Perception, 2001, volume 30, pages 1023 – 1026

DOI:10.1068/p3212

Discussion

A comment on the Anderson (1997), the Todorović (1997), and the Ross and Pessoa (2000) explanations of White's effect

White's effect (White 1979), also known as the Munker – White effect, is a lightness illusion that has proven to be especially difficult to explain. Previously, three explanations of White's effect have been suggested (Anderson 1997; Todorović 1997; Ross and Pessoa 2000). All three explanations are incomplete as none of them can explain a novel variation of White's display that is presented here.

Figure 1a is a simplified version of the conventional White's display, and consists of alternating white and black stripes onto which two gray bars have been superimposed. In the conventional White's display there are more than two gray bars and the effect is stronger. However, it should be stressed that White's effect is still present in this simplified display with the gray bar on the left appearing lighter than the one on the right even though they are both physically identical (White 1979, 1981). This effect cannot be attributed solely to simultaneous contrast as the gray bar on the left is bordered by more white and less black than the gray bar on the right (White 1979). Todorović (1997) explained White's effect using a T-junction rule: "... a simple qualitative T-junction rule can be formulated: the lightness of a patch that shares its borders with several other regions, and whose corners involve T-junctions, is predominantly a function of the ratio of its luminance and the luminance of *collinear* regions. The direction of the dependence is the same as in simultaneous lightness contrast, that is a gray patch collinear with white regions will look darker than a gray patch collinear with black regions" (page 384, italics his). When this rule is applied to figure 1a, it correctly predicts that the left gray bar appears lighter than the right.

Figure 1b has been constructed so that it has the identical T-junction structure to figure 1a. As Todorović's rule is based solely on T-junctions, it predicts for figure 1b the same result as it predicts for figure 1a: that the left gray bar should appear lighter than the right. Thirty out of thirty-three naïve observers did not find this to be the case,

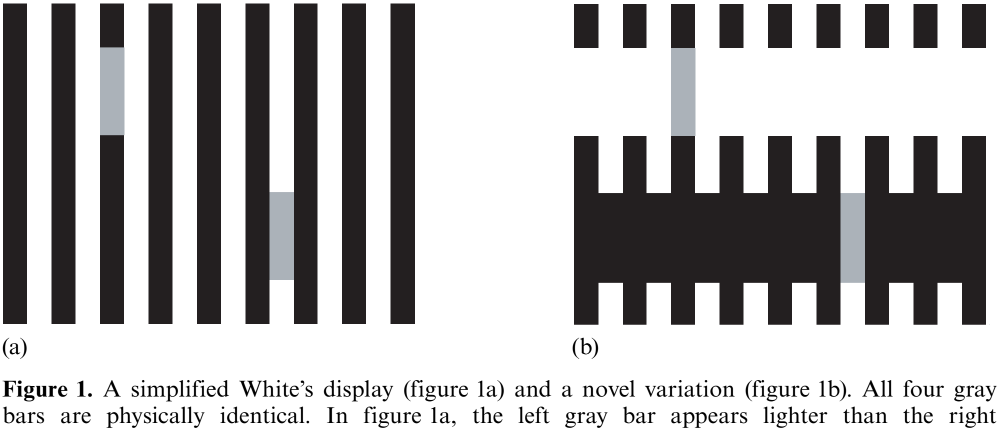

Figure 1. A simplified White's display (figure 1a) and a novel variation (figure 1b). All four gray bars are physically identical. In figure 1a, the left gray bar appears lighter than the right (White 1979). In figure 1b, thirty out of thirty-three naïve observers reported either that the left gray bar appeared darker than (seventeen observers) or the same as (thirteen observers) the right. Since corresponding gray bars in the two figures have identical junction structure, no theory based solely on junctions can explain why White's illusion is perceived in figure 1a but not in figure 1b.

reporting either that the left gray bar appeared darker than (seventeen observers) or the same as (thirteen observers) the right. Todorović's explanation of White's effect is therefore incomplete.

Anderson (1997) also suggested a lightness rule: "*When two aligned contours undergo a discontinuous change in the magnitude of contrast, but preserve contrast polarity, the lower-contrast region is decomposed into two causal layers*" (page 420, italics his). For the above quote, Anderson defined the term 'contour' as "a step function in a stimulus luminance profile" (page 420). Using his rule, he explained White's effect as follows: "Consider the luminance relationships that arise at the T-junctions in the Munker – White display. The aligned contours along the top of the T-junction preserve contrast polarity, but the contrast of one of the edges is reduced relative to that of the other ... The thesis forwarded here is that *the Munker – White illusion is the consequence of a perceptual scission that splits the lower contrast region along the top of the T into multiple sources*" (page 428, italics his). Anderson goes on to state that this decomposition could give rise either to a perception of transparency or to a perception of inhomogeneous illumination. He claims that either way the gray bar on the black stripe will appear lighter than the gray bar on the white stripe. Anderson's rule correctly predicts that in figure 1a the left gray bar looks lighter than the right. In addition, this rule also correctly predicts that White's effect only occurs when the luminance of the gray patches is between the luminances of the two sets of stripes (Spehar et al 1995; Ripamonti and Gerbino 1997; but see also Kingdom et al 1997; Spehar et al 1997). When this luminance condition is not met, either contrast polarity is not preserved along the contours shared by the gray patch and the stripe that it is on, or the gray bar is not the lower contrast region. In either case, the gray bar does not undergo scission and so Anderson's rule predicts the absence of the illusion.

Figure 1b was derived from figure 1a in such a way that any aligned contours in figure 1a that underwent a discontinuous change in the magnitude of contrast were preserved in figure 1b. Since Anderson's lightness rule (quoted previously) is expressed in terms of such contours, Anderson's rule predicts the same illusion in figure 1b as it does in figure 1a: that the left gray bar should appear lighter than the right. As previously noted, thirty out of thirty-three naïve observers did not find this to be the case, which indicates that Anderson's rule is incomplete.

Other authors have suggested that White's effect can be explained in terms of groupings (Agostini and Proffitt 1993; Gilchrist et al 1999; Ross and Pessoa 2000). Out of these three papers only Ross and Pessoa (2000) proposed a computational model. This model emphasizes lightness contrast within a grouping and reduces contrast between different groupings. As a simplification, their model segments visual scenes by means of T-junctions. It cannot therefore explain the lightness illusion seen in figure 1b for the reasons described previously. It will be interesting to see how their model can be extended to handle this new illusion.

In commenting on a previous version of this paper, one of the reviewers suggested that the gray bar on the black vertical stripe in figure 1a had approximately the same lightness as the gray bar on the black vertical stripe in figure 1b, but the gray bar on the white vertical stripe in figure 1a was darker than the gray bar on the white vertical stripe in figure 1b. To test this claim figure 1a and figure 1b were shown to twenty-eight naïve observers. When comparing the gray bar on the black vertical stripe in figure 1a with the gray bar on the black vertical stripe in figure 1b, nine observers reported that they were of equal lightness, eighteen reported that the gray bar in figure 1b was darker and one reported the converse. Conversely, when asked to compare the gray bar on the white vertical stripe in figure 1a with the gray bar on the white vertical stripe in figure 1b, nine reported that the two gray bars were of equal lightness and the remaining nineteen reported that the gray bar in figure 1b was lighter. This study was therefore unable to support the reviewer's claim. Instead, this study found that approximately as many people perceived the gray bar on the black vertical stripe to be darker in figure 1b than in figure 1a, as perceived the gray bar on the white vertical stripe to be lighter in figure 1b than in figure 1a.

The FACADE model of 3-D vision and figure–ground perception (Grossberg 1994, 1997) suggests how contextual factors, including but not restricted to T-junctions, can explain the percepts in figure 1a and figure 1b. Only a short summary of the FACADE explanation will be given, as it is beyond the scope of this letter to give an in-depth discussion of the FACADE model. For details of the FACADE model, the reader is referred to the original sources (Grossberg 1994, 1997) as well as to the FACADE simulation of White's effect (Kelly and Grossberg 2000) which can be downloaded at http://cns-web.bu.edu/Profiles/Grossberg.

In figure 1a there are four horizontal T-junctions associated with the left gray bar. The tops of these T-junctions excite cells coding vertical boundaries and the stems of these T-junctions excite cells coding horizontal boundaries. These two sets of cells compete where the top and the stem of the T are joined. The vertical boundary cells at this location win because these cells get support from both branches of the top of the T-junction, whereas the horizontal boundary cells get support from just the single branch that forms the stem. In losing the competition, the horizontal boundary-coding cells that abut the top of the T are suppressed, with the result that the horizontal boundary is not represented near the T-junction (Grossberg 1997, figure 25). These gaps in the horizontal boundaries (called *end-gaps*) allow the gray and black to diffuse across the stems of the T-junctions, causing the gray and black surfaces not to be represented in the same depth plane as the white stripes (Kelly and Grossberg 2000, figure 15c), but instead only in a further depth plane, via interactions between boundary and surface representations that ensure their consistency in the final percept (Kelly and Grossberg 2000, figure 15d). The left gray bar (and the adjoining black stripe) in figure 1a are therefore perceived as occluded by the adjacent white vertical stripes. The gray bar's lightening is attributed to simultaneous contrast between it and its black background. Similarly, the right gray bar (and adjoining white stripe) in figure 1a are perceived as occluded by the adjacent black vertical stripes and the gray bar's darkening is attributed to simultaneous contrast between it and its white background.

In figure 1b the situation is complicated by the presence of the four horizontal illusory contours. At the left gray bar, the FACADE model clarifies how each of the four T-junctions functions like an implicit X-junction. A similar suggestion was previously made by Grossberg and Mingolla (1985) and by Watanabe and Cavanagh (1993), although not with regard to White's effect. As before, each T-junction excites both horizontal and vertical boundaries. Now, however, the horizontal boundaries are strengthened by the illusory contours that form between the ends of the black stripes. For some observers, the horizontal boundaries at the T-junctions in figure 1b were stronger than the vertical boundaries. This caused the vertical boundaries to be suppressed near the implicit X-junctions, with the result that the brightness of the left gray bar in figure 1b was determined more by the horizontal white rectangle that is enclosed by these illusory contours than by the vertical black stripe. Similarly, for some observers, the brightness of the right gray bar was determined more by the horizontal black rectangle than by the vertical white stripe. Simultaneous contrast between the gray bars and their respective backgrounds can then cause the left gray bar to appear darker than the right, the opposite to what is perceived in figure 1a.

For other observers, the horizontal boundary may be approximately as strong as the vertical boundary. For these observers, an intermediate result between the two previous cases can occur. With these opposing tendencies in balance, such observers would be expected to report that both gray bars had approximately equal lightness.

The FACADE model can therefore explain both the illusion as well as the variance in the responses of the observers as a manifestation of contextual interactions that are aimed at realizing mutually consistent boundary and surface percepts. Other aspects of the FACADE explanation can be found in Grossberg (1997) and Kelly and Grossberg (2000).

Acknowledgements. The author would like to thank Jacob Beck, Stephen Grossberg, Ennio Mingolla, Heiko Neumann, Rajeev Raizada, Aaron Seitz, Takeo Watanabe, and an anonymous reviewer for helpful discussions. The author was supported in part by the Defense Advanced Research Projects Agency and the Office of Naval Research (ONR N00014-95-1-0409).

Piers D L Howe

Department of Cognitive and Neural Systems, Boston University, 677 Beacon Street, Boston, MA 02215, USA; e-mail: howe@cns.bu.edu, http://www.cns.bu.edu/~howe/

Received 25 September 2000, in revised form 15 February 2001

References

Agostini T, Proffitt D R, 1993 "Perceptual organization evokes simultaneous lightness contrast" *Perception* **22** 263 – 272

Anderson B L, 1997 "A theory of illusory lightness and transparency in monocular and binocular images: the role of contour junctions" *Perception* **26** 419 – 453

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

Grossberg S, 1994 "3-D vision and figure – ground separation by visual cortex" *Perception & Psychophysics* **55** 48 – 120

Grossberg S, 1997 "Cortical dynamics of three-dimensional figure – ground perception of two-dimensional pictures" *Psychological Review* **104** 618 – 658

Grossberg S, Mingolla E, 1985 "Neural dynamics of form perception: Boundary completion, illusory figures, and neon color spreading" *Psychological Review* **92** 173 – 211

Kelly F, Grossberg S, 2000 "Neural dynamics of 3-D surface perception: Figure – ground separation and lightness perception" *Perception & Psychophysics* **62** 1596 – 1619

Kingdom F A, McCourt M E, Blakeslee B, 1997 "In defence of 'lateral inhibition' as the underlying cause of simultaneous brightness contrast. A reply to Spehar, Gilchrist and Arend" *Vision Research* **37** 1039 – 1044

Ripamonti C, Gerbino W, 1997 "Inversion of White's effect" *Investigative Ophthalmology & Visual Science* **38**(4) S895

Ross W D, Pessoa L, 2000 "Lightness from contrast: a selective integration model" *Perception & Psychophysics* **62** 1160 – 1181

Spehar B, Gilchrist A, Arend L, 1995 "The critical role of relative luminance relations in White's effect and grating induction" *Vision Research* **35** 2603 – 2614

Spehar B, Gilchrist A, Arend L, 1997 "Qualitative boundaries critical in White's and square-wave brightness induction: a reply to Kingdom et al (1997)" *Vision Research* **37** 1044 – 1047

Todorović D, 1997 "Lightness and junctions" *Perception* **26** 379 – 394

Watanabe T, Cavanagh P, 1993 "Transparent surfaces defined by implicit X-junctions" *Vision Research* **33** 2339 – 2346

White M, 1979 "A new effect of pattern on perceived lightness" *Perception* **8** 413 – 416

White M, 1981 "The effect of the nature of the surround on the perceived lightness of grey bars within square-wave test gratings" *Perception* **10** 215 – 230