

# Munker – White-like illusions without T-junctions

Arash Yazdanbakhsh, Ehsan Arabzadeh, Baktash Babadi, Arash Fazl

School of Intelligent Systems (SIS), Institute for Studies in Theoretical Physics and Mathematics, PO Box 19395-5746, Tehran, Iran; e-mail: [Yazdan@cns.bu.edu](mailto:Yazdan@cns.bu.edu)

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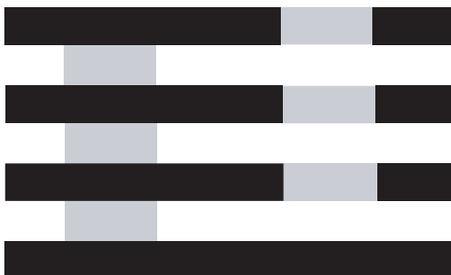
**Abstract.** Some interpretations of the Munker–White illusion were evaluated by designing new versions of this illusion devoid of T-junctions (Munker–White-like images). The magnitudes of both Munker–White and Munker–White-like illusions were then quantified by using a brightness-matching technique. The results showed the effect to persist in all proposed versions. Since the illusion still remains despite the absence of explicit T-junctions and any explanation considering transparency, mechanisms other than those proposed by these interpretations must be responsible.

## 1 Introduction

Optical illusions have provided some useful insights into the fundamental properties of the visual system. The amount of light reaching the eye from a surface is called luminance, which is the result of two independent factors—the quantity of light incident on a surface (illuminance) and the reflectance of the surface, which is the proportion of incident light it reflects. Of these two, reflectance is the informative one, to be extracted from luminance for different environment illuminations. The ability of the visual system to estimate reflectance from luminance is called *lightness constancy*, and has gained serious consideration by many researchers as a cornerstone of visual perception.

The well-known simultaneous-contrast (Chevreul 1839) illusion refers to the difference of perceived lightness between two identical gray squares, one surrounded by a black and the other by a white environment. It is interesting that this perceptual illusion can be explained well by some low-level visual mechanisms, such as lateral inhibition and the presence of centre–surround receptive fields in the retina.

Another contrast illusion, similar in appearance though rather more complex, is the Munker–White illusion (Munker 1970; White 1981). In this illusion two gray targets with the same luminance have different perceived lightnesses. The target patches collinear with white bars appear darker, while those collinear with the black bars seem lighter (see figure 1). Note that the Munker–White illusion cannot be explained in terms of simultaneous contrast per se. In fact, according to the simultaneous-contrast effect, the gray targets in line with the black strips would be expected to appear darker because of their longer boundary with the white strips (Wallach’s ratio rule: Wallach 1948). Surprisingly enough, the illusion is just the opposite.



**Figure 1.** The Munker–White illusion. The gray patches have the same luminance but those coaxial with black strips seem lighter. The illusion works in the opposite way to a simultaneous-contrast illusion. Since the right gray patches have a longer border with the white strips, lateral inhibition predicts that they should be perceived as darker. Other theories are needed to explain this effect.

Various attempts have been made to interpret this phenomenon. Spehar et al (1995) explained it in terms of boundaries with special luminance relationships, ie the effect is observed when the luminance measurement for the target patches is between those of the background strips. Anderson (1997) further emphasised the importance of a qualitative relationship in his definition of polarity-preserving junctions. He then made use of this luminance constraint and interpreted the illusion in terms of transparency induction. He showed that when the luminance of target patches lies between that of the surrounding strips (polarity preserving in terms of T-junctions), the gray patch would appear as a transparent layer covering its background strip, which ultimately would give rise to an apparent lightness difference. According to the colour-scission theory (Anderson 1997), the polarity-preserving T-junction induces the perception of gray patches as transparent layers covering their aligned strips. Since the transparent gray patch covering the dark aligned strip has the same luminance as the transparent one covering the white aligned strip, it should be interpreted to have a higher reflectance.

In general, some authors have suggested a role for T-junctions in image decomposition into different causal layers (occlusion T-junction theory: Gilchrist et al 1996). Anderson considers the Munker–White illusion as a consequence of a perceptual scission that splits the lower-contrast region along the top of the T into multiple sources (colour-scission theory: Anderson 1997).

As Zaidi et al (1997) showed, the T-junction supercedes any effect of occlusion or coplanarity as the examples of some explicit physical properties. Maybe that explains why the presence of a conscious inference is not considered necessary by the former researchers. In summary, T-junctions have an inhibitory effect on laterally induced contrast (separated by the top of T-junction), irrespective of any three-dimensional interpretation. To the extent that T-junctions explain the Munker–White illusion, they do so without requiring the observers using them to infer coplanarity, belonging, or any other perceptual organisation (Zaidi et al 1997).

In this respect the focus of interpretation is either on transparency induction or on the direct effect of T-junctions. In the following section we introduce two versions of Munker–White illusions, which do not contain any explicit T-junctions. We measure the magnitude of the illusions and then discuss if transparency induction could be responsible.

## 2 Method

### 2.1 Subjects

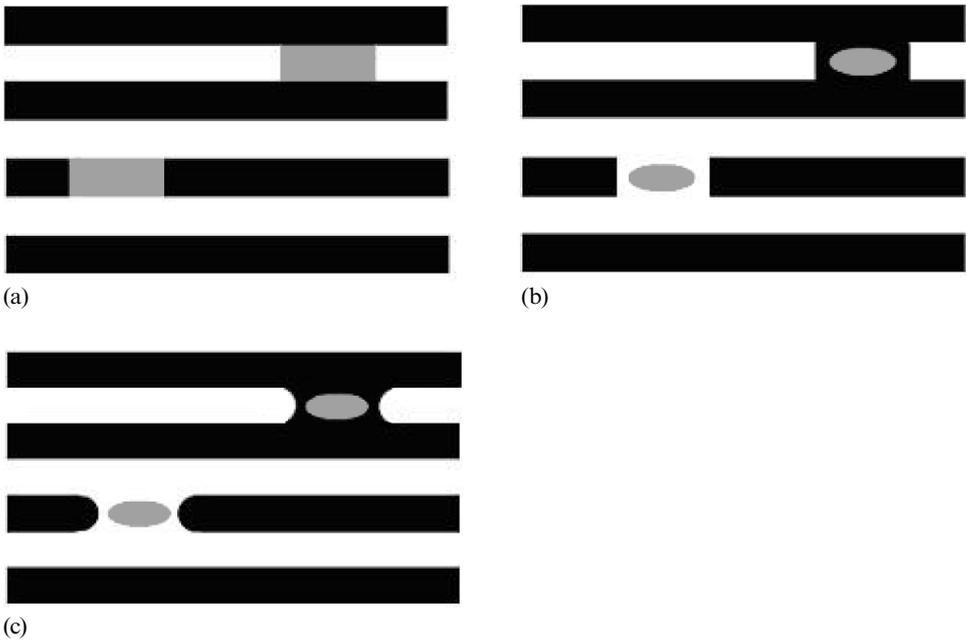
We tested fifteen subjects, including the four authors. Eleven were naïve as to the purpose of the experiments. They were all trained before performing the brightness match and had gone through a control match (see below) to guarantee their precision of matching. All had normal vision with spectacle correction if needed.

### 2.2 Stimuli and procedure

We used three types of stimuli.

- (1) The ordinary Munker–White image (figure 2a).
- (2) Variation 1 of the Munker–White image, which was constructed by shrinking the gray target patches of the classic Munker–White image into smaller ellipses and filling the remaining space with the colour of the upper and lower strips (figure 2b).
- (3) Variation 2, similar to variation 1, except that the sharp L-junctions at the vicinity of the gray ellipses are also rounded (figure 2c).

Figures 2a, 2b, and 2c, which show the target patches, do not show the whole of the real stimuli. In the real presentation, seven additional black and white strips lay above and below these figures, so that the real stimulus extended 27 deg × 18 deg.



**Figure 2.** Disruption of T-junctions. The subjects were asked to fixate between the gray patches and not simply to fixate one of the gray patches and attend the other. (a) The classic Munker–White stimulus used in our stimulus presentation. (b) Variation 1 of the Munker–White illusion. There are no T-junctions present but the illusion, though weakened, still persists. The upper ellipse is still perceived darker. To better perceive the illusion, do not focus on either of the patches; rather look at an intermediate point between the gray patches (as the subjects did). (c) Variation 2 of the Munker–White illusion. The stimulus is the same as in (b), but sharp edges are totally dismissed. Note that simultaneous contrast cannot explain the remaining illusion when the T-junctions are disrupted, because the upper ellipse periphery is completely adjacent to the dark regions of the image. By simultaneous contrast, it must be perceived as lighter, which is not the case.

We instructed the subjects to fixate on the point between the two gray patches and not to fixate on one of the patches and attend to the other one. The length and width of the gray patches were 1.8 deg and 0.9 deg respectively. The centres of the targets were 6 deg apart.

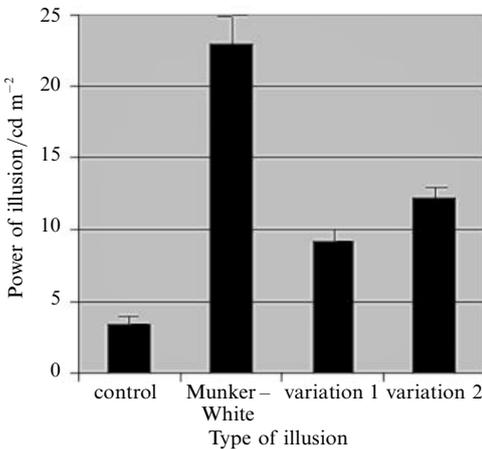
The subjects were asked to match the brightness of the two gray targets by clicking either a positive or a negative button. One click of the positive or negative buttons resulted in a fixed decrease or increase in the luminance of the lower patch and a unit increase or decrease in the luminance of the upper patch. Hence, the luminance of the two targets moved in opposite directions with each click. To prevent subjects from counting the clicks, each test started with a random difference in luminance of the target patches. All fifteen subjects were first asked to match the brightness of the two gray targets in the control stimuli. In control stimuli both the upper and the lower gray patches were embedded in black or white strips. We expected the subjects to match the brightness according to the physical luminance (illusion-free control). For all three types of the stimuli we designed a corresponding control stimulus (gray patches lying in the same black or white strips). The results showed that the subjects were able to match them with good precision. The means and standard deviations of their results were all alike as illustrated in figure 3. The subjects demonstrated the same precision in matching the brightness in all three control experiments corresponding to the three main stimuli.

We then proceeded to the main tests, starting with the Munker–White stimuli (figure 2a), followed by its two variants (figures 2b and 2c).

### 3 Results

The results of the brightness matches are illustrated in figure 3. The power of the Munker–White illusion was  $22.92 \pm 2.15$  (mean  $\pm$  SE)  $\text{cd m}^{-2}$ . The powers of variations 1 and 2 were  $9.23 \pm 1.0$  and  $12.15 \pm 1.34$   $\text{cd m}^{-2}$  respectively.

Though there is a meaningful difference in the magnitude of the Munker–White illusion and its variations 1 and 2 (Scheffe a posteriori test  $p < 0.01$  and  $p < 0.05$  respectively), they all showed a significant and strong difference from the control image, which had a power of  $3.38 \pm 0.47$  (mean  $\pm$  SE)  $\text{cd m}^{-2}$  ( $F_{3,56} = 32.2$ ,  $p < 0.00001$ ). All subjects were able to match the gray patches in the control images with a good precision. This shows that the results from the Munker–White stimuli and its two variations can be relied on.



**Figure 3.** Power of the variation 1 and variation 2 illusions in comparison to the Munker–White illusion and a control. Both variation 1 and variation 2 illusions are weaker than the Munker–White illusion. However, they are strong enough to be significantly different from the control stimuli.

### 4 Discussion and conclusion

Lightness illusions can be considered useful by-products of the visual system's endeavour toward achieving lightness constancy, and have guided numerous researchers in their attempt to understand some properties of the visual system. Various experiments have proposed that the perceived lightness of a patch depends on the surrounding area. The simultaneous-contrast illusion presents an example of the impact of surrounds which can be explained in terms of low-level visual mechanisms such as lateral inhibition in the retina. Some other factors, such as junctions, seem to be involved in the phenomenon of lightness constancy, giving rise to some curious illusions such as the Munker–White illusion where the perceived reflectance is contrary to what lateral inhibition predicts.

There has been a long debate on different mechanisms underlying the Munker–White illusion. Many of these interpretations [including occlusion, transparency induction, and direct generalisation; see Zaidi et al (1997)] are mediated through explicitly visible T-junctions. The stimuli discussed in this article (figures 2b and 2c) contain no explicit T- or X-junctions, especially in figure 2c where any sharp angle is rounded. Both variations 1 and 2 should have produced the opposite effect if the transparency interpretation was to be considered; the apparent lighter patch is embedded on the lighter background and the apparent darker patch is embedded on the darker background. The upper gray ellipses in figures 2b and 2c are surrounded along their whole circumference by a dark region and the dark area in the vicinity is larger than the light area. Hence, if simultaneous contrast is to be considered, the upper ellipses should be perceived as lighter, which is quite contrary to our findings. Thus, there is no room for the illusion to be interpreted through either simultaneous contrast or transparency induction.

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**References**

- Anderson B L, 1997 “A theory of illusory lightness and transparency in monocular and binocular images: the role of contour junctions” *Perception* **26** 419–454
- Chevreul M E, 1839 *De la Loi du Contraste Simultané des Couleurs* (Paris: Pitois-Levreault)
- Gilchrist A, Kossyfidis C, Bonato F, Agostini T, Cataliotti J, Li X, Spehar B, Annan V, Economou E, 1996 “An anchoring theory of lightness perception” *Psychological Review* **106** 795–834
- Munker H, 1970 “Farbige Gitter, Abbildung auf der Netzhaut und übertragungstheoretische Beschreibung der Farbwahrnehmung” Habilitationsschrift, Ludwig-Maximilians-Universität München
- 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
- Wallach H, 1948 “Brightness constancy and the nature of achromatic colors” *Journal of Experimental Psychology* **38** 310–324
- White M, 1981 “The effect of the nature of the surround on the perceived lightness of gray bars within square-wave test gratings” *Perception* **10** 215–230
- Zaidi Q, Spehar B, Shy M, 1997 “Induced effects of backgrounds and foregrounds in three-dimensional configurations: the role of T-junctions” *Perception* **26** 395–408