# A Brief Classification of Colour Illusions

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Published online: 18 May 2010

## Summary

Several colour illusions with strong effects are classified within this review. They include colour constancy, colour illusion of assimilation and contrast, visual completion, visual scission, and colour induction by motion.

## Introduction

There are a cumulative number of visual illusions in shape, motion, brightness or colour. Although shape illusion (geometrical illusion) has been well documented and classified in the literature [1,2], colour illusion has not. Within this article, the hue illusions that have been selected will be demonstrated and attempts will be made to classify them. Although this article is intended to review strong colour illusions briefly, references are not abundant because some of the illusions or ways of demonstration shown here depend on author's original contribution.

## Colour Illusion by Colour Constancy

Colour constancy refers to a phenomenon in which observers can see the 'true' colour of an object to some extent, even the illumination is changed altering the 'physical' colour. I regard colour constancy as a kind of colour illusion and an example is depicted in Figure 1 [3]. In this figure, the left portion of each image has a different coloured filter with the observed eye colour beneath the three filters (red, blue and green) being cyan, yellow and red, respectively. In the right portion of each image, the eye colour is actually the same as each counterpart. Colour constancy is supposed to be perfect when in each image the right iris appears to be the same colour as the bead on the hair. These images are produced by adding 50% transmittance colour filters. For example in Figure 1a, the basic portrait is a grey-scale girl with cyan irises. The 50% transmittance red colour filter covers the left half of the image including her right iris, while the filter is superimposed on her left iris only in the right half of the image. The filter physically changes cyan (R, 0%; G, 100%; B, 100%) to the intermediate grey (R, 50%; G, 50%; B, 50%). The left iris then appears to be grey as it 'physically' is, whereas the right eye appears

Colour: Design & Creativity

 

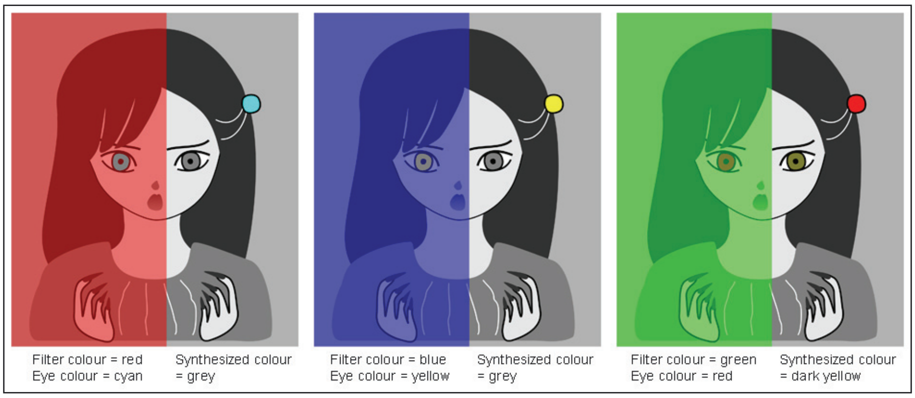


**Figure 1** Colour illusion by colour constancy (see description in the text)

to be cyan as it 'really' was. The latter is called colour constancy, a human vision ability to see the 'true' colour of an object even if illuminated or filtered by different colours.

Colour constancy resembles colour contrast, because the opponent colour of the surround is induced in the target area; however, the effect of colour contrast is much weaker than that of colour constancy (Figure 2). In this, the same colour combinations are used as in Figure 1. The small square in each image is the same colour as the 'iris' in Figure 1 and surround in each image is the same colour as the 'skin' in Figure 1.

The snake illusion is a well-known lightness illusion [4]. Its chromatic version is also possible [5] and this is shown in Figure 3; in each 'snake' panel, the two diamonds in the upper row, which appear to be chromatic, are really the same neutral grey as those in the lower row. It may be true that this effect looks like colour constancy because it is accompanied by perceptual

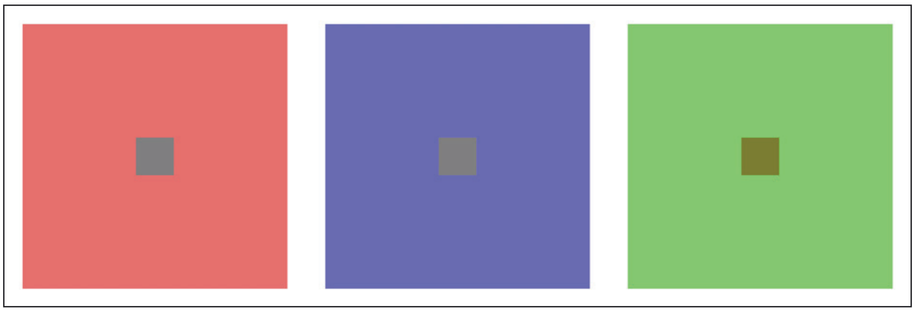

**Figure 2** Colour contrast using the same colour combinations as Figure 1; the small square in each image is the same colour as the 'iris' in Figure 1 and surround in each image is the same colour as the 'skin' in Figure 1

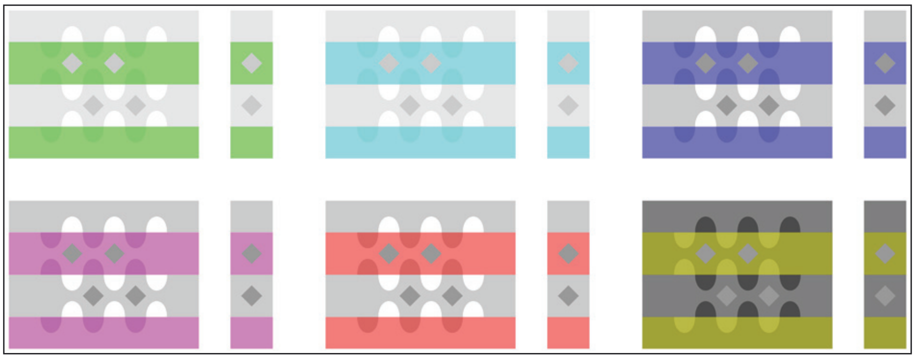

**Figure 3** Chromatic snake illusion; in each 'snake' panel, the two diamonds in the upper row, which appear to be chromatic, are really the same neutral grey as those in the lower row

 

transparency, like Figure 1, but this effect cannot always be attributed to colour constancy, because the colour of diamonds embedded in each 'colour-filtered' or 'colour-illuminated' area is not guaranteed to accord with this filtering or illuminating idea.

For example, in the top-middle 'snake' image of Figure 3, the upper two diamonds appear to be slightly reddish though they are physically light-grey (R, 80%; G, 80%; B, 80%). Suppose that the red diamonds (R, 100%; G, 0%; B, 0%) were superimposed by a 50% transmittance cyan filter, then the resultant colour should be the intermediate grey (R: 50%, G: 50%, B: 50%), much darker than the light-grey used in this image. In preliminary observations, the intermediate grey surrounded by cyan rendered much weaker colour induction (not shown here) than does this image.

In contrast, such a configuration as Figure 4 is regarded as an instance of colour constancy because the induced colour of the target is consistent with the colour-filtering idea.

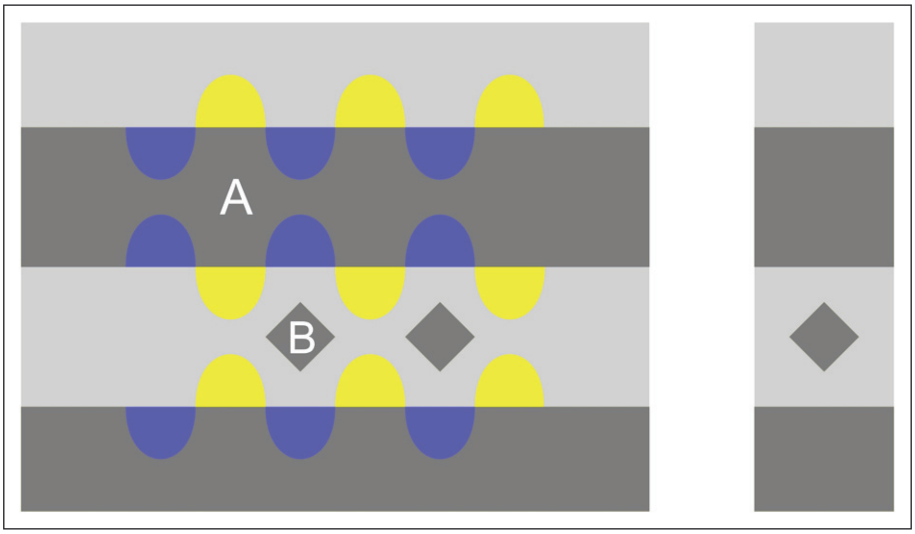


**Figure 4** A colour constancy representation in the snake illusion display; the area A appears to be yellowish but is the same neutral grey as the diamond B

## Colour Illusion by Assimilation and Contrast

When an area is enclosed by a coloured surround and both are partly occluded by a coloured grating, the area appears to be tinted in the same direction as the colour of the grating (assimilation) as well as in the direction opposite to the colour of the surround (contrast) [6–8]. Colour illusion by assimilation and contrast is shown in Figure 5. The name of this effect is not well established but can be called the Munker illusion or chromatic White's illusion (Figure 5a). A similar effect is obtained when the occluder is replaced by a coloured grid (chromatic dungeon illusion, Figure 5b), repetitive coloured dots (dotted colour illusion, Figure 5c), or a coloured checker pattern (De Valois-De Valois illusion, Figure 5d) [9]. The chromatic dungeon illusion is the colour version of Bressan's dungeon illusion [10]. The dotted colour illusion is the colour version of White's dotted brightness illusion [11].

In these illusions, the contribution of colour contrast appears to be weaker than that of colour assimilation if they are examined separately (Figure 6). However, there is evidence that colour contrast plays an important role in this group of colour illusions. For example, Figure 7 shows illusory yellow in the left circle in each image though it is the same white as the right circle. To explain this effect, colour contrast should be taken into account, as follows. In the left half of Figures 7a or 7c, colour contrast induces red as the opponent colour of cyan, while

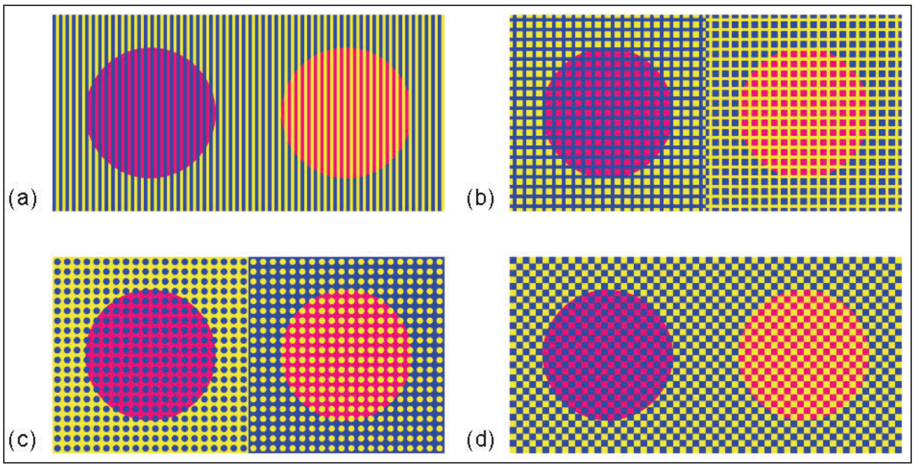


**Figure 5** Colour illusion by assimilation and contrast. In each panel, the left circle appears to be magenta while the right one appears to be orange, though they are physically the same colour; (a) Munker illusion or chromatic White's illusion, (b) chromatic dungeon illusion, (c) dotted colour illusion, (d) De Valois-De Valois illusion. Throughout all images (a, b, c and d), the apparent magenta is physically the same colour as the apparent orange.

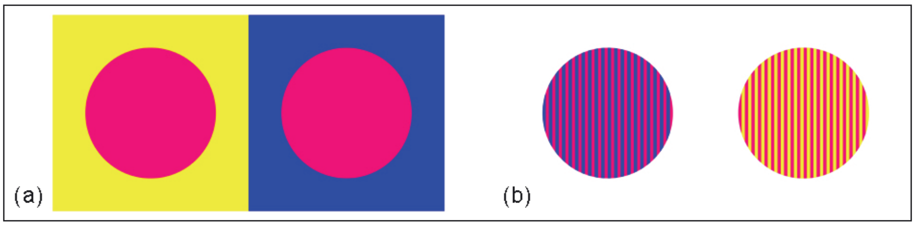


**Figure 6** Colour effects involved in the Munker illusion: (a) colour contrast shows a relatively weak effect; (b) colour assimilation renders a relatively strong effect

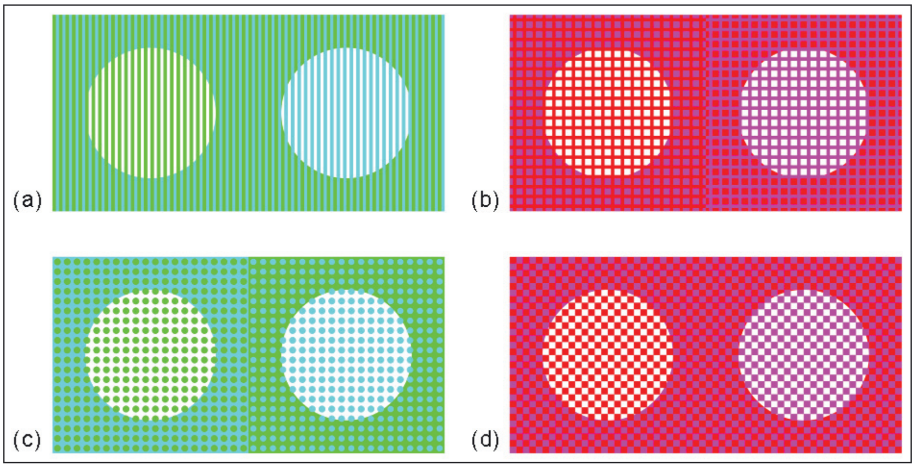


**Figure 7** Yellow induction: in each image, the left circle is physically the same white as the right one but the former appears to be yellowish; this effect can be explained with colour mixture between the colour induced by contrast and the one induced by assimilation; (a) Munker illusion, (b) chromatic dungeon illusion, (c) dotted colour illusion, (d) De Valois-De Valois illusion

colour assimilation gives green; then the induced red and green are mixed to produce yellow. In the left half of Figures 7b or 7d, colour contrast induces green as the opponent colour of magenta, while colour assimilation gives red; then the induced green and red are mixed to produce yellow [12].

On the other hand, illusory blue is induced in the right circle of each image. This effect is manifest when the induced area is dark (Figure 8). Moreover, when the induced area is intermediate in luminance, the induced colour seems to be unbalanced mixture of colour contrast and colour assimilation, with the former being more effective than the latter (Figure 9) [12]. This effect is observed when the induced area is close to the inducing areas in luminance; in (a) and (c), yellowish red is induced in the left circle while bluish magenta is shown in the right, and in (b) and (d) yellowish green is induced in the left circle while bluish cyan is shown in the right. In each image, however, the left circle is physically the same grey as the right one.

In summary, not only colour assimilation but also colour contrast plays an important role in this group of colour illusions.

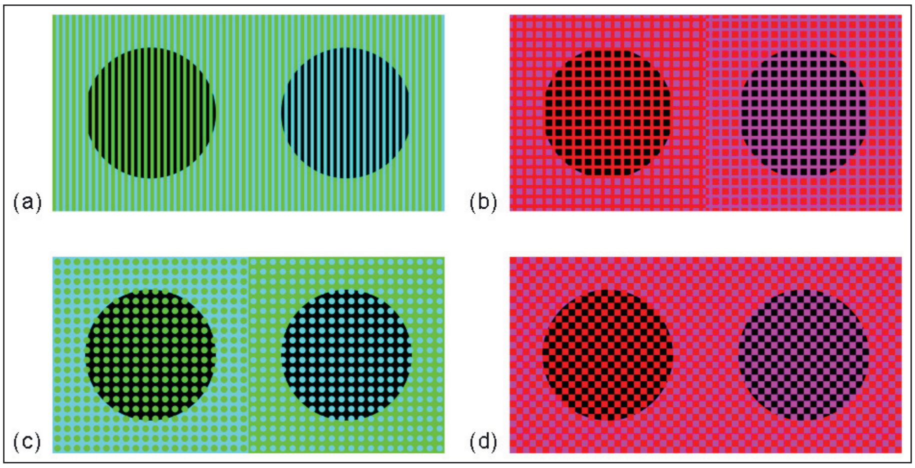


**Figure 8** Blue induction: in each image, the right circle is physically the same black as the left one but the former appears to be bluish;. (a) Munker illusion, (b) chromatic dungeon illusion, (c) dotted colour illusion, (d) De Valois-De Valois illusion

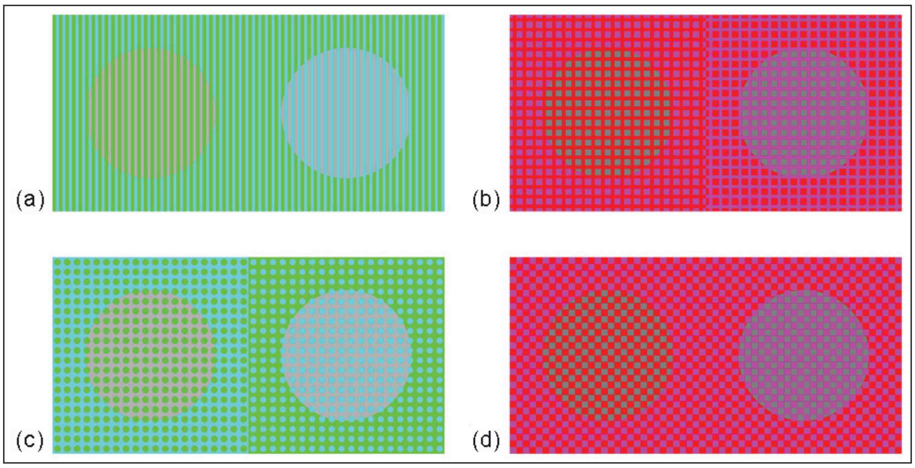


**Figure 9** A condition showing slight superiority of colour contrast to colour assimilation: this effect is observed when the induced area is close to the inducing areas in luminance; (a) Munker illusion, (b) chromatic dungeon illusion, (c) dotted colour illusion, (d) De Valois-De Valois illusion

## Colour Illusion by Visual Completion

'Colour filling-in' phenomena are observed in several configurations with examples shown in Figure 10, e.g. neon colour spreading (Figures 10a–c) [13–16], Pinna's watercolour illusion (Figure 10d) [17], Sohmiya illusion (Figure 10e) [18], or the chromatic Craik–O'Brien–Cornsweet effect (Figure 10f) [19]. These illusions are characterised not only by colour

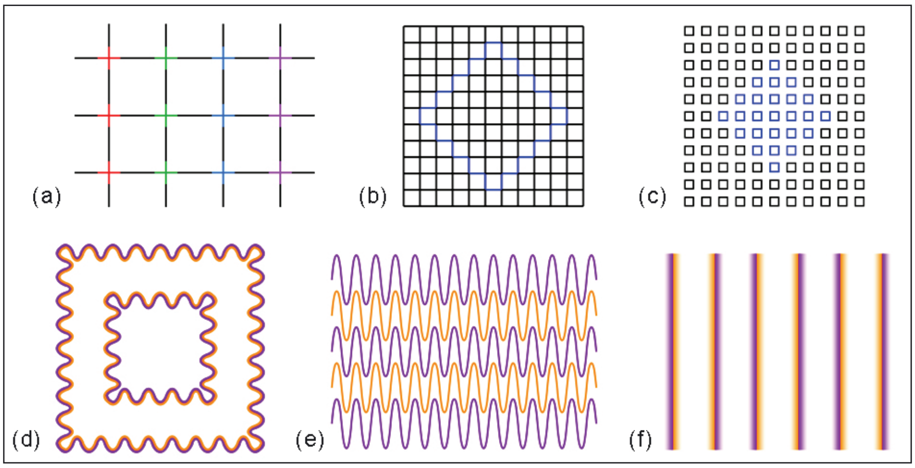


**Figure 10** Colour illusion by visual completion (colour filling-in phenomena): (a), (b), (c) neon colour spreading;(d) watercolour illusion; (d) Sohmiya illusion (wave–line colour illusion); (e) chromatic Craik–O'Brien–Cornsweet effect [colour contrast also work in (d), (e) and (f)]

assimilation coming from the coloured inset but also by colour contrast coming from the surround [14,16,18].

For the neon colour spreading examples: Figure 10a shows transparent circular or diamond-like patches of the same colour as crosses are observed over the crosses; in Figure 10b, a bluish contour of diamond shape is observed over the blue staircases and in Figure 10c, a bluish diamond is observed over the lump of blue squares that form a diamond shape. In the watercolour illusion (Figure 10d), the corridor area appears to be coloured yellowish orange, though it is actually white and, similarly, in the wave–line colour illusion (Figure 10e), the white background of the second and fourth rows of waves appears to be coloured yellowish orange, though it is actually white. Finally, in Figure 10f (the chromatic Craik–O'Brien–Cornsweet effect), the white areas flanked by orange borders appear to be coloured yellowish orange, though it is actually white. Colour contrast also works in (d), (e) and (f).

## Visual Scission

Visual scission or figure-ground segregation also produces colour illusion. Figure 11 shows the chromatic version of the Anderson illusion [5,21], in which the inset appears to be either

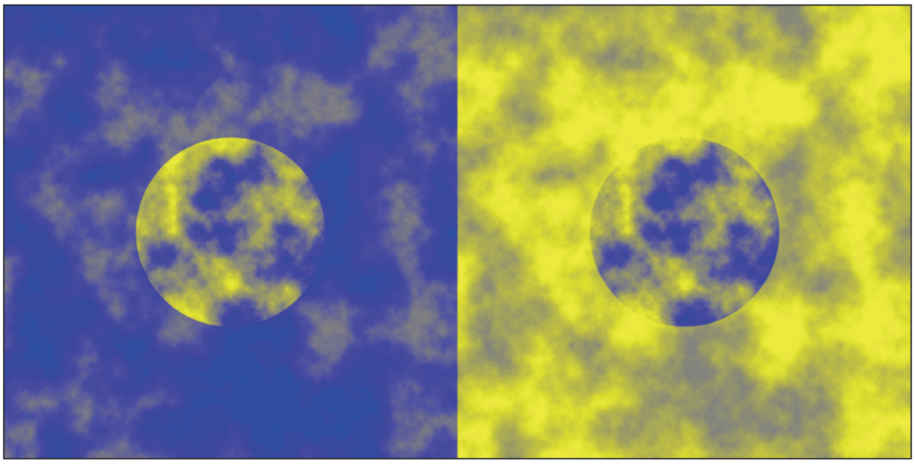

**Figure 11** Colour illusion by visual scission (chromatic version of the Anderson illusion); the left disk appears to be yellow while the right one appears to be blue, though both are physically identical in colour and texture

 

a yellow disk or a blue one depending on the surround. The Anderson illusion is a remarkable lightness illusion [20]. This colour effect does not depend on colour contrast. For example, in Figure 12, Australia (as seen from Space with a dust storm over the country) [5], the left image does not appear to be yellowish though the surround is bluish.

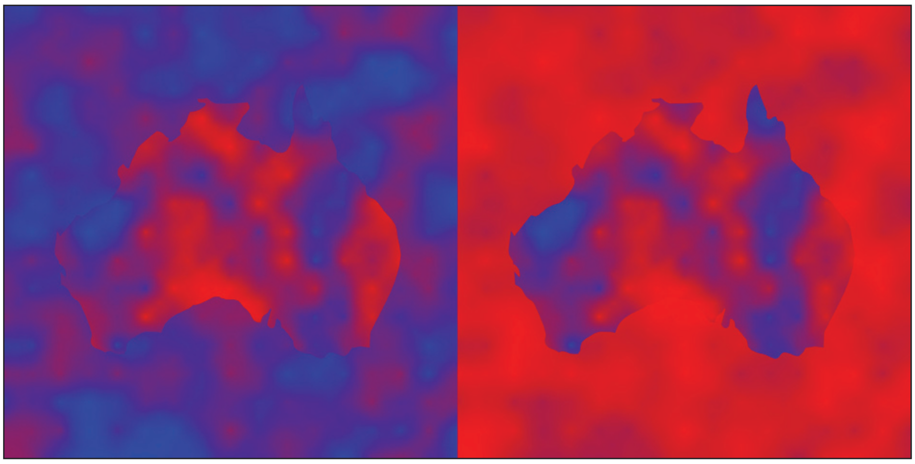

**Figure 12** Visual scission of 'Australia seen from space and dust storm over Australia' [5]; the left Australia appears to be red while the right one appears to be blue, though both are physically identical in colour and texture

## Colour Illusion by Motion

Motion produces colour in some situations, such as Benham's top. Here a novel colour illusion induced by motion is demonstrated. Figure 13 shows colour increment when observers fix their eyes on the centre and approach or leave the image [22]. The inner ring appears to get more reddish during observers are approaching, while the outer one appears to get more reddish during they are leaving. My speculation is that this phenomenon might depend on different latencies of colour perception that a longer-wavelength colour is perceived faster than a shorter-wavelength colour (Figure 14) [23]. When a repetitive pattern of black, yellow, white, red and black is moved in this direction (towards the right) then (i) the front edge of the red strip simply goes in the black area, (ii) the front edge of a white strip emits a red margin ahead (solid arrow), and (iii) the rear edge of the white strip leaves a blue margin behind and this blue part cancels colour with the following yellow (dotted arrow). In total, this process of colour separation or cancellation gives the apparent increment of red.

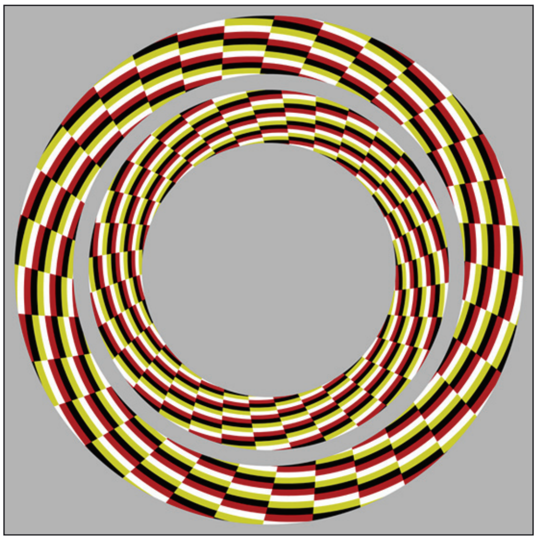

**Figure 13** Colour illusion by motion: the inner ring appears to get more reddish during observers approach the image fixing their eyes on the centre, while the outer one appears to get more reddish during they leave the image

 

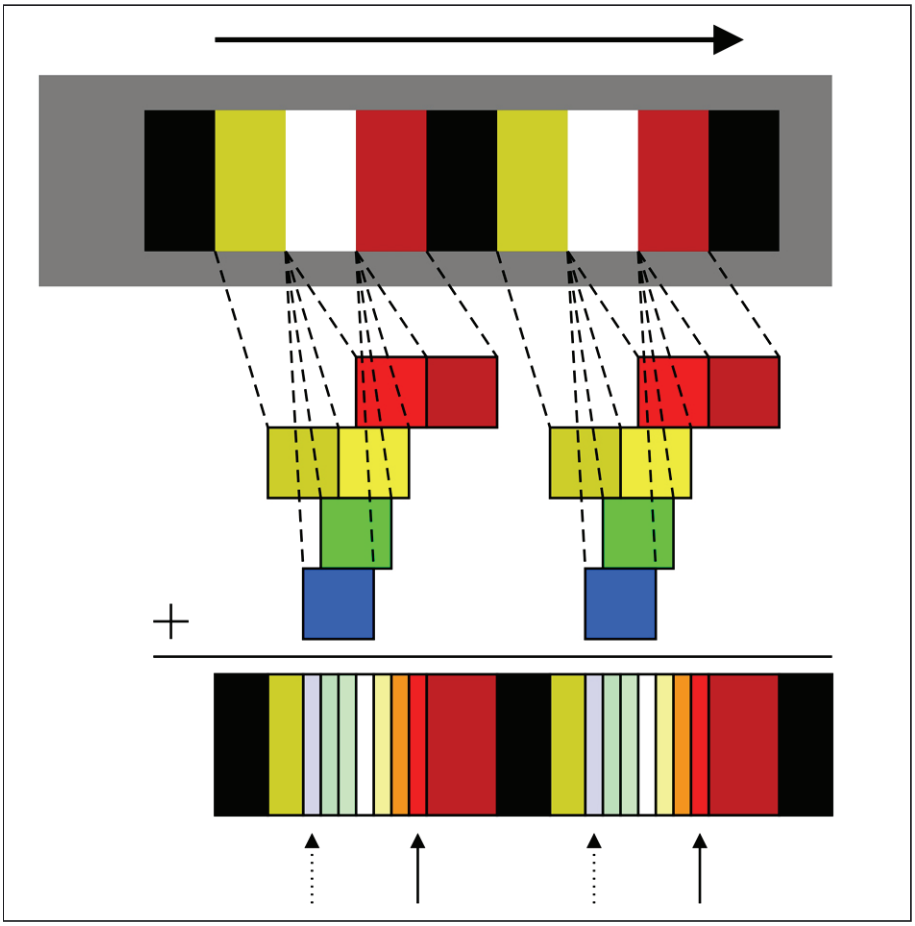

**Figure 14** Different latency hypothesis that explains the motion-induced red increment (see description in the text)

In Figure 13, there are also two anomalous motion illusions. One is that the inner ring appears to contract while the outer one appears to expand (optimised Fraser–Wilcox illusion) [24]. The other is that the inner ring appears to rotate counter-clockwise during observers approach the image fixing their eyes on the centre, while it appears to rotate clockwise during they leave the image (rotating demonstration of the Ouchi illusion) [25]. These two motion illusions do not necessarily depend on colour.

## Conclusion

In this article, a number of strong colour illusions have been classified into the following categories: colour constancy, colour illusion of assimilation and contrast, visual completion, visual scission, and colour induction by motion. It is hoped this brief classification can help other researchers in their studies for applying colour illusions more extensively. Comprehensive classification will be fruitful in the future.

## Acknowledgement

This research was supported by the grant-in-aids (R-GIRO program 2009 and Kaken-linked program 2009) awarded to the author from the Ritsumeikan University.

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