COLOUR PSYCHOLOGY

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WHAT'S THE POINT?

This handout:

- ✓ is an excerpt from Chapter 3 of my thesis *(hence why it refers to other parts of the thesis in the text)*;
- ✓ helps you to understand key aspects about the use of colour; and
- ✓ provides a foundation for identifying what truly works, and what does not *(Note: There has been a great deal written on the use of colour in graphic design which is just WRONG).*

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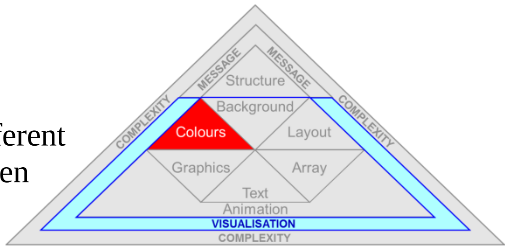
1.1. Colours



The human perception of colour is a response to different wavelengths of light entering the eye, which is then processed within the retina (Gegenfurtner & Kiper, 2003) and the perceptual paths described in Appendix 1[(1)].

The use of colour in presentations is important, because it can provide significant benefits, which include (Jones, 1997; Kose, 2008; Pett & Wilson, 1996):

- adding reality to the information;
- assisting the viewer to discriminate between visual elements;
- focussing attention on the important information *(e.g. salience)* [(2)];
- coding and linking logically related elements;
- creating impressions; and
- generating emotional responses *(e.g. arousal).*

Colour is also critical in many object recognition tasks (Otsuka & Kawaguchi, 2009), and the use of colour can enhance the retention of semantic information through association *(e.g. shapes and colour associations)* (Delvenne & Dent, 2008; Xu, 2002). Additionally, viewers typically prefer to view coloured *(chromatic)* visuals, rather than achromatic[(3)] information *(e.g. black and white)* (Jones, 1997; Kaya & Epps, 2004; Smaldino, Lowther, & Russell, 2008). The appropriate use of colour also appears to aid perception, comprehension and learning (Jones, 1997).

Care should therefore be taken when selecting colours, because they can have 'enormous power' (Hanke, 1998, p. 45) in terms of comprehension, retention and impressions (Hanke, 1998; Rider, 2009; Singh, 2006). As an example, colour salience can dominate perceptual load in some circumstances *(e.g. when top-down task related processes do not dominate attention)* (Biggs & Gibson, 2010), so colour can play a significant role in cognition.

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1. See Section 1.3.1 in Appendix 1 for more information on colour perception.
2. It appears that colour encoding is an automatic and unconscious process (Huang, 2006; Ro, Singhal, Breitmeyer, & Garcia, 2009), and this can have a direct effect on shaping attention, particularly in response to top-down task related processing *(e.g. visual search for a particular colour, or colour difference)* (Goolsby & Suzuki, 2001; Vierck & Miller, 2005). This automatic encoding of colour involves both perception and higher level cognition, as illustrated by the colour constancy effect identified by Reeves, Amano, & Foster (2008). This research found that human perception of colour can remain constant even with changes in luminance (Reeves, et al., 2008), which infers that colour related percepts are rapidly evolved into more complex representations (Dresp & Fischer, 2001). See the handout at http://www.seahorses-consulting.com/DownloadableFiles/ShapingAttentionHandout.pdf for more information on Top Down and Bottom Up processes.
3. See Figure 2.2 in Appendix 2 for a visual representation of chromatic and achromatic colours.

Just as importantly, the misuse of colour can create memory overload, lead to confusion[(4)] (Ling & van Schaik, 2002; Marshall, Christie, & Gardiner, 1987), and markedly slow visual search times (Ling & van Schaik, 2002).

1.1.1. What affects the Experience of Colour?

An individual's experience of colour can be highly subjective (Nishiyama, 2012), because of the interaction between:

- ***Innate Reactions.*** Specific innate reactions to colour are defined by the way in which the human perception system operates (Crozier, 1996; Crozier, 1999; Elliot & Maier, 2007; Gegenfurtner & Kiper, 2003)[(5)]. In practical terms, this means that the reactions are generated at a fundamental level within the human brain, and for this reason they can be considered relatively universal[(6)].
- ***Learned Reactions.*** Some of the effects of colour may also be quite specific to the individual (Abbas, 2006). For instance, the interplay of a range of demographic issues can affect the cognitive experience of colour for each person (Crozier, 1999; Elliot & Maier, 2007)[(7)]. These include aspects such as, gender (Ellis & Ficek, 2001), age (Beke, Kutas, Kwak, & Sung, 2008), culture (Madden, Hewett, & Roth, 2000) and knowledge (Froner, Purves, Lowell, & Henderson, 2013). These variables can affect the learned reactions to colour, and therefore the individual's experience of particular colours (Crozier, 1996; Rider, 2009).

The learned reactions to colour are affected by such diverse variables, that it can make it difficult to determine how different colours will work with varying audiences (Rider, 2009). Therefore, although some aspects of learned reactions can be useful *(particularly if the audience can be identified in detail)*, the most appropriate approach is typically to apply colour to leverage the innate reactions. The following sections identify key principles that can be applied to generate these innate reactions, to optimise communication through colour.

1.1.2. Generating Innate Reactions

The research conducted by Madden, et al. (2000)[(8)] identified that there were some colours that generate cross-cultural reactions. In other words, there appears to be some level of

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4. This confusion may be directly attributable to visual complexity. You can find an introduction to complexity issues within the handout at this web location: http://www.seahorses-consulting.com/PresentationContent/ComplexityVariables.pdf
5. Using the systems described in Section 1.3 in Appendix 1.
6. For the purposes of this thesis, the innate reactions are aligned to the perception processes *(See Section 1.3 in Appendix 1)*, and the learned reactions relate to the cognitive elements for the processing of colour *(See Section 1.4 in Appendix 1)* (Derefeldt, Swartling, Berggrund, & Bodrogi, 2004). Therefore, innate reactions can be associated with percepts and learned reactions with representations. Although this is an over-simplification, it provides an effective framework for categorising these aspects.
7. This aspect is explained in more detail in Section 2.2 in Appendix 2.
8. See Section 2.2.1 in Appendix 2 for more information on this research.

commonality in colour perception (Derefeldt, et al., 2004)[(9)]. For instance, the following points summarise key findings from Madden, et al's. (2000) experiments:

- ***Blue, Green and White.*** Each of these hues[(10)] appears to be associated with terms like peaceful, gentle, calming and pleasant. This may account for the fact that cool colours like blue appear to be preferred across many cultures (Hemphill, 1996; Wiegersma & Van der Elst, 1988).
- ***Black and Brown.*** These colours were typically identified across all of the researched cultures as sad, stale and formal.
- ***Red.*** The colour red stands out as being active, emotional, hot and vibrant.

This listing is a good illustration of the concept that perceptions may be linked to the coolness or warmth of the colour[(11)]. For example, longer 'wavelength colours tend be more perceived as energetic and extraverted, [and] the shorter wavelengths calmer and more introverted' (Crozier, 1996, p. 70). Common arousal[(12)] effects may therefore be directly related to the wavelength of light being received through the eyes (Cajochen, 2007; Lockley et al., 2006)[(13)]. The following subsections explain some of the key aspects of these innate reactions in more detail.

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9. Derefeldt, et al. (2004) identified a separation between perceived colour, which is managed as a percept *(which utilises the physiological elements described in Section 1.3 in Appendix 1)* and cognitive colour *(which is processed through the neural regions discussed in Section 1.4 in Appendix 1)*. The low level percepts consist of combinations of chromatic and achromatic content (Derefeldt, et al., 2004). The percepts are then transformed through 'subsequent higher-order processes', which leverage semantic memory to define cognitive colour (Derefeldt, et al., 2004, p. 7) *(which equates to the concept of representations utilised in this thesis)*. Therefore, the commonality in response is probably due to the initial processing as a percept, and the more complex aspects of learned meaning *(e.g. cultural differences)* are developed at the cognitive level. By understanding these differences, colour can be utilised effectively to assist in optimising communication, by working predominantly at the level of the percept.

10. The term hue refers to the pigment of a colour (Jansson, Marlow, & Bristow, 2004), and it is directly related to the dominant wavelength of the light reaching the retina *(see Section 1.3.1. in Appendix 1)* (Aebi, Gunzburg, Nazarian, & Olmarker, 1997). Hue typically provides the primary way to identify the colour (Hall & Hanna, 2004), but it is also affected by saturation and luminance *(brightness)*. See Section 2.1 in Appendix 2 for more information on hues and how these have been handled in this thesis.

11. See Section 2.1.3 in Appendix 2 for more details on colour temperature.

12. See Section 8 in the document at this web location http://www.seahorses-consulting.com/DownloadableFiles/ShapingAttentionHandout.pdf for more information on arousal.

13. This arousal may be directly related to the effect of the light on the suprachiasmatic nucleus (SCN) *(see Section 1.3.3.2 in Appendix 1)* and subsequently areas such as the reticular formation *(see Section 1.3.4.3 in Appendix 1)* and the pons *(see Section 1.5 in Appendix 1)*. For instance, aspects such as autonomic arousal are influenced by the effect of light on the SCN and the associated hypothalamus (Challet, 2010).

1.1.2.1. Common Effects of Light Wavelength on Perception, Cognition and Arousal

Some of the key effects attributed to the differences in the wavelength of light entering the eyes are illustrated in Figure 1.1[14]. These wavelengths are shown in terms of the perceived colour generated *(See Section 2.1.2 in Appendix 2 for more information on this colour wheel concept).*

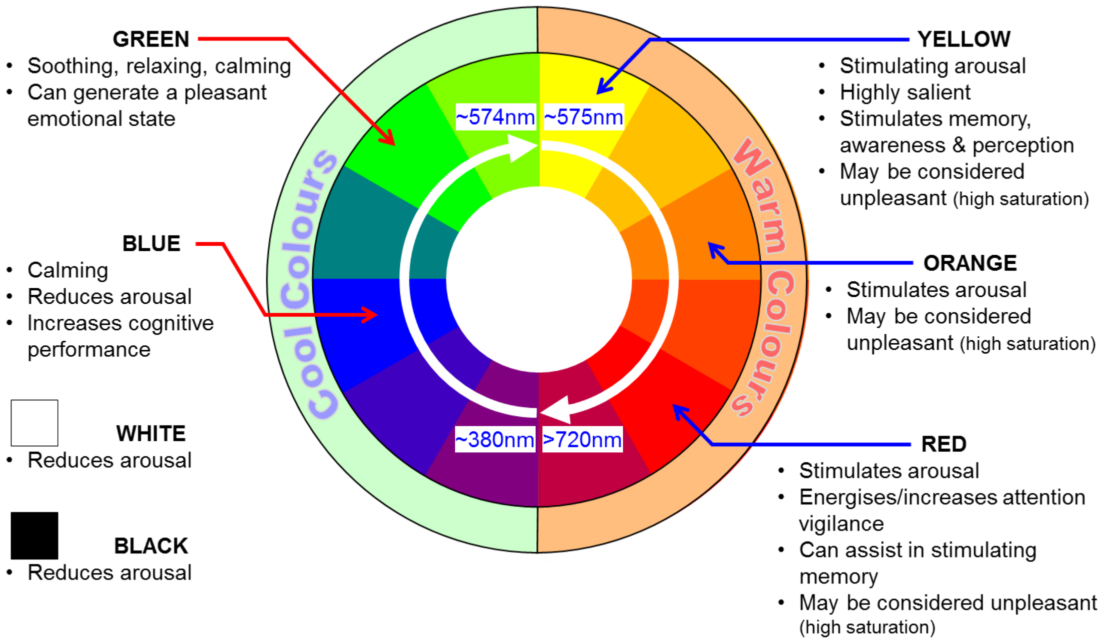

Figure 1.1: Effects of Different Colours (Wavelengths of Light)

The following are the key points illustrated within this diagram:

- ***Blue.*** Blue light may aid perception and cognition[15] (Massachusetts General Hospital, 2009). In particular, research conducted by Mehta & Zhu (2009) indicated that blue could be used to enhance performance on a creative task[16]. There is

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14. This diagram was developed by the author, by coalescing and rationalising information provided in Lehrl, et al. (2007), Massachusetts General Hospital (2009), Fordham & Hays (2009), Lockley, et al. (2006), Abbas, (2006), Crozier (1996), Valdez & Mehrabian (1994), Jones (1997) and Derefeldt, et al. (2004).

15. The cognitive stimulation created by the blue and yellow colours may be associated with the processing within the koniocellular pathway *(see Section 1.3.2.3 in Appendix 1)*. Because this very fast pathway for blue/yellow information is associated with rapid transmission of information through to the dorsal stream *(see Section 1.4.2 in Appendix 1)*, this may be involved in the prompt triggering of conscious processing *(see Section 1.2.3.2 in Appendix 1)*. However, at the time of publishing this thesis, no specific research has been identified to validate this hypothesis. Additionally, the blue/yellow light processing has been linked with cerebral dopamine production, which is an important chemical for stimulating cognition (Hulka, Wangner, Preller, Jenni, & Quednow, 2012).

16. However, they did not posit a psychophysical or biopsychological reason for this outcome.

evidence to indicate that this influence on cognitive processing may be due to the effects of blue light on the human circadian rhythm[17] (Lehrl, et al., 2007). However, this effect may also be attributable to the level of luminance (Figueiro, Bierman, Plitnick, & Rea, 2009).

- ***Cool Colours.*** Green light appears to provide a pleasant effect on the emotional state of many viewers, however, blue light appears to have the most relaxing effect on many viewers (Abbas, 2006; Crozier, 1996).
- ***Yellow***. Yellow light has been identified as also stimulating perception[15], awareness and perception (Massachusetts General Hospital, 2009). However, large areas of high hue yellow can cause visual fatigue, and produce psychological stress (Daggett, Cobble, & Gertel, 2008).
- ***Warm Colours.*** The warmer colours appear to stimulate arousal, but may become unpleasant for the viewer if there is too much of these hues in the field of view (Abbas, 2006; Galitz, 1997; Hempel, 2012; Valdez & Mehrabian, 1994).
- ***Red.*** The following are some of the key effects reported for red colours:
    - ***Suppress Cognition.*** According to the research conducted by Elliot, Maier, Moller, Friedman & Meinhardt (2007), significant amounts of red appear to suppress cognition.
    - ***Cause avoidance behaviours.*** Red colours can also lead to avoidance behaviours (Elliot & Maier, 2007).
    - ***Suppress processing.*** There is evidence which indicates that the presence of significant amounts of red hue may attenuate the processing of information within the perception system (Edwards, Hogben, Clark, & Pratt, 1996; Pammer & Lovegrove, 2001). For example Seno, Sunaga, & Ito (2010) identified that red may suppress processing within the Magnocellular pathway[18], which could retard visual gist assessment, and the processing of perceived motion *(e.g. animation)*, and adversely affect the viewer’s ability to read (Chase, Ashourzadeh, Kelly, Monfette, & Kinsey, 2003).
    - ***Provides stimulation for attentional focus.*** Research conducted by Mehta & Zhu (2009) also found that some red in the field of view could enhance performance on focussed detail-oriented tasks. This outcome may be due to the generation of arousal in the viewer[19] (Rosenbloom, 2006), because red lighting *(and natural light)* has a significant impact on arousal (Abbas, 2006).
- ***Achromatic Hues.*** The achromatic[20] colours appear to be less arousing Massachusetts General Hospital (2009), and may not facilitate the generation of

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17. See Section 1.3.3.2 in Appendix 1 for more information on the circadian rhythm and the suprachiasmatic nuclei, which are key drivers for this rhythm.
18. See Section 1.3.2.2 in Appendix 1 for more information on this pathway.
19. This type of arousal may be due to the generation of neuro-regulating chemicals such as catecholamines, dopamine, and norepinephrine in the presence of red lighting (Rosenbloom, 2006).
20. See Section 2.1.2 in Appendix 2 for more information on the terms chromatic and achromatic.

memories as effectively as coloured *(chromatic)* content (Spence, Wong, Rusan, & Rastegar, 2006). In particular:

- ***White.*** Pure white light may provide the most neutral and relaxing effect on arousal (Abbas, 2006). However, research by Hau, Miao, & Zhang (2009) also identified that white light generated vigilance, but this may have been due more to the higher level of luminance than the hue.
- ***Black.*** Black is a non-arousing colour (Hau, Zhang, & Miao, 2009). Additionally, large areas of this achromatic colour may reduce the luminance of the display (Mantiuk, Daly, & Kerofsky, 2008), which can directly reduce arousal (Figueiro, et al., 2009), and also make it harder for the viewer to focus, due to the induced dilation of the iris[21].

In addition to the influence of hue, saturation and luminance[22] may actually have more impact on innate reactions (Crozier, 1996; Wang & Ding, 2012). For example, as cited by Crozier (1996):

- brighter saturated colours may be assessed as being more pleasant;
- saturated darker colours may be more arousing than less saturated darker colours; and
- less bright and more saturated colours appear to generate judgements of greater dominance *(see colour weight in Section 1.1.2.3).*

1.1.2.2. Colour Salience

The wavelength of light also affects the salience of the colour, due to the level of stimulation that it provides to the human perception system. Figure 1.2[23] illustrates the relative

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21. Reducing the level of luminance can induce dilation of the pupil through the Edinger-Westphal reflex *(see Section 1.3.4.2 in Appendix 1)*, and in turn this reduces the scope for focussing the eye.

22. Saturation refers to the vividness of the colour, and can be measured by the lack of grey in the colour (Valdez & Mehrabian, 1994). Some publications further delineate saturation as tints *(the amount of white in the colour)*, or shades *(the amount of black in the colour)* (Duarte, 2008). In other words, saturation is used to define the proportion of the primary pigment in the hue *(e.g. the amount of white or black in the colour)* (Jansson, et al., 2004). Brightness, or luminance, refers to the intensity of light reaching the retina (Fulton, 2008).

23. This diagram was developed by the author, by rationalising information provided in Garrett (2003), Pridmore (1999), Bowmaker & Dartnell, Fulton (2003), Wiesel & Hubel (1966), Roorda & Williams (1999), Lillo, Aguado, Moreira, & Davies (2004) and Hofer, Carroll, Neitz, Neitz, & Williams (2005). This graph modifies the basic stimuli peak information provided at Figure 1.10 in Appendix 1, to reflect the influence of each type of retinal photoreceptor on perception. Firstly, the ratio of L *(Red: ~63% on average)*, M *(Green: ~ 32% on average)* and *S (Blue: ~ 5% on average)* cones has been taken into account. Additionally, the ratio of rods to cones (~20:1) has also been built into this model. However, these ratios are modified by the preponderance of connections within the retina for L and M cone cells in the fovea and peripheral region *(see Section 1.3.1 and Figure 1.13 in Appendix 1)*, and the focus on the foveal and parafoveal perceptual information in the visual cortex *(see Section 1.3.5 in Appendix 1)*. For this reason, the L and M cone influence has been increased in the graph by between 12 and 24 times (Duncan & Boynton, 2003) the level applied for rod cells *(the weightings are based on mosaic information provided in Roorda & Williams*

influence that different wavelengths of light may have on arousal and perception, by linking this information to the relative effect of stimulation through the rods and cones in the retina.

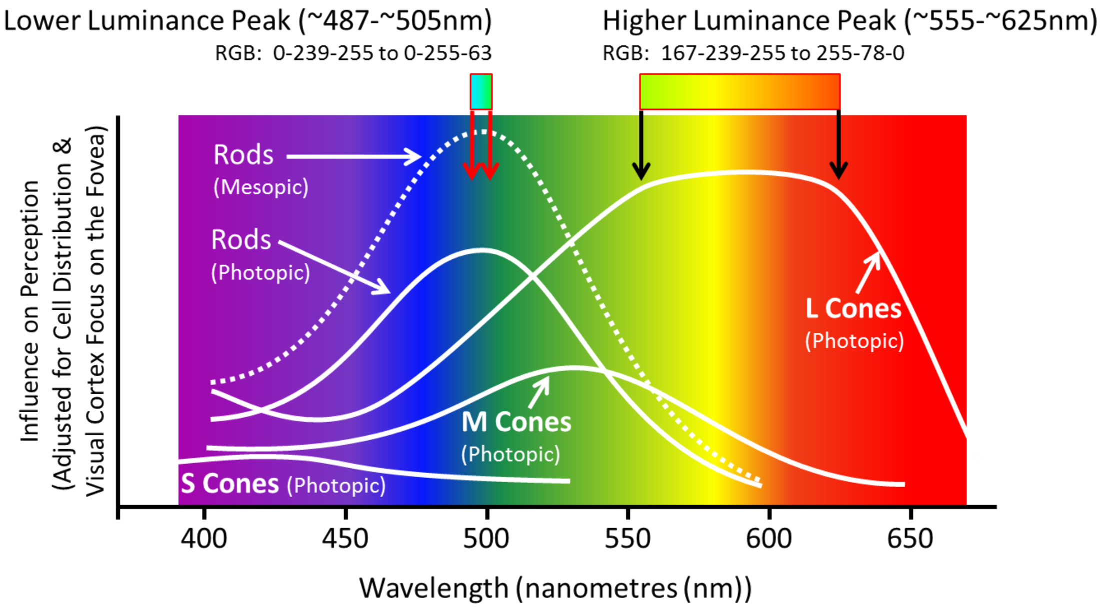

Figure 1.2: Salience by Colour Wavelength

In Photopic conditions *(see Figure 1.11 in Appendix 1)* the L *(Red)* and M *(Green)* cones have significant influence on perception, as shown in this diagram. As the level of illumination reduces, the rod cells become much more influential on perception (Fulton, 2005). However, this diagram also illustrates the importance of the rod cells in providing stimulation in the presence of bluish-green colours (~498 nm) in Photopic conditions (Brown & Wald, 1964).

This diagram also takes into account the effects of the Perkinje[(24)] and Bezold-Brücke[(25)] shifts, which are created by changes in luminance. Therefore, as illustrated at the top of

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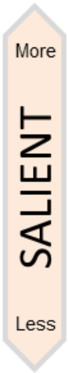
(1999)), because the rods are predominantly in the peripheral areas *(as illustrated in Figure 1.12 in Appendix 1)*. Additionally, the curves for rod cells take into account the shift in luminosity from the Photopic to the Mesopic range, and the growing effectiveness of the rods, as the level of brightness decreases *(see Figure 1.11 in Appendix 1)*. Curves for the cone cells stimulation in Mesopic conditions have not been included in this graph to minimise ambiguity, and because these cone curves become progressively less significant as the luminosity reduces. This diagram also takes into account the feed of colour information from rod cells, which increment or decrement the colour stimuli being processed by the cones (Shepherd & Wyatt, 2008). Finally, this diagram cannot be definitive as there is considerable variation in the ratios of S, M, and L cones, and their array within the retinal mosaic (Roorda & Williams, 1999). However, this diagram appears to be strongly indicative, and the findings from this model align with the other research information specified in this section.

24. ***Perkinje shift.*** As the level of luminance changes, the perception of the wavelength of light also shifts (Anstis, 2002; Zagarenski, 2007), and therefore the points of peak stimuli also move (Fulton, 2007). For example in the Photopic range, as the level of luminance increases the maximal stimulation is linked to colours like yellow-green *(~555nm)* (Anstis, 2002), to yellow *(~580nm)* and then to reddish-orange *(~625nm)* (Fulton, 2005). Additionally, as the

Figure 1.2 there are two ranges of peak stimulation, which roughly equate to colours in the greenish-blue to shades of green *(~487 to ~505nm)* range, and yellowish-green, to yellow, and then to reddish-orange *(~555 to ~625nm)* wavelengths (Anstis, 2002; Fulton, 2003; Pridmore, 1999)[26]. These light wavelengths are therefore more likely to stimulate the perception system, and should tend to be more salient. For example, research conducted by Gelasca, Tomasic, & Ebrahimi (2005) identified that the most salient colours were those illustrated in Figure 1.3[27]



	Example	Colour	R	G	B	Salience Hits
1		Red	255	0	0	128
2		Yellow	255	255	0	87
3		Green	0	255	0	81
4		Pink	255	192	203	60
5		Orange	255	126	0	44
6		Blue	0	0	255	32
7		Cyan	0	255	255	32
8		Magenta	255	0	255	26
9		Light Blue	173	216	230	16
10		Maroon	128	0	0	14
11		Violet	238	130	238	11
12		Dark Green	0	100	0	10

Figure 1.3: Most Salient Colours

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luminance increases, the maximum for the lower peak shifts from shades of green *(~505nm)* (Anstis, 2002) to the greenish-blue range *(~487nm)* (Fulton, 2003), which is also partly due to the Bezold-Brücke shift.

25. ***Bezold-Brücke shift.*** This concept explains changes in hue perception, as light intensity is modified. For instance, as light intensity increases, spectral colours appear to shift toward blue for wavelengths below 500nm, or yellow for wavelengths above 500nm (Fulton, 2003; Pridmore, 1999). Therefore, in the Photopic range of luminance *(that is pertinent to this thesis)*, wavelengths below 500nm will tend to shift toward blue and this is likely to shift the position of the optimal lower peak stimuli to the lower end of the range illustrated in Figure 1.2. A description of the reason for this is beyond the scope of this thesis, but a useful explanation of likely causation is provided in Walraven (1961).

26. There is significant ambiguity in the literature in relation to the extent of these ranges of maximum stimulation. For example, Fulton (2005) identified a unique peak for stimulus at 580nm *(yellow)*, but in high luminance this peak may be as high as 625nm *(reddish-orange)*. At the other end of the scale, Kose (2008) reported that the maximum stimulation was at around 556 nm *(yellowish-green)*, and this also aligns roughly to the information provided in Anstis (2002) *(555nm)*. This peak equates to the situation in which equal luminance is provided across hues (Fulton, 2003), and does not take into account the Perkinje and Bezold-Brücke shifts. The lower wavelength peak has been identified within the range of greenish-blue *(487nm)* (Fulton, 2003) to shades of green *(505nm)* (Anstis, 2002). Pridmore (1999) also identified similar peaks within these ranges during Bezold-Brücke shift experiments. To avoid limiting the results, the full range of identified peaks has been included in the diagram, but the actual peak experienced within these ranges will be directly related to the level of luminance.

27. The primary information was drawn from Figure 2 in Gelasca, et al. (2005, p. 3).

The right hand column in Figure 1.3 also illustrates the number of visual hits applied to each colour within Gelasca, et al's (2005) experiment *(n=11)*, and therefore the level of salience. This data indicates that the most salient colours are closely linked to the two stimulation peaks illustrated in Figure 1.2. Figure 1.3 also illustrates two other significant salience factors:

- ***Saturation.*** Higher colour saturation can create salience and draw attention (Camgöz, Yener, & Güvenç, 2004; Macaulay, 1995), particularly when there are differences from surrounding objects or the background (Egusa, 1983). For example, in the research shown at Figure 1.3, the most salient colours are highly saturated.
- ***Luminance.*** Areas of highest brightness also tend to be the most salient (Camgöz, et al., 2004). This effect is demonstrated in Figure 1.3, by the prevalence of lower luminance colours at the bottom end of the salience scale. Such salience may be due to the propensity for rod cells in non-foveal vision to detect changes in luminance, which can then generate significant overt attention (Lambert, Wells, & Kean, 2003)(28).

Therefore, when identifying the most salient chromatic colours, hue, saturation and luminance should be taken into account. Additionally, chromatic hues will typically be more salient than achromatic colours like black and white (Evans, Moutinho, & van Raaij, 1996), except in contrast situations (Camgöz, 2000).

1.1.2.3. Colour Harmony

Colour harmony relates to the interaction of different colours, and it is one of the most important aspects for shaping a viewer's impressions (Ou, Luo, Woodcock, & Wright, 2004b). Such harmony issues affect innate reactions at a fundamental biological level (Garrett, 2003), and some aspects are also learned (Burchett, 2002). According to Burchett (2002) there are key harmony configuration issues influencing the use of colour, and these can be defined as follows:

- ***Area.*** Area refers to the size of the colour areas, in relation to other coloured areas within the field of view. As the area of a specific colour increases, the effect of that colour will also tend to increase, and this must be taken into account within the design of the visual harmony.
- ***Association.*** The term association relates to the learned meanings and impressions related to certain colours. Where possible, colour harmony should take these aspects into account *(e.g. linking colours based on cultural meanings and preferences where these can be identified and isolated for the viewers, by applying the types of insights detailed in Section 2.2 in Appendix 2).*
- ***Attitude and tone.*** The attitude and tone of a colour may be defined by its innate aspects, such as salience, and also inferred meanings such as those described in Section 2.2 in Appendix 2. For example, Figure 1.4(29) illustrates the perceived colour attitude

28. This is likely to be due to the fast tracking of percepts through the magnocellular pathway through the dorsal stream *(which is highly responsive to changes in luminance)* (Lambert, et al., 2003).

29. This data is drawn from the research conducted by Ou, et al. (2004a; Ou, et al., 2004b), which is described in Footnote 43 in Section 2.2.1 in Appendix 2.

and tone, in terms of the perceived activity, weight and heat of different colours. In relation to the innate reactions, the perceptions of the participants may be understood in terms of the following:

- the perception of how active a colour is appears to be associated with the salience colour issues described earlier;
- the colour weight can be equated to the shade *(saturation and luminance)* of the hue in many cases *(e.g. more shade equals more colour weight)*; and
- the perceived colour heat appears to be closely aligned to the wavelength of the light *(higher wavelengths are typically perceived as warmer)*, and the shade and luminance *(e.g. higher tints and brightness should typically be perceived as warmer)*.

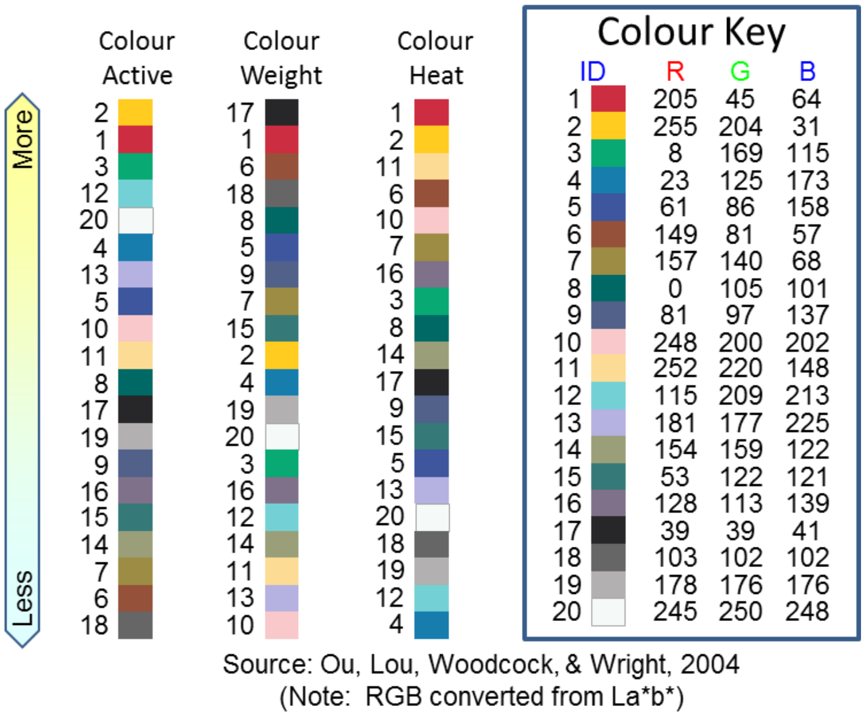

Figure 1.4: Examples of Colour Attitude

- ***Interaction.*** This aspect of harmony relates to the way different colours interact within the perception system. As shown in Figure 1.5[(30)], significant negative impacts on perception can be induced by some colour interactions. For example, as shown in Example 1, when saturated opponent colours[(31)] are placed near each other, an

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30. Example 1 is sourced from Luke (2009). A detailed description of the reasons for these illusions is beyond the scope of this thesis. However, further information on causation can be sourced in Eagleman (2001); Martinez-Conde & Macknik (2009); Wilkins, et al. (1984); Coello, Danckert, Blangero, & Rossetti (2007) and Seckel (2006).

31. This refers to the colour opponent grouping within the photoreceptor mosaics in the retina, as illustrated in Figure 1.15 in Appendix 1. As illustrated in this example, the effect is initiated by the interaction between the green and red, and blue and yellow groupings, and the interplay with pure black and white.

uncomfortable vibrating illusion can be created (Smaldino, et al., 2008). Alternatively, Example 2 illustrates how the perception of a colour can be modified by interaction with other colours within their vicinity[(32)] (Camgöz, 2000; Macaulay, 1995).

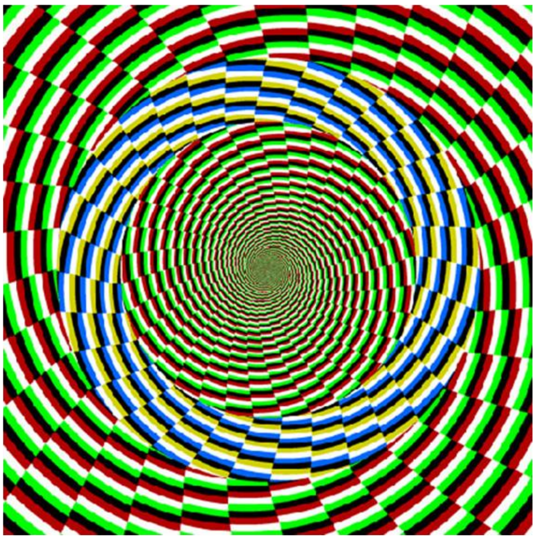
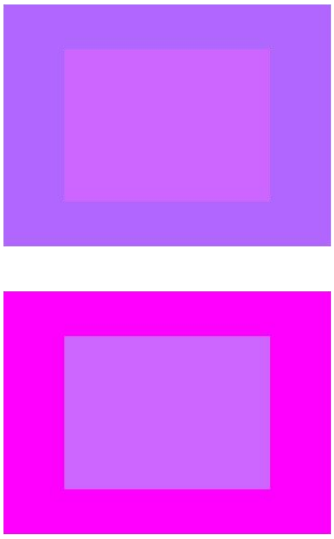
EXAMPLE 1	**EXAMPLE 2**
	
If a viewer gazes into the middle of this picture they are likely to see apparent movement. This is partly due to salience induced shifts in attention, which are created by the colour interactions.	Is the central box the same colour in each of these two rectangles? It is…although the one on top appears darker. The illusion is created by the interaction of colour.

Figure 1.5: Examples of Colour Interaction

- ***Order.*** This last harmony aspect relates to the selection of colour combinations which do not create interaction problems. Figure 1.6[(33)] illustrates some examples of colour ordering methods, which typically generate positive colour interactions. Although this diagram utilises fully saturated colours, the same effects can be achieved with different shades and tints of each hue, by modifying the saturation and luminance of the colour. Additionally, combinations of this nature anywhere within the colour wheel can also be appropriate. By adjusting these colour combinations subliminal inferences can be generated (Ivanov & Werner, 2007). For example, opposite/complementary colours can create striking mental contrasts (Duarte, 2008), or analogous/related combinations *(similar colours)* can support the visual linking of information to create an impression (Reynolds, 2010).

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32. The perceived colour from one location is influenced by light being reflected from surrounding regions (Blackwell & Buchsbaum, 1988; Land & McCann, 1971). This is called simultaneous contrast (Macaulay, 1995). The mixing of the colours in this way may be achieved in area V4 (Crick & Koch, 1998) *(see Section 1.3.5 in Appendix 1 for more information on V4).*

33. This model was developed by the author using information provided in Duarte (2008); Lamb & Bourriau (1995); Valdez & Mehrabian (1994); Macaulay (1995); and Smaldino, et al. (2008).

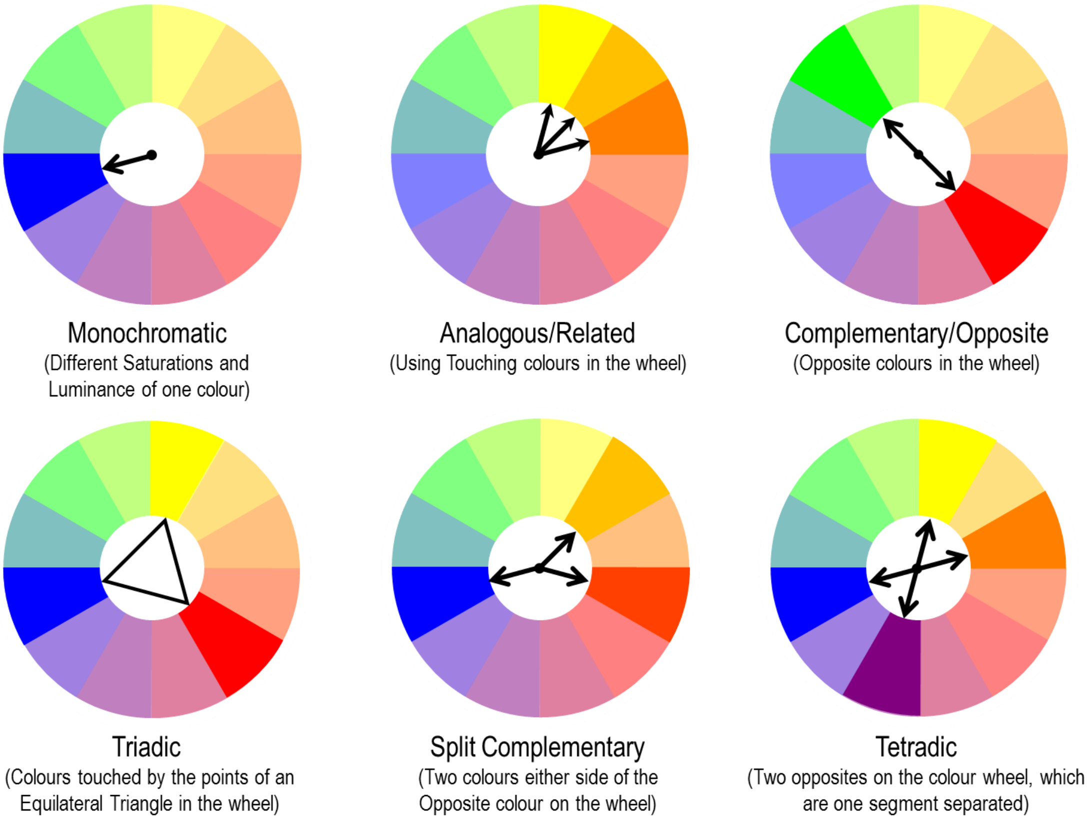

Figure 1.6: Common Colour Harmonies

1.1.3. Identified Optimal Approach

The preceding sections identify key colour principles that can be applied to optimise communication.

- ***Develop a Colour Code.*** In compliance with the recommendation provided by Jones (1997) a colour code system should be developed. This colour scheme should be designed to meets user expectations (Macaulay, 1995; Pett & Wilson, 1996), by applying the colour harmony principles. This colour coding system should then be applied consistently, in accordance with the advice from Pett & Wilson (1996). For example, a triad colour combination of yellow, red and blue can be selected *(see Figure 1.6).* This combination is harmonious and generally aligns to the most salient colours within the two stimulation peaks illustrated in Figure 1.2. Additionally, achromatic colours *(white, grey and black)* should then be added to this standard colour scheme. Different tints and shades can then be applied within this standard colour coding, as illustrated in Figure 1.7.

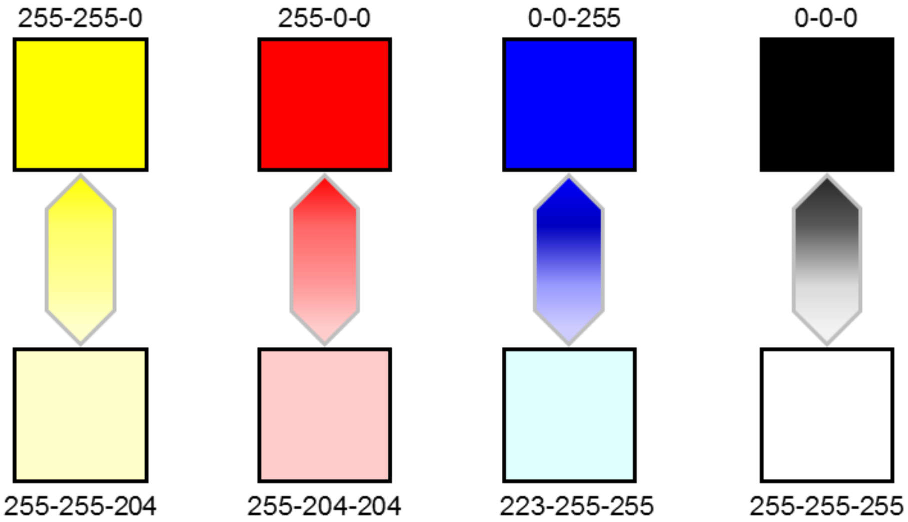

Figure 1.7: An example of a standard colour scheme

- ***Use colour to optimise complexity.*** This standard colour scheme should then be utilised to optimise complexity[34], by applying the strategies listed in Table 1.1. The references used to define each strategy are also included in this table.

Table 1.1: Managing the complexity variables for colour

Complexity Variable	**Managing the Variable**
Content	▪ Colour should be applied to group and highlight common elements (Macaulay, 1995), to form relationships between visual objects (Jones, 1997), and make the content easier to identify. ▪ Colours should be applied to create salience for key information (Jansson, et al., 2004) *(e.g. key words should be highlighted in red and blue, and low saturation high luminance yellow should be used to attract attention to key visual information).* This approach is designed to help the viewer to readily identify the most important content.
Context	▪ The colours applied to each screen element should be designed to reinforce meaning (Jones, 1997; Macaulay, 1995) *(e.g. warmer colours should be used for action inference, cooler colours should be applied to denote stability and authority)*, to assist the viewer to contextualise the information.
Continuity	▪ The common colour scheme should be utilised to prime the viewer in preparation for each search task (Vierck & Miller, 2008) *(e.g. focussing on yellow first)*, to reinforce the continuity of the presented material.

34. You can find an introduction to complexity issues within the handout at this web location: http://www.seahorses-consulting.com/PresentationContent/ComplexityVariables.pdf.

Complexity Variable	Managing the Variable
	▪ Colour should be applied to enhance the reality of the visual information (Crozier, 1996) *(e.g. adding coloured pictures)*, so the viewer can link to the innate and learned inferences.
Clutter	▪ As recommended by Elliott (2003), the selected colour scheme should be applied to simplify the visualisation. ▪ Only a few colours should be used in each slide *(apart from colour in the pictures)* (Macaulay, 1995) to minimise visual complexity (Roberts, 2007). ▪ Saturated warm colours should only be utilised in relatively small areas, to reduce the risk of over-stimulation *(in accordance with the recommendations by Macaulay (1995))* that generates fundamental visual complexity. ▪ Solid colours *(without patterning)* should normally be applied, as these are the most effective in multi-colour presentations (Hoadley, 1988; Humar, Gradisar, & Turk, 2008). These types of colour appear to be best at generating understanding, and reducing visual complexity.

1.2. *For more information*

Should you wish to contact the author, he can be reached at the following email address:

info@seahorses-consulting.com

Appendix 1: Description of the Key Neural Processes used for Managing Visual Information

This appendix can be found at the following web address:

http://www.seahorses-consulting.com/DownloadableFiles/Appendix1.pdf

Appendix 2: Additional Colour Information

2.1. Colour Standards in this Thesis

2.1.1. Different Colour Models

The interaction between colours in the printed *(e.g. on a piece of paper)* and displayed *(e.g. on a computer screen)* is quite different (Garrett, 2003). For example, when they are printed, colours interact in a subtractive model, whereas colours shown on an electronic display combine through integration (Gradisar, Humar, & Turk, 2007). Figure 2.1(35) illustrates key differences within these two colour interaction models.

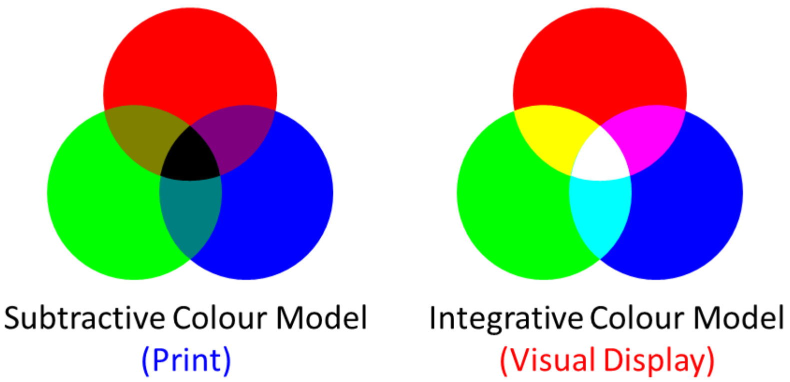

Figure 2.1: Subtractive and Integrative Colour Models

A key difference is that integrating hues *(e.g. red, green, blue)* on a computer display creates white, whereas adding more pigment in the printed medium produces black (Garrett, 2003). Additionally, the colours generated on a screen, or through projection, will typically provide higher levels of luminance than printed material, and this variation can have a significant effect on perception (Ries, 2007; Shieh & Lin, 2000), as discussed in Section 3.4.1.2.2 in Volume 1 of this thesis.

The colour quality in integrative displays can also be inferior to subtractive colour prints(36) (Humar, et al., 2008; Ramadan, 2011), but this situation appears to be changing as screen resolution improves (Grizzle, 2008). However, when these experiments were conducted, resolution issues could have introduced some level of variability from findings related to the subtractive colour model.

For these reasons some of the more traditional research findings for colour have been treated with caution.

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35. This diagram is adapted from Figure 9.9 in Garrett (2003, p. 261).

36. This is likely to be due to the fact that the image quality on a screen is considerably less than the level of definition that is feasible due to the close packing of cells within the retina, particularly within the fovea and parafovea *(see Section 1.3.1.2.1 in Appendix 1 for more details)*.

2.1.2. Colour Descriptions

The perception of colour is highly subjective (Nishiyama, 2012), because of the interaction of the various physiological and neural elements involved in perception (Gegenfurtner & Kiper, 2003). Therefore the description and naming of colours can also be highly subjective (Şahin Ekici, Yener, & Camgöz, 2006).

To avoid confusion in this paper, all colours will be referred to by their Red, Green, Blue (RGB) colour code(37). Where colour names are utilised the following two conventions will be applied:

- the colour names used by the various researchers will be applied in the text or diagrams, and the associated RGB code will also be included wherever this is possible; and
- where other colour names are used in this thesis, the terms will comply with the colour nomenclature listed in Table 2.1(38).

Table 2.1: Colour Descriptions and the Associated RGB Codes

CIE 1976 UCS Descriptors		**Nominal RGB code or Approximate RGB range**
Wavelength (nm)	**Description**	
< 380	Purple	160-32-240 to 51-0-76
381-400	Bluish Purple	53-0-80 to 73-0-165
401-439	Purplish-Blue	73-0-170 to 2-0-255
440	Blue	0-0-255
441-481	Shades of Blue	0-5-255 to 0-209-255
482-488	Greenish-Blue	0-214-255 to 0-244-255
489-492	Bluegreen	0-249-255 to 0-255-229
493-498	Bluish-Green	0-255-216 to 0-255-153
499-531	Shades of Green	0-255-140 to 76-255-0

37. As explained in Section 1.3.1.2.1 in Appendix 1, there are three types of cone photoreceptor cells in the human retina, which are predominantly responsible for perceiving colour. These can be classified by their general stimulation preference for different wavelengths of light. The three types of cone can be categorised as Red *(Long wavelength)*, Green *(Medium wavelength)*, and Blue *(Short wavelength)* cells. Additionally, rod cells tend to be stimulated by Blue and Green wavelength light. Because the human perception of colour is defined by these three types of cone and the rod cells, colour generated within computer screens can be defined by changing the amount of red, green or blue colouration applied to each pixel. This is applied through a scale, which ranges from 0 *(none of that colour)* to 255 *(full hue for that colour)*. The RGB scale has also been used because tools like PowerPoint® use this as a primary method for setting screen colour.

38. The left two columns of this table are drawn from the International Commission on Illumination (CIE) Uniform Chromaticity Diagram (UCS) and they show the associated wavelength *(in nanometres (nm))* and the standardised name used for that colour. For the purposes of clarity, the terms used in this CIE UCS standard for Red, Green, Blue and Yellow have been listed as 'Shades of' those colours. The Red, Green, Blue and Yellow names have been reserved for the pure versions of these colours, as specified within the RGB code. The final column in this table provides the nominal RGB code for specific colours, or ranges of colours that apply to that nomenclature.

CIE 1976 UCS Descriptors		Nominal RGB code or Approximate RGB range
Wavelength (nm)	Description	
510	Green	0-255-0
532-558	Yellowish-Green	80-255-0 to 174-255-0
559-569	Yellow-Green	178-255-0 to 214-255-0
570-574	Greenish-Yellow	218-255-0 to 233-255-0
575-579	Shades of Yellow	236-255-0 to 251-255-0
580	Yellow	255-255-0
581-586	Yellowish-Orange	255-251-0 to 255-231-0
587-597	Orange	255-227-0 to 255-188-0
598-625	Reddish-Orange	255-184-0 to 255-78-0
626-720	Shades of Red	255- 74-0 to 76-0-0
650	Red	255-0-0
720 >	Purplish Red & Reddish Purple	184-0-0 to 76-0-38

These colours can be shown graphically as illustrated in Figure 2.2[39], which demonstrates the relationship between the naming conventions, and RGB codes.

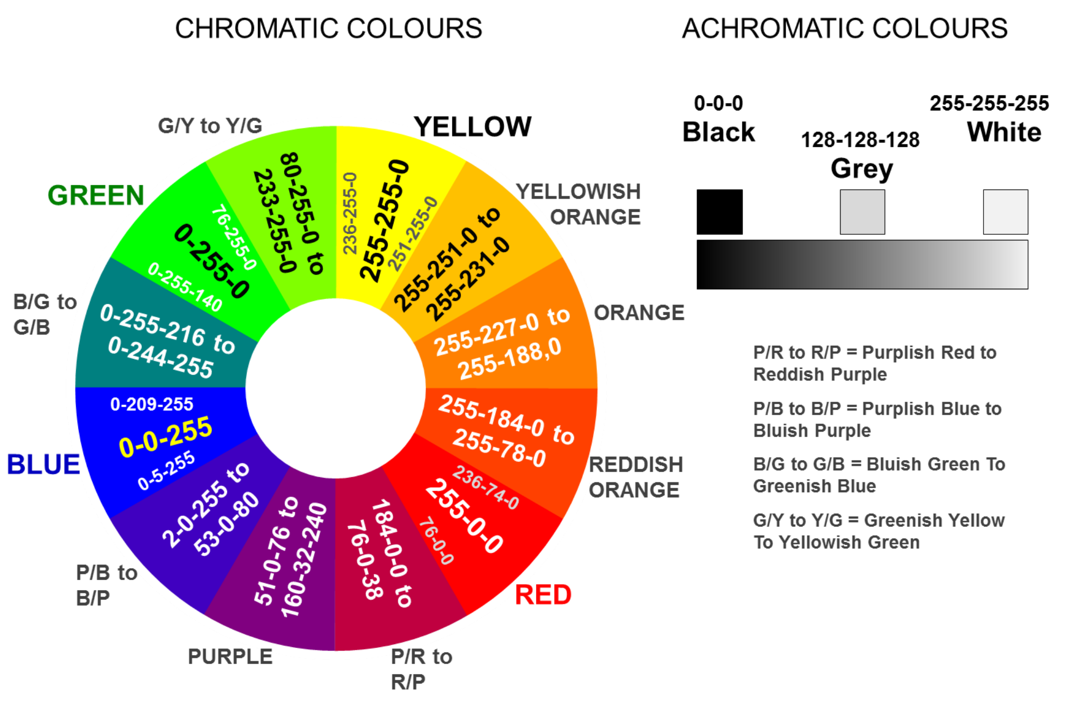

Figure 2.2: Colour Wheel (Chromatic Colours) and Achromatic Colour Scale

The left side of this diagram represents a colour wheel (Harkness, 2006), which identifies the range of chromatic colours. The full hue[(40)] red, green, blue and yellow colours are

39. This model was developed from information provided in Harkness (2006), Duarte (2008), Willard (2001), Reynolds (2010) and Lujin, Giesen, Mcdonnell, Zolliker, & Mueller (2008). These publications were selected, because they represent information provided within the two paradigms *(graphic design/psychology)*.

40. The term hue refers to the pigment of a colour (Jansson, et al., 2004), and it is directly related to the dominant wavelength of the light reaching the retina *(see Section 1.3.1. in Appendix 1)*

specifically highlighted. The right side of Figure 2.2 illustrates the achromatic colour range *(e.g. black, grey, white)*.

2.1.3. Colour Temperature

As shown in Figure 2.3[41] colours can be classified as cool or warm (Kaya & Epps, 2004), and this categorisation is directly related to the wavelength of the light being received by the eye (Ou, et al., 2004a).

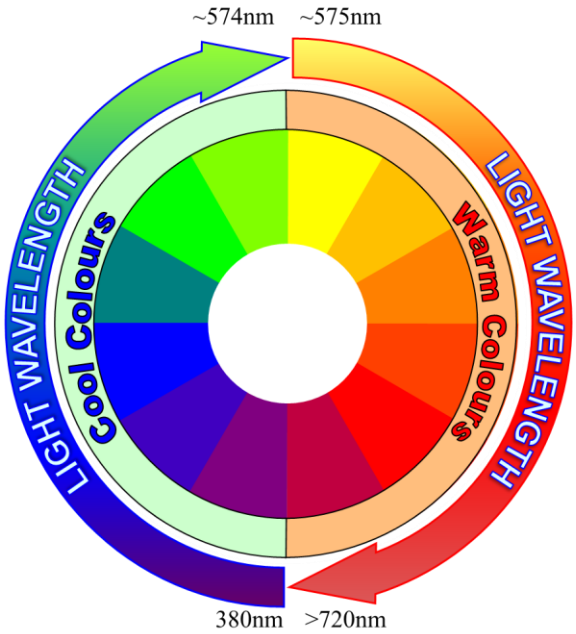

Figure 2.3: Warm and Cool Colours

However, this is a generalised model for classification, and it is the interaction between colours that defines the relative coolness or warmth of the hue (Singh, 2006).

The effects of warm and cool colours have been characterised as follows:

- ***Warm Colours.*** The warm colours have been identified as exciting emotions and drawing attention (Wang, et al., 2008), and may also induce anxiety in some people *(e.g. red and yellow)* (Kaya & Epps, 2004). Warm colours, such as red, are also more

(Aebi, et al., 1997). Hue typically provides the primary way to identify the colour (Hall & Hanna, 2004), but it is also affected by saturation and luminance *(brightness)*. Saturation refers to the vividness of the colour, and can be measured by the lack of grey in the colour (Valdez & Mehrabian, 1994). Some publications further delineate saturation as tints *(the amount of white in the colour)*, or shades *(the amount of black in the colour)* (Duarte, 2008). In other words, saturation is used to define the proportion of the primary pigment in the hue *(e.g. the amount of white or black in the colour)* (Jansson, et al., 2004). Brightness, or luminance, refers to the intensity of light reaching the retina (Fulton, 2008).

41. This model was developed from information provided in Ou, Luo, Woodcock, & Wright (2004a), Harkness (2006), Duarte (2008), Willard (2001), Reynolds (2010) and Lujin, Giesen, Mcdonnell, Zolliker, & Mueller (2008).

likely to be identified as being closer, or in the foreground[42] (Kosslyn, Kievit, Russell, & Shepard, 2012; Wang, et al., 2008). Additionally, warm colours have been reported to generate autonomic arousal (Bellizzi & Hite, 1992). It is possibly because of this arousal, that warm colours are often believed to relate to action (Kaya & Epps, 2004; Pearson & van Schaik, 2003).

- ***Cool Colours.*** Cool colours have been identified as creating openness and distance (Wang, et al., 2008). Additionally, these colours have been associated with terms such as peaceful, calming and restful (Bellizzi & Hite, 1992; Kaya & Epps, 2004), so they are often seen as more passive (Pearson & van Schaik, 2003).

2.2. Colour Preferences and Induced Emotions

2.2.1. Colour Preferences

A significant amount of research has been conducted to identify specific colour preferences, and some general trends have been identified (Crozier, 1996). However, there is also a substantial amount of misinformation applied within this field, and some of the widely cited information used in graphic design literature has been superseded (O'Connor, 2011). For example, the general colour preference listing developed by Eysenck (1941) *(which is shown in Figure 2.4* [43]*)* is widely quoted in academic and research papers *(e.g. Adams & Osgood, (1973), Ou, Lou, Woodcock, & Wright (2004b), Lehrl et al (2007), Manav (2007), Rider (2009))*, and graphic design web sites *(e.g. Hallock (2010), Lynch & Horton (2002))*.

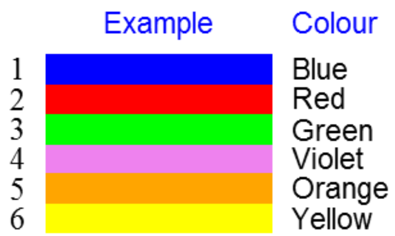

Figure 2.4: General Colour Preferences

However, following research has illustrated considerable variability in preference findings. For example, Figure 2.5[44] illustrates the preferences identified in three different research

42. This appears to be due to ‘chromostereopsis (where the lens refraction causes red objects to be perceived closer than blue objects)’ (Wang, et al., 2008, p. 1745).

43. Eysenck (1941) identified the first four colour preferences as being common across both genders, but the order of the bottom two positions were different for men and women. In this experiment (n=30) the absolute hue of the colours was not fully identified. However, Eysenck (1941) did specify that these colours were fully saturated *(e.g. full hue)*. The colours applied in the diagram are therefore based on commonly acknowledged RGB definitions for hues, which are listed in *Table 2.3*.

44. Example 1 is drawn from Ou, et al. (2004a, 2004b). This research was conducted using cross cultural *(English and Chinese)* and mixed gender groups (n=31). Example 2 applies the findings presented by Adams & Osgood (1973), who conducted cross cultural colour

projects. In each diagram, the most preferred colour is shown at the top of the scale, and the least favoured hue is shown at the bottom.

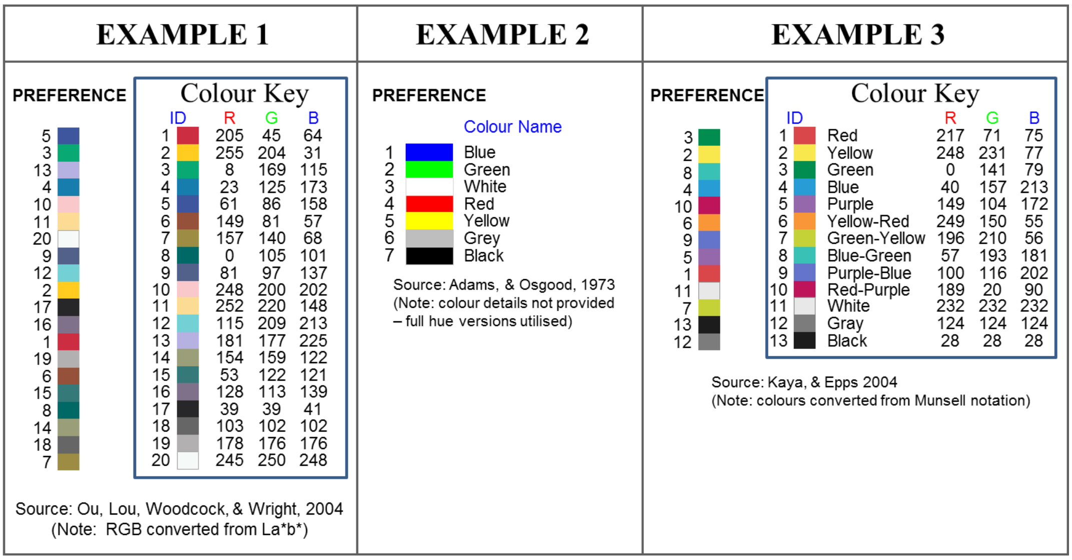

Figure 2.5: Results from different colour preference experiments

The first thing that is noticeable in Figure 2.5 is that there is considerable variation between the three experiments. Some of this variation may be due to the change in saturation within the samples. For instance, the low saturation yellow used in Example 3 was liked, whereas the versions of yellow used in the other experiments were less preferred. Additionally, the colour preference order appears to be significantly different in many respects to Eysenck's (1941) findings *(e.g. yellow is rated more highly in Examples 1 and 3, and red is rated as less preferred than green in all three examples).*

The analysis of preference becomes even more ambiguous when other demographic issues are taken into account. For instance, some cultural variations in colour preference are illustrated in the two research examples illustrated in Figure 2.6[(45)].

preference analysis of high school students (n=851). Example 3 utilises data from college students (n=98), which was collected by Kaya & Epps (2004). In Examples 1 and 3 the RGB codes were calculated from the information provided. Example 2 is typical of some earlier research on this topic, because specific colour definitions were not provided. The colours applied are therefore those listed in *Table 2.3*, because these reflect standard colour naming and hue conventions.

45. The information provided in Example 1 is drawn from Ou, et al. (2004b), which was discussed in Footnote 44. The second example, utilises data collected in the research conducted by Madden, et al. (2000) using participants from Austria (n=29), Brazil (n=26), Canada (n=29), Colombia (n=48), Hong Kong (n=19), China (n=31), and Taiwan (n=22). The colours in the Example 2 research were also not specifically defined, so the standard colours listed in Table 2.3 have been applied in the diagram.

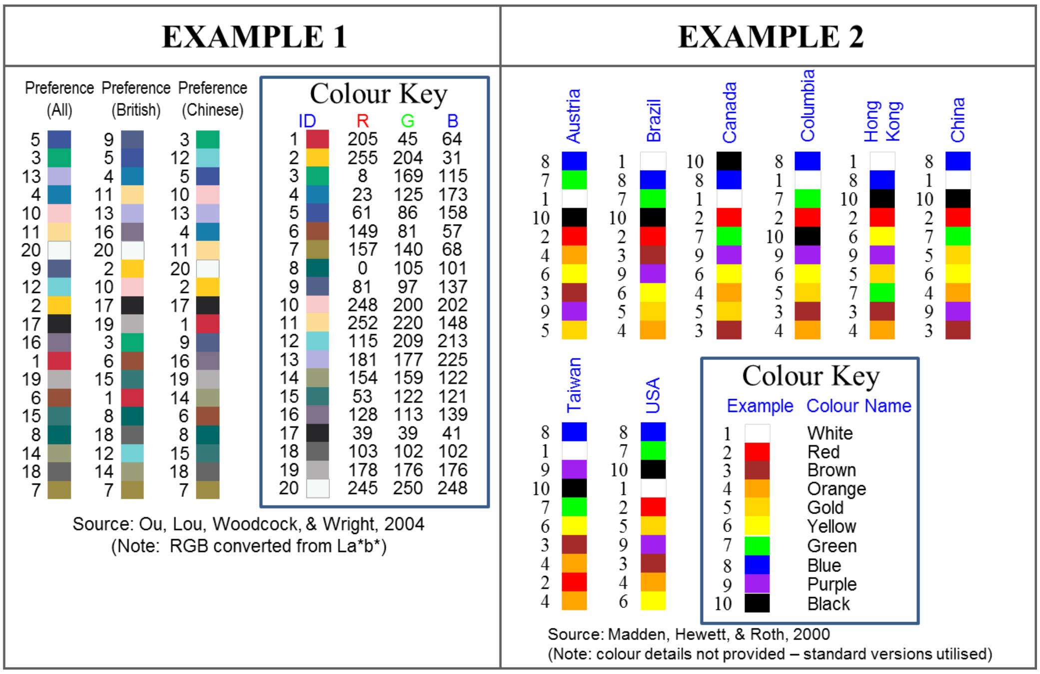

Figure 2.6: Cultural Variability of Colour Preferences

Although there still seems to be a preference in many of these countries for cooler colours *(e.g. blue, green)*, there appears to be significant variation in preferences between cultures. Variations are also demonstrated within cultural groups. For instance, both studies utilise Chinese participants, and the results appear to be indicating significant differences in the order of preference. These differences could be due to the different hues and saturations applied in the two experiments, or personal variations within the sample groups.

Even more variation can be identified in terms of gender. For example, Figure 2.7[46] illustrates the colour preference information from two gender related experiments.

46. The information provided in Example 1 is drawn from Ou, et al. (2004b), which was discussed in Footnote 44. Example 2 utilises data collected by Ellis & Ficek (2001), which identified colour preferences for male (n=1924) and female (n=3766) students in 22 universities in the United States and Canada. It is particularly noteworthy that the blue preference for males was extremely clear *(Blue=45% vs Green in second position at 19.1% preferred*), whereas for females the top two preferences were very similar *(Green=27.9% vs Blue=24.9%)*. The colours in the Example 2 research were also not specifically defined, so the standard colours listed in Table 2.3 have been applied in the diagram.

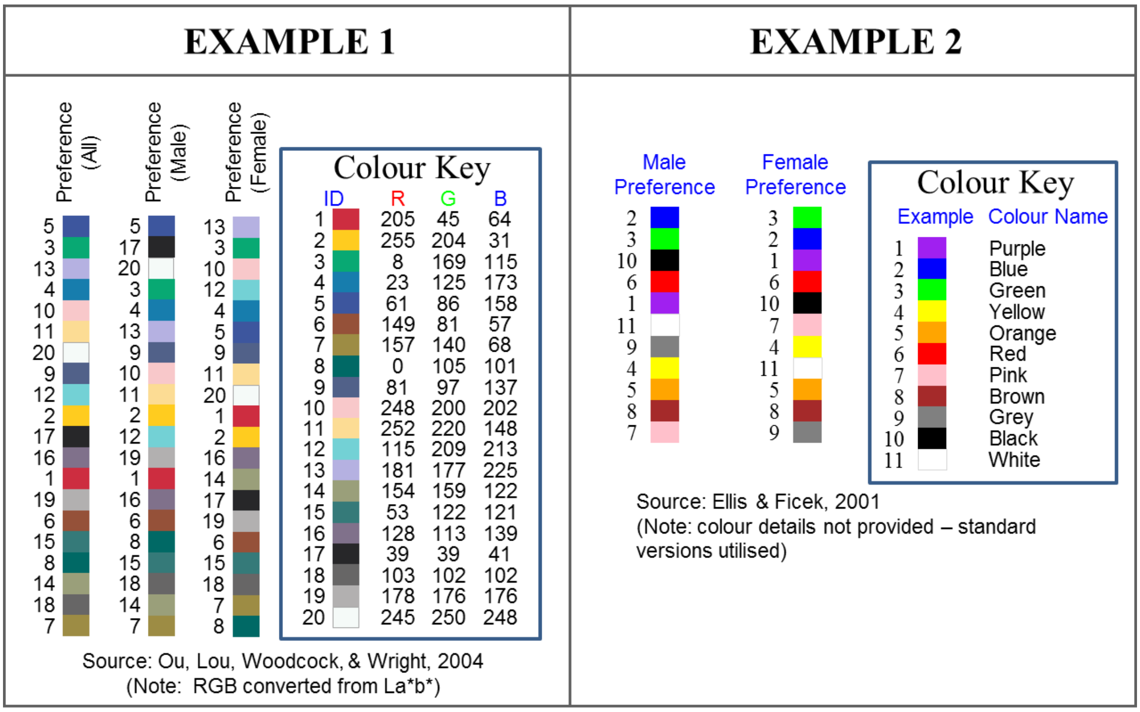

Figure 2.7: Gender Variations

As illustrated in these examples, cooler colours still appear to be preferred. However, below the highest preference level, the most preferred colours do not appear to be uniform across genders, or even between experiments. There are also some interesting aspects apparent, within these two experiments. For example, women within the sample groups for both experiments rated pink more highly than men. According to LoBue & Deloache (2011), such preferences appear very early in life *(by around the age of two to two and a half)*, and may be linked to gender stereotyping. An alternative view postulated by Hurlbert & Ling (2007), indicates that preferences of this nature may be induced by physiological differences in the perception mechanisms utilised by men and women(47).

Age can also affect the perception of colour and colour preferences (Beke, et al., 2008) (48). For example, Table 2.2(49) illustrates changes in colour preference and perception for males and females in different age groups.

47. Hurlbert & Ling (2007) identified that both sexes have a natural preference for bluish contrast, but females also have a preference for reddish contrasts. Hurlbert & Ling (2007) postulated that this difference evolved as a result of gender based roles during human evolution. For instance, women were gatherers, who needed to see red and have better spatial vision capacities, whereas men had less need of this capability as hunters (Hurlbert & Ling, 2007).

48. Such changes in colour preferences and perception may be induced by neurophysiological transformations associated with the aging process (Beke, et al., 2008).

49. Information in this table is drawn from research (n=320) conducted by Kose (2008).

Table 2.2: A Matrix of colour preferences and perception for Age and Gender

Age Grouping	Female	Male
6 – 17	• ***Preferred Colours***: Blue & Pink	• ***Preferred Colours***: Blue
	• ***Light or Dark***: Prefer Lighter Tones	• ***Light or Dark***: Prefer Lighter Tones
	• ***Best Perceived***: Cyan, Magenta, Yellow	• ***Best Perceived***: Cyan, Magenta *(Green not perceived well)*
17 – 30	• ***Preferred Colours***: Blue	• ***Preferred Colours***: Blue, but Red very important
	• ***Light or Dark***: Prefer Lighter Tones	• ***Light or Dark***: Poorer tone perception
	• ***Best Perceived***: Cyan, Magenta, Yellow	• ***Best Perceived***: Blue, Red
30 – 50	• ***Preferred Colours***: Blue, Green, White, Red	• ***Preferred Colours***: Red
	• ***Light or Dark***: Perceived as darker	• ***Light or Dark***: Lighter tones better perceived
	• ***Best Perceived***: Cyan, Magenta, Yellow	• ***Best Perceived***: Good colour perception
More than 50	• ***Preferred Colours***: Red, Green	• ***Preferred Colours***: Red, Black
	• ***Light or Dark***: Dark hue perception poorer	• ***Light or Dark***: Lighter tones better perceived
	• ***Best Perceived***: Prefer intense hues	• ***Best Perceived***: Most errors with green

The cool colour preference *(and particularly the blue preference)* is still evident in this research. However, these experiments also indicated that preferences change during the aging process. For instance, as pointed out by Macaulay (1995) older viewers may require higher levels of luminance to distinguish colours. Additionally, the perception of saturation may also vary during the aging process, and colours may appear cooler (Ou, Luo, Sun, Hu, & Chen, 2012). As an example, Kose's (2008) experiments identified that pink is a preferred colour for girls in the 6-17 year age category, but this colour is less preferred by women later in life, and by their 50s they may prefer more saturated hues such as red, rather than lighter colours like pink. Additionally, for men within this sample, their preferred colour appeared to evolve from blue to red, as they became older[(50)].

Preferences are also associated with the moods and emotions that they induce (Madden, et al., 2000), and this aspect is discussed in the following section.

50. These findings do not directly align to the findings published by Hurlbert & Ling (2007) *(See Footnote 47)*, and this may indicate that other physiological changes are affecting perception.

2.2.2. Colour Induced Moods, Emotions and Meanings

As identified by Jones (1997), colours can induce moods and emotions, and they can also be associated with specific meanings (Elliot & Maier, 2007). Table 2.3[(51)] provides a listing of some of the common meanings associated with different colours.

Table 2.3: Examples of emotions elicited by colour - as identified in the literature review

Colour Group	Colour Example	Colour Name	RGB	Emotion Elicited
Purple		Purple	160-32-240	• Grand, royal, majestic, excitement, royal (western culture) [ζ] • Meditative, royalty, luxury, wisdom, spiritual, exotic, creative, artistic, inspirational, spiritual [η] • Dignified, stately [θ]
Blue		Blue	0-0-255	• Calming [α] • Affectionate, cautious, pleasant, soothing, calm and restful [β] • Attractive, effective [δ] • Moving, soulful, compassionate, heart, emotion [ζ] • Dignified, professional, successful, loyal, calm, peaceful, tranquil, positive, authoritative (dark blue), melancholy [η] • Wealth, trust, tender, soothing [θ] • Cold, dull, peaceful [κ]
Shades of Blue		Sky Blue	135-206-250	• Calm, true, honest, philosophical, non-threatening, peace, tranquillity, goodwill [ζ]
Greenish-Blue		Teal	0-128-128	• Primitive, intuitive, ancient, strong, free [ζ]
Bluegreen		Cyan	0-255-255	• Analytical, cold, intelligent, direct, to the point, articulate [ζ]
Bluegreen		Emerald	80-200-120	• Brilliant, expensive, eternal, splendid [ζ]
Bluish-Green		Sea Green	46-139-87	• Mature, strong, restless, wise, ancient [ζ]
Bluish-Green		Lime	50-205-50	• Fresh, naïve, clean, youthful [ζ]

51. This table contains information from Singh[α] (2006), Crozier[β] (1996), Elliot & Maier[γ] (2007), Kauppinen-Räisänen & Luomala[δ] (2010)), Bellizzi & Hite[ε] (1992), Pralle[ζ] (2007), Reynolds[η] (2010), Madden, et al.[θ] (2000), Manav[κ] (2007) and Kaya & Epps[λ] (2004). These publications were selected, because they represent a mixture of the design and psychological paradigms.

Colour Group	Colour Example	Colour Name	RGB	Emotion Elicited
Green		Green	0-255-0	• Calming and restful [β] • Attractive, neutral [δ] • Healthy, natural, secure, life, self-confident [ζ] • Natural, balanced, harmony, the environment, earthy, healthy, persistent, calm, lucky, rebirth, go *(traffic light)*, spring, envy [η] • Vivid, boring, fearful, relaxing, tiring, annoying, purity [κ] • Nature, trees, relaxed, calm, happiness, comfort, peace [λ]
Yellow		Yellow	255-255-0	• Attracts attention [α] • Cheerful, jovial, exciting, affectionate, impulsive [β] • Highly stimulating [γ] • Attracts attention, joyful [δ] • Sour, anxious, sharp, startling, uneasy *(when overused)* [ζ] • Optimistic, cheerful, happy, energetic, fun, sunshine, inspiring, summer, caution *(warning signs)* [η] • Cheerful, jovial, joyful [θ] • Lively, energetic, positive, happy, exciting [λ] • Warm, plain and simple, dynamic, classical, enjoyable [κ]
Shades of Yellow		Gold	255-215-0	• Rich, sunny, joyful, warm, associated with power [ζ]
Yellowish Orange		Amber	255-126-0	• Mellow, abundant, fertile, comfortable, distinctive [ζ]
Orange		Orange	255-165-0	• Zesty, nutritious, hazard warning [ζ] • Warmth, compassion, excitement, enthusiasm, spiritual, energised, playful, fun [η] • Distressed, disturbed, upset [θ]
Shades of Red		Coral	255-127-80	• Wild, fiery, explosive, out of control, very noticeable [ζ]
Shades of Red		Brown	165-42-42	• Natural, earthy, solid, reliable, strong, comfortable, rustic, bland, conservative, ordinary [η]
Shades of Red		Scarlet	255-36-0	• Desirable, believable, friendly, dramatic, warm [α]
Shades of Red		Crimson	220-20-60	• Powerful, aggressive, threatening, demanding attention [ζ]

Colour Group	Colour Example	Colour Name	RGB	Emotion Elicited
Red		Red	255-0-0	• Stimulates [α] • Adventurous, sociable, powerful, protective and exciting [β] • Danger *(in many contexts)*, passion, or incorrect [γ] • Attracts attention, too strong [δ] • Distracting [ε] • Danger, exciting, loud, battle [ζ] • Assertive, powerful, bold, urgent, emotionally hot, love, passion, stop, danger, evil, murder [η] • Exciting, stimulating [θ] • Tiring, striking [κ]
Shades of Red		Pink	255-192-203	• Lovely, sensitive, feminine [ζ] • Romantic, soft, tranquil, passive, feminine, health, love, romance, joy [η] • Warm, cheerful, romantic [κ]
Purplish Red		Mauve	224-176-255	• Bold, stylish, impressive, cultured, classical [ζ]
Reddish Purple		Violet	238-130-238	• Serious, thoughtful, reflective, meditative, soul searching [ζ]
Black		Black	0-0-0	• Classy, formal, artistic, simplicity, authority, power, death, fright, loss, troubles, mourning [η] Sad [θ]
Grey		Grey	128-128-128	• Neutral, respect, humility, stable, wise, simple, uncommitted, cloudy, dull, depression, negative *(lack of colour)* [η]
White		White	255-255-255	• Pure, innocent, clean, new, simple, spacious, cool, winter *(snow)*, bland, ordinary, sterile [η]

This table illustrates that colour can have very different meanings, depending on the context (Elliot & Maier, 2007; Madden, et al., 2000; Rider, 2009). For example, yellow is reported to be both cheerful and jovial (Crozier, 1996), and as creating anxiety and uneasiness (Pralle, 2007). Clearly both of these meanings cannot be correct all of the time, and the differences may be based on individual preferences (Carroll Childress, 2008), or the characteristics of the colour *(e.g. hue, saturation, luminance)*, because these can have a direct effect on the induced meaning of a colour (Noiwan & Norcio, 2006).

Additionally, although some publications appear to treat the types of colour meanings shown in Table 2.3 as universal *(e.g. Finkelstein (2003), Sloboda (2003))*, there also appear to be significant variations induced by cultural differences (Carroll Childress, 2008). Table 2.4[(52)]

52. Information within this table was drawn from Kyrnin[α] (2012), Scott-Kemmis[β] (2009), Williams[γ] (2008), Hasan, Al-Sammerai, & Kadir[δ] (2011), Spinney[ε] (2007) and Marable[η] (1991). These references were selected because they provide a reasonable cross-section of information developed within the graphic design and psychological paradigms. This table is

illustrates some of the contrasting colour meanings, which have been attributed to different cultures within the literature that was assessed on this topic.

Table 2.4: Examples of emotions elicited for different cultures (from the literature)

Colour Example	Colour Name	Country: Emotional Linkage
	Purple	• Eastern cultures: Wealth [α] • Egypt: Virtue, faith [γ] • European: Royalty, mourning, death *(Catholic religion)* [γ] • India: Sorrow, comforting [γ] • Iran: Related to omens [γ] • Japan: Privilege, wealth [γ], Imperial [η] • Thailand: Mourning, widows [α] • Western cultures: Royalty [α]
	Blue	• Arab: Nature *(sea, sky, divinity)*, jealousy, depression [δ] • Belgium: Colour for baby girls [β] • China: Immortality [α], associated with pornography, feminine colour [β] • Eastern cultures: Wealth, self-cultivation [α], immortality [β] • Egypt: Virtue, protection *(ward off evil)* [β] • France: Royalty, aristocracy [γ] • India: Religious *(Krishna)* [β] • Iran: Colour of heaven and spirituality, mourning [α], immortality [β] • Judaism: Holy colour [γ] • Japan: Everyday life [β] • Korea: Colour of mourning [β] • Mexico: Mourning, trust, serenity [β] • Middle East: Protection *(ward off evil)* [β] • Thailand: Colour for Friday [β] • United Kingdom: Conservatism *(political)* [β] • United States: Liberalism *(political)* [β] • Western cultures: Depression, sadness, conservative, corporate, 'something blue' from bridal tradition [α]
	Sky Blue	• Most western cultures: babies, especially male babies[α]

also not designed to provide a comprehensive listing, but simply illustrate some key differences that have been identified for various cultures.

Colour Example	Colour Name	Country: Emotional Linkage
	Green	• China: Green hats imply a man's wife is cheating on him, exorcism [α], new life, regeneration, hope, fertility [β] • Eastern cultures: Eternity, family, health, prosperity, peace [α], new life, fertility [β] • Egypt: Hope, spring [β] • Indonesia: A forbidden colour [β] • Ireland: Symbol of the entire country, religious (Catholics) [α] • Islam: Perfect faith [α] • Japan: Life [α], eternal life, youthfulness, freshness [β] • Middle East/Islamic: Islamic [α], goodness [δ]. hope, new beginnings, harvest, virtue, fertility, luck [β] • North Africa: Corruption, drug culture [β] • Saudi Arabia: Wealth and prestige [β] • South America: Death [β] • Thailand: Colour of Wednesday [β] • United States: Money, jealousy [β] • Western cultures: Spring, new birth, go, money, Saint Patrick's Day, Christmas *(with red)* [α]
	Yellow	• Arab: Nature, sun, desert, envy, jealousy, mean, cruel [δ] • Africa: Usually reserved for high rank [β] • Buddhism: Wisdom [β] • Burma: Colour of mourning [β] • China: Nourishing, royalty [α], sacred, honour, masculine [β] • Eastern cultures: Proof against evil, for the dead, sacred, imperial [α] • Egypt: Mourning [α] • Europe: Happiness, joy, cowardice, weakness, hazard, warning [β] • France: Jealousy [β] • Greece: Sadness [β] • Hindu: Sacred colour [η] • India: Merchants [α], sacred and auspicious [β] • Islam: Wisdom [β] • Japan: Courage [α], beauty and refinement, aristocracy, cheerfulness [β], nobility [η] • Middle East: Happiness, prosperity [β] • Thailand: Auspicious, represents Buddhism, royal colour [β] • Western cultures: Hope, hazards, coward, weakness, taxis [α]
	Gold	• Eastern cultures: Wealth, strength [α] • Western cultures: Wealth [α]
	Orange	• Eastern cultures: Happiness, spirituality • Hinduism: Auspicious, sacred (saffron) [β] • Ireland: Religious (Protestants) [α] • Netherlands: House of Orange [α] • Other Western Cultures: Creativity, autumn [α] • United States: Halloween *(with black)* [α]
	Brown	• Australian Aboriginals: Colour of the land [α] • India: Colour of mourning [β] • Nicaragua: Sign of disapproval [β] • Western cultures: Wholesome, earthy, dependable, steadfast, health [α]

Colour Example	Colour Name	Country: Emotional Linkage
	Red	• Arab: Blood, love, passion, positive meaning [δ] • Australian Aboriginals: The land and earth [α] • Celtic Background: Death and afterlife [α] • China: Good luck, celebration, summoning [α], vitality, happiness, long life, wedding colour, funerals [β] • Eastern cultures: Prosperity, good fortune, worn by brides, symbol of joy [β] • Greece: Dominant, male [β] • Hebrew: Sacrifice, sin [α] • India: Purity [α], fertility, love, beauty, wealth, opulence, power, used in wedding ceremonies, married woman, fear, fire [β] • Japan: Life, anger, danger [β], female reproduction [γ], protection from evil [η] • Middle East: Danger, evil [γ] • Nigeria: Ceremonial [β] • Russia: Bolsheviks and Communism [α], beauty, used in marriage ceremonies [β] • South Africa: Colour of mourning [α] • Thailand: Colour for Sunday [β] • Western cultures: Excitement, danger, love, passion, stop, Christmas *(with green)* [α]
	Pink	• Belgium: Baby boys [β] • Eastern: Marriage [α], Feminine [β] • Europe: Feminine [β] • Korea: Trust [α] • Thailand: Colour for Tuesday [β] • Western cultures: Love, babies, especially female babies, Valentine's Day [α]
	Violet/ Magenta	• Spain: Liberal (political) [β] • Some Western and Eastern cultures: Mourning, rituals [γ] • Japan: Wealth, power [γ] • Ukraine: Faith, patience and trust [γ]
	Black	• Africa: Age and wisdom • Arab: Death, funerals, hell, bad omens, danger [δ] • Australian Aboriginals: Colour of the people *(cultural representational link)* [α] • China: Colour for young boys [α] • Eastern cultures: Career, evil, knowledge, mourning, penance [α], wealth, health and prosperity [β] • France: Negative, but chic [ε] • India: Evil, negative, anger, apathy [β] • Japan: Mystery, feminine *(positive and negative connotations)* [β] • Judaism: Unhappiness, bad luck, evil [β] • Middle East: Evil, mystery [β] • Thailand: Bad luck, unhappiness, evil [α] • Western cultures: Funerals, death, Halloween *(with orange)*, bad guys, rebellion [α]
	Grey	• Eastern cultures: Helpers, travel [α] • Western cultures: Boring, dull, plain, sad [α]

Colour Example	Colour Name	Country: Emotional Linkage
	White	• Arab: Nature, purity, clean, death shrouds [δ] • China: Death, mourning [α], humility, age, misfortune • Eastern cultures: Funerals, helpful people, children, marriage, mourning, peace, travel [α], sadness [β] • France: Purity, cleanliness, honesty [ε] • India: Unhappiness [α], sorrow, death, funerals, peace and purity [β] • Japan: White carnation symbolises death [α] • Korea: Purity, innocence, morality, birth and death [β] • Middle East: Purity, mourning [β] • Western cultures: Brides, angels, good guys, hospitals, doctors, peace *(white dove)* [α]

As illustrated in this table there is significant diversity for colour meanings in various countries, and they can have opposite meanings dependent on the culture and context. What is even more important is that even the fairly extensive colour nomenclature utilised in this table cannot adequately reflect the effect of different shades and tones of colour (Areni & Sutton-Brady, 2011). For example, in this table green is associated with Irish nationalism, but the full hue green (RGB: 0-255-0) applied here does not definitively evoke that impression in the Irish, because they identify with a different shade known as Kelly or Shamrock Green (RGB: 0-158-96). Therefore, numerous variations could also be applied to this already complex matrix of colour meanings.

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