979; Adelson & Pentland, 1996; Anderson, 1997; Eagleman, Jacobson & Sejnowski, 2004; Anderson & Winawer, 2005 and many others). According to this view, contrast may descend from a luminance misattribution into the two perceptual components: illumination and surface lightness (Gilchrist, 1988; Soranzo & Agostini, 2004; 2006a; 2006b).

By combining the luminance decomposition process with the figure/ground segregation process, it may be argued that the luminance of the ground contributes in determining the perceived level of illumination of the figures that perceptually belong to it. The higher will be the luminance of the ground the lower will be the luminance of its figures that will be attributed to the figure lightness; and vice-versa, the lower will be the luminance of the ground the higher will be the luminance of its figures that will be attributed to the figure lightness. Therefore, the lightness of figures having the same luminance is computed differently by the visual system if they belong to different grounds because the luminance of the grounds is used to evaluate the illumination level of the figures.

This way of interpreting the contrast phenomenon has two main advantages:

1) It accounts also for assimilation without any need to put it in another domain than contrast; Assimilation simply derives from a missed figure/ground segregation;

2) It provides an account of why contrast occurs.

Further experiments are needed to test this interpretation. For example, it may be interesting to manipulate the figure/ground appearance on one side and the apparent illumination on the other.

In sum, our study suggests that central mechanisms are involved in both assimilation and contrast phenomenon. In addition, it seems that the role of belongingness on lightness perception is not univocal. Strengthening the belongingness between two, distinct, perceptual units produced contrast; but when belongingness unifies separate items into a single perceptual unit, it generates assimilation. We conclude that, if a model is to predict lightness perception, it needs to include both contrast and assimilation phenomena.

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