

The Early History of White's Illusion

Michael White

*Psychology Department, University of Adelaide, North Terrace, Adelaide SA 5000, Australia
Email: mawhite8@bigpond.com*

Published online: 16 July 2010

Summary

The illusion that is now commonly referred to as 'White's illusion' involves changes in the lightness of the mid-grey test elements that replace sections of the black or white bars of a black–white square-wave grating. This paper describes the discovery of White's illusion; an attempt to explain it in terms of assimilation theory; the interest it has generated amongst vision researchers; the subsequent discovery of dotted versions of the illusion; and the earlier discovery by other researchers of coloured versions.

Introduction

The term 'lightness' refers to neutral colours from black to white, through the range of greys. For many years after its publication in 1979, White's illusion was the strongest known lightness illusion [1]. It is inexplicable in terms of pointwise spatial interactions or edge-contrast and filling-in [1]. It evidently involves complex interactions between pattern and lightness. Many such explanations have been proffered over the last thirty years, but none are widely accepted. The early history of White's illusion is briefly described in this paper.

Although corresponding effects in the domain of hue [2–4] were published before White's illusion [1], they have received very little attention from vision researchers. They presumably involve complex interactions between pattern and hue; and should provide a fertile ground for future exploration of such interactions.

Discovery of White's Illusion

In early 1976 while reading a book, *Optical Art* by Parola [5], I saw a design by Susan Hirth, who was one of Parola's 11th grade students. It was a 'busy' design with black, white and grey elements, where two wedge-shaped sets of physically identical mid-grey annular segments appeared to be different in lightness (Figure 1). Although the illusion was in a chapter describing various lightness contrast and assimilation effects, Parola offered no real explanation for it. Presumably, he assumed that it was some sort of contrast or assimilation effect. He simply noted that 'The grey wedges seem different' [5] (p17). To me, it was



Figure 1 The Hirth design from Parola [5]

with the colour (black or white) with the longer border, but they fail to do so. Instead, the grey elements can be described as ‘assimilating’ to the colour with the longer border. This history is described in my PhD thesis [6], but is absent from my four journal articles on the illusion, which were published between 1979 and 1985 [1,7–9].

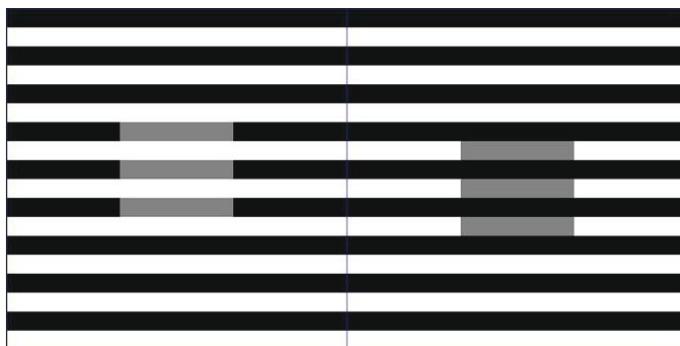


Figure 2 White's illusion

As well as producing variants of the illusion, I read the relevant vision research literature and speculated about possible explanations. By the end of 1976, scores of designs had been produced and some simple experiments conducted. Progress was satisfactory, but the remainder of my PhD research would take another five years (1977–1981) during which time I was employed as a tutor in the Psychology Department at the University of Adelaide.

Assimilation Theory

One way of describing White's illusion is to say that the mid-grey elements assimilate to the colour of the uninterrupted bars at their sides, such that the grey elements in the grey–black

clear that the illusion was not readily explicable in terms of pointwise spatial interactions or edge-contrast and filling-in, and I believed that I had stumbled across a new effect.

I started by designing simple variants of the illusion to see if I could increase its strength by extracting its essential ingredients. This was before image digitisation was readily available, so the designs were created by cutting shapes from black, white and mid-grey paper and gluing them together. Eventually, I isolated what I considered to be the essential effect, which is now commonly known as ‘White's illusion’ (Figure 2). The grey test elements are relatively large in size and therefore should contrast

test region become darker, while the grey elements in the grey–white test region become lighter. It is worth noting that a number of other lightness illusions can be described as involving assimilation within a central test region. Two such examples are Bressan's dungeon illusion [10] and the contrast–contrast illusion [11].

My explanatory approach was described by Gilchrist [12] (p281) as 'assimilation theory'. However, it should be noted that my explanation involved much more than simple lightness assimilation [7]. Three types of lightness assimilation were postulated to play a role: (i) classical lightness assimilation; (ii) pattern-specific inhibition (PSI) assimilation, where the presence of a surrounding pattern increases assimilation in a central test region in proportion to the degree of similarity between the patterns in the surround and test regions; and (iii) counter-phase lightness induction, which is the strongest form of PSI assimilation that occurs when the patterns in the surround and test regions are phase-locked [9]. My assimilation theory is very similar to the later 'texture interaction' theory of Chubb *et al.* [11].

While conducting my research, I believed that 'assimilation' was both an accurate description of White's illusion, and a reasonable low-level explanation for it. I now believe that, although the illusion can be described as 'assimilation', a more satisfactory mid-level explanation might be provided by Gilchrist's anchoring theory [12], or Anderson's transparency theory [13]. Both theories correctly predict that what can be described as assimilation will be found in grey–black or grey–white test regions within surrounding black–white patterns.

Interest in White's Illusion Generated Amongst Vision Researchers

Explanations for visual phenomena can generally be 'located' at one of three 'levels of processing'. In the domain of lightness perception, levels of processing are defined in terms of how lightness processing relates to depth processing [14]. Low-level explanations for lightness effects make no reference to depth processing. However, reference is usually made to the known or presumed neurophysiology of the retina or visual cortex of the brain. Mid-level processing follows low-level processing. Mid-level explanations for lightness effects claim that some of the cues used in depth processing (such as the presence of T-junctions) are also used in lightness processing. High-level processes act in a 'top-down' direction to modify the outputs of lower-level processes. High-level explanations for lightness effects claim that perceived depth can directly alter lightness processing.

Some of the liveliest debates in visual perception are between the advocates of different levels of processing. The main reason for the current widespread interest in White's illusion amongst vision researchers is that plausible explanations have been proposed at all three levels of processing. At the lowest level, explanations have been proposed in terms of retinal receptive fields [15–17], cortical receptive fields [18–19], pattern-specific inhibition, which is also known as 'contrast–contrast' [7,20], and a combination of low-level effects [21]. At the middle level of processing, explanations have been proposed in terms of belongingness to figure or ground as cued by T-junctions [22–25], other cues to belongingness [26], transparency as cued by T-Junctions [27]; and transparency that is unrelated to T-junctions [28]. At the highest level of processing, an explanation has been proposed in terms of experience with 'natural contexts' [29]. White's illusion has become a proving ground for theories of lightness perception. There is currently no single widely-agreed explanation. There is not even an agreed level of processing at which it would be most appropriate to locate an explanation.

Discovery of Dotted Versions of White's Illusion

On the basis of my observation that the grating illusion could be described as involving lightness assimilation within the central test region, I predicted that lightness assimilation would also be found in the central test regions of regular dotted patterns. I created a family of such patterns and published one of them, the ‘groundal dotted illusion’ (Figure 3), in *Perception* in 1982 [8]. I am a little surprised that this illusion has never been referred to in the vision research literature, despite being the strongest lightness illusion known for some years after it was published.

Figure 4 shows its close relative, the ‘figural dotted illusion’. This illusion, which is an example of a reverse-contrast illusion, was one of a family of patterns that I produced but did not publish. It was later published by Bressan and Kramer in 2008 [30].

A number of low-level and mid-level explanations for White’s illusion required the presence of T-junctions at the ends of the grey test elements. Such junctions are present in the original grating version of the illusion but are missing from the dotted versions. If all versions are to be explained in the same general terms, the role of T-junctions must be incidental to the effects.

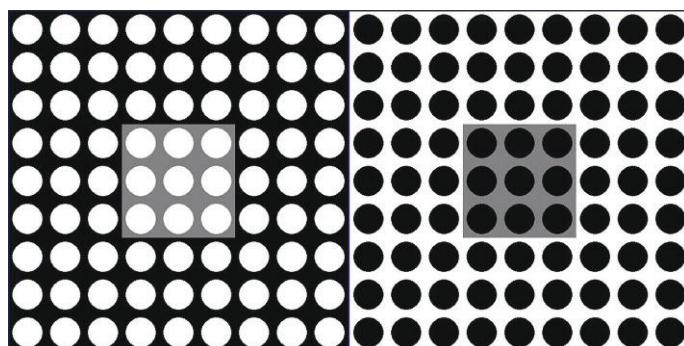


Figure 3 Groundal dotted illusion

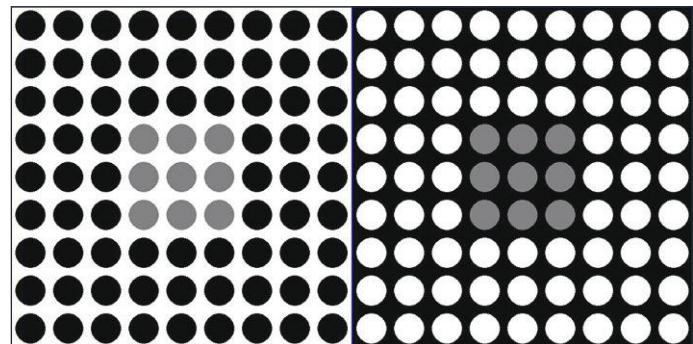


Figure 4 Figural dotted illusion

Earlier Discovery of Coloured Versions of White's Illusion

A coloured version of the grating illusion was published in a PhD thesis by Gindy in 1963 [2]. It was later reproduced as Plate 6 in the 1964 book, *The Measurement of Colour*, by Wright [31] (Figure 5). The figure comprised small coloured squares superimposed on the bars of a blue-yellow grating. The coloured squares were red, orange, green and grey. The colour of the squares weakly assimilated to the colour of the uninterrupted bars at their sides. Gindy confusingly attributed the effect to ‘scattered light in the eye, chromatic aberration of the optical system of the eye, simultaneous contrast, eye movements and local adaptation’ [31] (p49).

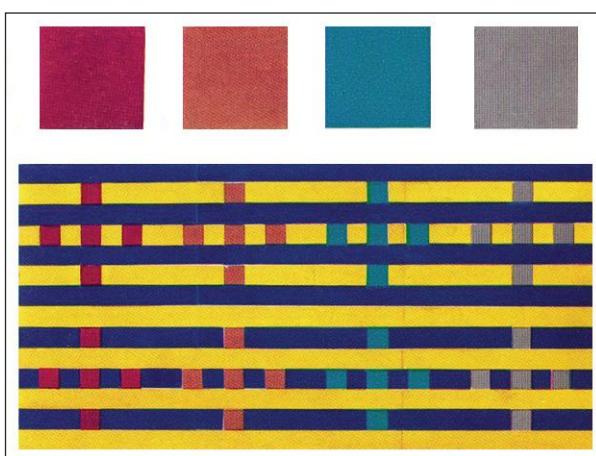
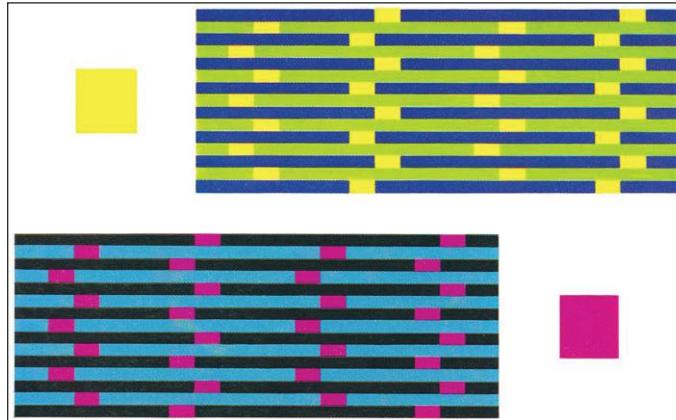


Figure 5 The Gindy design from Wright [31]

Two other coloured versions of the grating illusion were published in 1969 in a short article by Henry [3], who was apparently unaware of Gindy's earlier work. Henry's two figures (Figure 6) were later reproduced as Plate 12 in the 1972 book, *Colour: Its principles and their applications*, by Clulow [32]. In one of Henry's figures, small yellow rectangles were superimposed on the bars of a blue-green grating. In the other, small pink rectangles were superimposed on the bars of a black-blue grating. Again, the colour of the small rectangles weakly assimilated to the colour of the uninterrupted bars at their sides. Henry, who worked for a textile research institute, was interested in the fact that the colours of adjacent threads in tweed 'seem to approach each other in quality' [3] (p4). He considered that the bars of coloured gratings underwent assimilation just like textile threads. He seems to have considered that the small coloured patches that were superimposed on the bars played no role other than to passively reflect the assimilation that was happening around them. He instructed the viewer to 'note how the small coloured patches become more like the nearest bars' [3] (p4).

Figure 6 The Henry figures



Coloured versions of the grating illusion were again rediscovered by Munker in 1970 [4]. His effects were considerably stronger than those previously published. Figure 7 shows two of his colour combinations. At the top of Figure 7, identical red elements have replaced sections of the blue and yellow bars. The red seems to assimilate to the colour of the uninterrupted bars, appearing orange where the uninterrupted bars are yellow, and purplish where they are blue. In the other combination, identical green elements have replaced sections of the blue or yellow bars. The green appears yellowish where the uninterrupted bars are yellow, and bluish where they are blue. Viewing from a distance enhances the effects. I was unaware of the publication

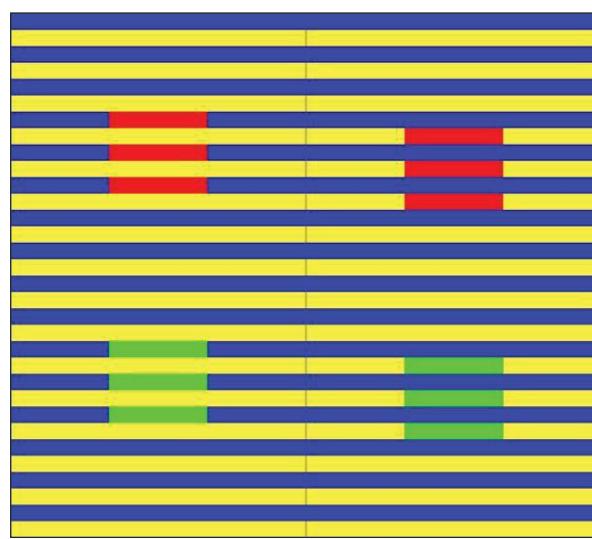


Figure 7 Two colour combinations studied by Munker; the identical red (top) and green (bottom) elements appear different [4]

of coloured versions of the grating illusion [2–4] when I was conducting my research on grey-scale versions.

Despite the fact that ‘White’s illusion’ was discovered in the domain of colour before it was discovered in the domain of lightness, very little research has been conducted on coloured versions. A conference paper by McCann (2002) which asked the question ‘When do we assimilate in colour?’ is one exception [33]. Another more recent paper by Anstis (2006) that looked at White’s effect in lightness, colour and motion is another [34]. Neither McCann nor Anstis cited any prior journal articles on coloured versions of the illusion. It is also known that the group of Bressan *et al.* has conducted some research on coloured versions of their ‘dungeon illusion’, which is a version of the figural dotted illusion [30].

Summary

White’s grating illusion, and related lightness effects for dotted patterns, require explanations beyond simple pointwise spatial interactions or edge-contrast. Complex effects of pattern on lightness must be involved. If there are genuinely comparable effects in the domain of colour, and it seems that there are, they would similarly need to invoke complex effects of pattern on colour.

References

1. M White, *Perception*, **8** (1979) 413–416.
2. S S Gindy, *Techniques for subjective colour measurement and their application to colour contrast phenomena*, PhD Thesis, London University, UK (1963).
3. P S H Henry, *The Shirley Link*, J. Cotton Silk Man-Made Fibres Res. Assoc. (summer) (1969) 1–4.
4. H Munker, *Farbige gitter, abbildung auf der netzhaut und übertragungstheoretische beschreibung der farbwahrnehmung* [Coloured grids, picture on the net skin and transference-theoretical description of the colour perception], Postdoctoral Qualification Report, Ludwig-Maximilians-Universität, Germany (1970).
5. R Parola, *Optical art: theory and practice* (New York: Beekman House, 1969).
6. M White, *The effect of pattern on perceived lightness*, PhD Thesis, University of Adelaide, Australia (1982).

7. M White, *Perception*, **10** (1981) 215–230.
8. M White, *Perception*, **11** (1982) 103–106.
9. M White and T White, *Vis. Res.*, **25** (1985) 1331–1335.
10. P Bressan, *Perception*, **30** (2001) 1031–1046.
11. C Chubb, G Sperling, and J A Solomon, *Proc. Natl Acad. Sci. USA*, **86** (1989) 9631–9635.
12. A Gilchrist, *Seeing black and white* (New York: Oxford University Press, 2006).
13. B L Anderson, *Perception*, **32** (2003) 269–284.
14. J J McCann, *Proc. Human Vis. Electron. Imaging IV*, San Jose, USA (1999) 97–104.
15. J A McArthur and B Moulden, *Vis. Res.*, **39** (1999) 1199–1219.
16. J J McCann, *Proc. AIC 9th Colour Congress*, Rochester, USA (2001) 375–378.
17. Y Yu, T Yamauchi, and Y Choe, *Proc. 1st Int. Workshop on Biologically Inspired Approaches to Advanced Inf. Technol. (Bio-ADIT)*, Lausanne, Switzerland (2004) 1–10.
18. B Blakeslee and M E McCourt, *Vis. Res.*, **44** (2004) 2483–2503.
19. A E Robinson, P S Hammon, and V R de Sa, *Vis. Res.*, **47** (2007) 1631–1644.
20. Y Barkan, H Spitzer, and S Einav, *J. Vis.*, **8**(7): 27 (2008) 1–26 (online: www.journalofvision.org/content/8/7/27; last accessed 2 June 2010).
21. X Otazu, M Vanrell, and C A Parraga, *Vis. Res.*, **48** (2008) 733–751.
22. Q Zaidi, B Spehar, and M Shy, *Perception*, **26** (1997) 395–408.
23. D Todorovic, *Perception*, **26** (1997) 379–394.
24. A Gilchrist, C Kossyfidis, F Bonato, T Agostini, J Cataliotti, X Li, B Spehar, V Annan, and E Economou, *Psychol. Rev.*, **106** (1999) 795–834.
25. W D Ross and L Pessoa, *Percept. Psychophys.*, **62** (2000) 1160–1181.
26. P D L Howe, *Perception*, **34** (2005) 557–564.
27. B L Anderson, *Perception*, **26** (1997) 419–453.
28. M Singh and B L Anderson, *Psychol. Rev.*, **109** (2002) 492–519.
29. Z Yang and D Purves, *Proc. Natl Acad. Sci. USA*, **101** (2004) 8745–8750.
30. P Bressan and P Kramer, *J. Vis.*, **8**(2): 16 (2008) 1–8 (online: www.journalofvision.org/content/8/2/16; last accessed 2 June 2010).
31. W D Wright, *The measurement of colour* (Princeton: D Van Nostrand, 1964).
32. F W Clulow, *Colour: Its principles and their applications* (London: Fountain Press, 1972).
33. J J McCann, *Proc. 10th Colour Imaging Conf.*, Scottsdale, USA (2002) 10–16.
34. S Anstis, in *Seeing Spatial Form*, Eds M R M Jenkin and L R Harris (Oxford: Oxford University Press, 2006).