COLOUR PSYCHOLOGY

(BACKGROUND COLOURS)

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, and some of these are in the previous Colour Psychology handout)*;
- ✓ helps you to understand key aspects about the use of colour in backgrounds; 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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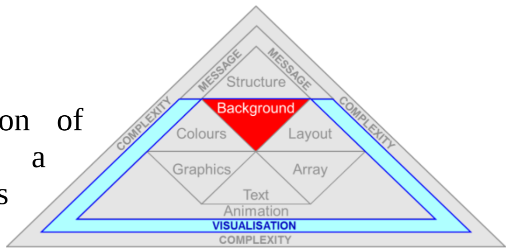
1.1. Background



It has long been recognised that the interaction of foreground and background colours can have a significant effect on comprehension and impressions (Greco, Stucchi, Zavagno, & Marino, 2008; Loosmore, 1994; Smaldino, Lowther, & Russell, 2008; Wheildon, 2005). For example, work conducted by Le Courrier de Livre (1912), Luckiesh (1923) and Tinker & Paterson (1931) identified that certain foreground and background combinations optimise comprehension. However, as cited in Section 2.1.1 in Appendix 2, there are significant differences between the display of information on a screen and on paper. Therefore, concepts that may be applicable in the printed medium, may not be appropriate (Humar, Gradisar, & Turk, 2008), for use in tools like PowerPoint®. This section is therefore focussed on the effects of background and foreground colour combinations in these types of presentation tools.

The following subsections address the key issues as:

- ***Comprehension of Text.*** Utilising different text *(foreground)* and background colours can affect:
  - ***Legibility.*** 'Legibility refers to perceptual properties of text that influence readability. Text which is hard to read … may be incomprehensible, but still highly legible' (Legge, 2006, p. 107). In other words, legibility relates to feature detection within the characters of text, so these can be recognised for reading (Greco, et al., 2008). This measure is therefore focussed on 'how rapidly, easily, and accurately one character can be recognised and distinguished from another' (Ramadan, 2011, p. 90).
  - ***Readability.*** The concept of readability goes beyond the legibility of the text, and relates to the viewer's capacity to 'recognise the form of a word or a group of words for contextual purposes', so 'it is the property that permits an individual to read sentences from the stimulus material easily' (Humar, et al., 2008, p. 886). The major difference between legibility and readability is that readability triggers language parsing[(1)] (Greco, et al., 2008). Additionally, readability is a better indicator of comprehensibility than legibility (Wooyong, Park, & Kwangsu, 2011).
- ***Impressions from Aesthetics.*** Aesthetics go beyond the more functional aspects of colour combinations within the foreground and background (Humar, et al., 2008). This aspect reflects the use of colour combinations to influence viewer impressions (Hall & Hanna, 2004).
- ***Attention from Salience.*** Different background colours can also affect the viewer's ability to focus attention on the important content (Camgöz, Yener, & Güvenç, 2004).

1.1.1. Comprehension of Text

In many PowerPoint® presentations the viewer must be able to gain information, or reinforcing content, by reading text characters (Krieger, 2011; Levasseur & Kanan Sawyer, 2006). In some situations, only text legibility is required *(e.g. displaying single words or letters)*, and in other cases readability is essential (Dalenbäck, 2012). The following subsections describe the effect of colour on these aspects.

1.1.1.1. Legibility

Foreground *(text colour)* and background colour combinations can significantly affect the legibility of text (Gazbar & Pelet, 2011; Gradisar, Humar, & Turk, 2007; Zuffi, Brambilla,

1. This is predominantly implemented through lexical parsing in Wernicke's area *(see Section 1.4.1.2 in Appendix 1)*, and depending on the situation, also in neural regions such as Broca's area *(see Section 1.4.1.3.6 in Appendix 1)* and the insula *(see Section 1.4.1.3.5 in Appendix 1)*.

Beretta, & Scala, 2007). However, different research projects have produced differing results for the optimal combination of hues. For instance, Figure 1 illustrates the results from legibility research conducted by Humar, et al. (2008)[(2)].

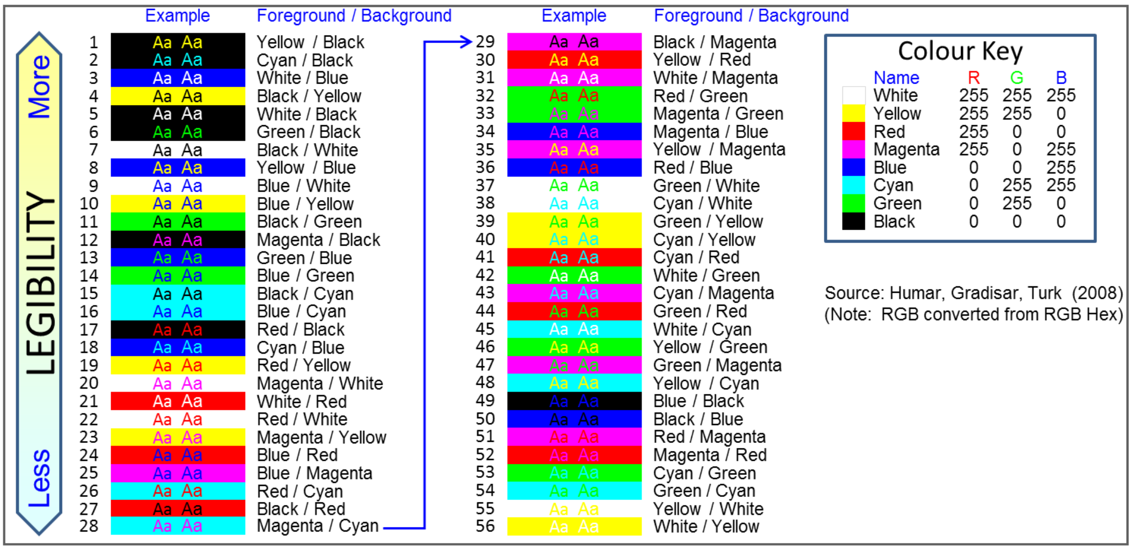


Figure 1: Legibility Colour Combinations

From this research, combinations with a negative polarity *(light coloured text on a dark background)* and high contrast, rated highly in terms of legibility (Humar, et al., 2008). However, there is relatively little difference in legibility scores within the first 10 combinations, which also contain positive polarity *(dark text on a light background)* examples (Humar, et al., 2008). Additionally, Humar, et al. (2008) found that luminance and contrast were highly significant factors in creating this legibility.

As an alternative, Shieh & Lin (2000) utilised other combinations of foreground and background colours to determine which was the most legible. Figure 2[(3)] *(overleaf)* illustrates the findings from this research project.

2. The research by Humar, et al. (2008) tested 56 colour combinations for text legibility using 477 participants *(209 males and 268 females aged between 18 and 21)*. Each colour combination was displayed on a computer screen.

3. This research by Shieh & Lin (2000) tested legibility of text characters distributed in different locations on computer screens. 192 participants viewed different colour combinations, and they were scored on how many characters they perceived correctly during a short exposure period.

	Example	Foreground / Background	Mean Score
1	Aa Aa	Blue / Yellow	62.3
2	Aa Aa	Yellow / Red	60.9
3	Aa Aa	Blue / Purple	60
4	Aa Aa	Yellow / Blue	57.3
5	Aa Aa	Red / Purple	55.7
6	Aa Aa	Yellow / Purple	54.4
7	Aa Aa	Purple / Yellow	52.2
8	Aa Aa	Blue / Red	52.2
9	Aa Aa	Red / Yellow	51.2
10	Aa Aa	Red / Blue	51.2
11	Aa Aa	Purple / Blue	42.9
12	Aa Aa	Purple / Red	36.0

Colour Key

Name	R	G	B
Yellow	255	230	40
Red*	255	8	12
Purple	255	31	204
Blue*	0	96	255

Source: Shieh & Lin (2000)

* Note: RGB converted from x, y, L

Figure 2: Legibility Colour Combinations – Alternative Experiment Results

As shown in this diagram, the top three combinations *(which are reasonably close together in score)* include two with a positive polarity, and one has a negative polarity. Shieh & Lin (2000) also identified that luminance contrast between the foreground and background was a significant factor in determining legibility, and the hues used were only marginally significant. This finding is reinforced when these two sets of experiments are analysed together, as shown in Figure 3.

	Example	Foreground / Background	Ranking in Humar et al (2008)
1	Aa Aa	Blue / Yellow	10
2	Aa Aa	Yellow / Red	30
3	Aa Aa	Blue / Purple	25
4	Aa Aa	Yellow / Blue	8
5	Aa Aa	Red / Purple	51
6	Aa Aa	Yellow / Purple	35
7	Aa Aa	Purple / Yellow	23
8	Aa Aa	Blue / Red	24
9	Aa Aa	Red / Yellow	19
10	Aa Aa	Red / Blue	36
11	Aa Aa	Purple / Blue	34
12	Aa Aa	Purple / Red	52

Source: Shieh & Lin (2000),
Humar, Gradisar, Turk (2008)

Figure 3: Differences in outcomes between the two experiments

Although there are some similarities in the ranking for legibility shown in this diagram, there are also significant differences. For instance, the ranking of yellow on blue in Humar, et al's (2008) research, is much higher in the legibility score than it was ranked in combination's identified in Shieh & Lin's (2000) findings. These differences may therefore be more attributable to the following factors, rather than just the hue:

- ***Luminance.*** The luminance difference between the foreground and background appears to be more significant than hue, in terms of character legibility (Shieh & Lin, 2000). Additionally, ambient illumination has a significant effect on legibility.

Therefore, within reason, the brighter the screen the more legible the content[(4)] (Shieh & Lin, 2000). Equal luminance displays can also be just as legible, as long as there are significant variations in the other two key factors discussed here (Travis, Bowles, Seton, & Peppe, 1990).

- ***Contrast.*** According to research conducted by Snyder (1988), the optimal contrast ratio between the foreground and background should be a minimum of 3:1. Contrast[(5)] and luminance also interact to support legibility (Lin, 2005). For example, at lower screen luminance, higher contrasts work better, but at higher screen luminance, lower contrast differences are more effective (Lin, 2005)[(6)].
- ***Polarity.*** The research from Shieh & Lin (2000) and Humar, et al. (2008) identified that the positive or negative polarity for legibility is likely to be less important than the preceding factors. However, Humar, et al. (2008, p. 897) also identified a preference for negative polarity, which could 'be explained by the flickering nature of a picture, which is more evident in case[s] of positive polarity'. However, Humar, et al. (2008), also identified that positive *(dark on light)* polarity displays reduced screen reflection, which made the content easier to view[(7)]. Therefore, in terms of creating legibility, positive or negative polarities may be used.
- ***Colour interaction.*** In addition to the preceding factors, some colour combinations appear to work better than others. For example, blues and yellows feature highly in legibility research from Shieh & Lin (2000) and Humar, et al. (2008), as well as research published by Ling & Van Shaik (2002)[(8)]. Additionally, combinations such as blue on white, were faster to find than red on white (Pearson & van Schaik, 2003). This aspect is discussed in more detail in Section 1.1.3.

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4. This is likely to be due to the fact that reading is conducted using the fovea and parafoveal regions *(see Section 1.3.1.2.1 in Appendix 1 for a description of these regions)* (Kambe, 2004). As these regions mostly contain cone cells *(see Figure 1.12 in Appendix 1)* these parts of the retina are best activated in Photopic levels of luminance *(see Figure 1.11 in Appendix 1)*.

5. There may be a rapid neural processing channel for contrast, which may actually lead to faster perception and cognition for contrast than for colour (Shapiro, 2008). This processing is initially managed with areas V1 and V4 *(see Section 1.3.5 in Appendix 1)* (Shapley & Hawken, 2011). Additionally, this fast processing channel for contrast may be mediating other aspects of colour perception, which is why colour interaction can be so important (Shapiro, 2008).

6. This may be due to the difference in luminance perception in rods and cones *(See Section 1.3.1.2.1 in Appendix 1)*. At higher luminance levels the cones are more strongly activated and these are more receptive to differences in hue than luminance changes. As the level of luminance falls the rods become more active, and these are much more sensitive to changes in contrasting brightness. However, they are also slower to react to changes (Fulton, 2003).

7. Their findings may be influenced by the fact that they were using Cathode Ray Tube (CRT) displays, and modern low reflection LCD screens may be less prone to this problem.

8. This may be due to the fact that blue and yellow are handled within the very fast koniocellular pathway *(see Section 1.3.2.3 in Appendix 1)*, which can then be rapidly passed through the dorsal stream *(see Section 1.4.2 in Appendix 1)* to generate conscious awareness more effectively *(see Section 1.2.3.2 in Appendix 1)*.

1.1.1.2. Readability

Text colour and background combinations can also have a significant impact on readability (Leykin & Tuceryan, 2004). The key colour related factors that support readability appear to be:

- ***Contrast.*** As with legibility, colour combinations with a greater contrast ratio between the foreground and background improve the readability of the content (Hall & Hanna, 2004). The following aspects are pertinent to the optimised use of contrast for readability:
  - ***Using Colour Opposites.*** Farini, Arrighi & Gheri (2007) identified that colour opposites *(or near colour opposites)* in the foreground and background can provide optimal readability. However, *(as pointed out in the previous Colour Psychology Handout)* high saturation opposite colours can create a vibrating illusion (Clarke, 2002; Hall & Hanna, 2004; Smaldino, et al., 2008). Therefore, when utilising opposites, the foreground should be full hue and the background less saturated (Wang, Giesen, McDonnell, Zolliker, & Mueller, 2008). Alternatively, an achromatic background colour can be used, as these colours tend to be less salient than chromatic hues (Dobkins, Rezec, & Krekelberg, 2007; Goolsby, 2003; Guimaraes, 1992).
  - ***Maximising the contrast ratio.*** If the text's contrast from the background is low, then this can significantly reduce readability (Leykin & Tuceryan, 2004). This contrast induced readability may also have a direct bearing on comprehension, as illustrated in the graph provided in Figure 4(9). The graph shows that reductions in the contrast ratio by only small amounts *(e.g. > 20%)* can have a significant impact on comprehension.

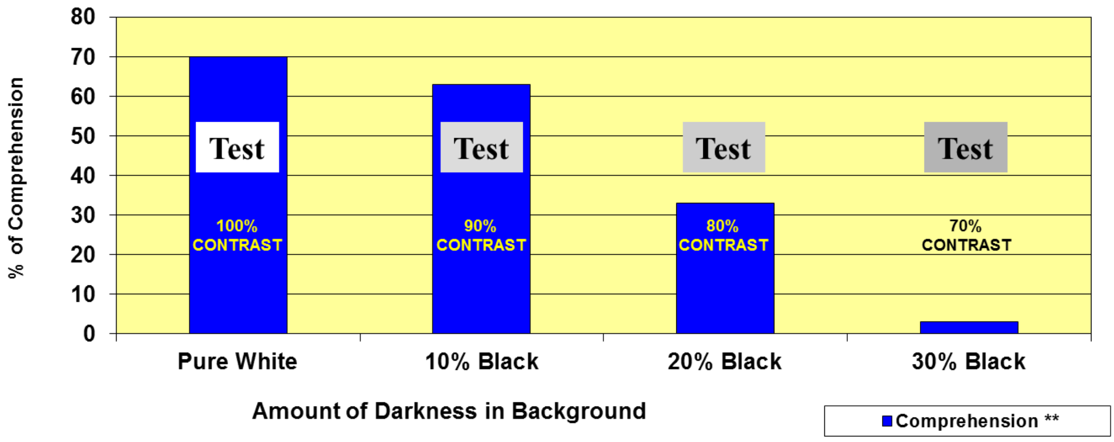

Figure 4: The effects of contrast on comprehension

9. The information in this graph was drawn from Wheildon (Wheildon, 1990, 2005). Although this research is based on reading on paper, the effects appear to be similar on screens *(although luminance on the screen also plays a more important role than on paper)*, as evidenced by the other research cited in this thesis. This data is only utilising achromatic colours, and other factors related to hue can also affect these outcomes (Wheildon, 2005).

- ➢ ***Small or large text.*** Additionally, for small text *(less than 1º of visual arc)*, the level of contrast between the foreground and background needs to be higher, than would be required for larger text *(scaling up to 6º of visual arc for each character, where the difference then becomes negligible)* (Legge, Parish, Luebker, & Wurm, 1990)[(10)].

- ***Polarity.*** Research conducted by Hall & Hanna (2004) and Ramadan (2011)[(11)] ascertained that positive polarity combinations tend to be much more readable, as illustrated in Figure 5. Buchner, Mayr, & Brandt (2009), Buchner & Baumgartner (2007), Coronel-Beltrán & Álvarez-Borrego (2010) and Zuffi, et al. (2007) also found that positive polarity provided significantly better readability than negative polarity. Additionally, Wang, Fang & Chen (2003), and Fritischi (2008), identified that positive polarity aided comprehension. However, Buchner, Mayr, & Brandt (2009) postulated that these benefits may not just be generated by the polarity, but by the higher levels of ambient luminance, which are created when the background is a lighter colour.

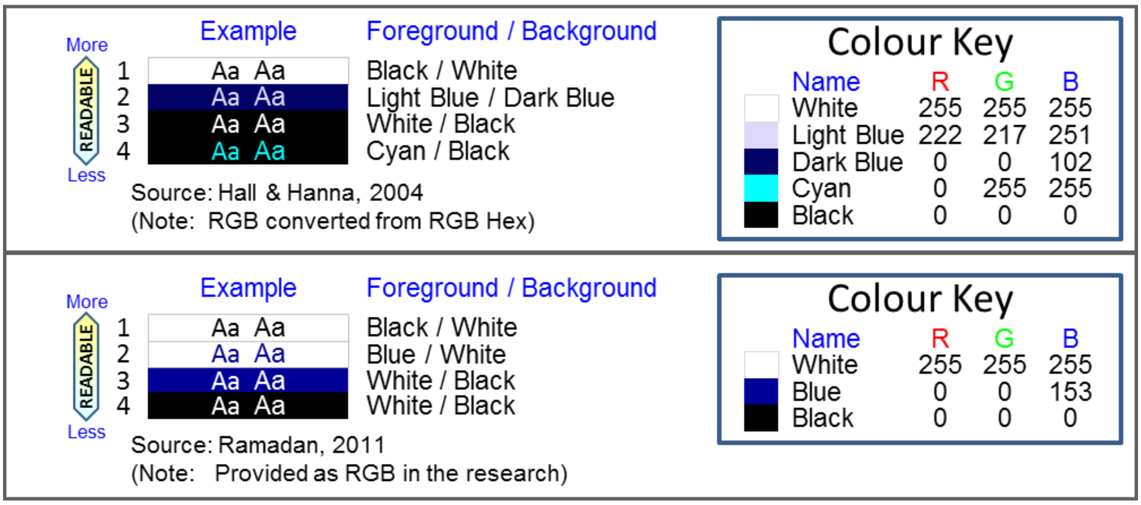

Figure 5: Positive polarity is more readable

- ***Luminance.*** As specified by Buchner, et al. (2009) the level of ambient luminance is important in generating readability, because of the effect on pupil dilation and focus[(12)]. The higher levels of luminance may also assist in generating arousal[(13)]. Therefore, in

10. This may be caused by the small text *(< 1 º)* just being handled by the foveal and parafoveal areas (Kennedy & Pynte, 2005). The vision is therefore typically being handled predominantly by cone cells *(see Figure 1.12 in Appendix 1)*. On the other hand, the larger text *(>6 º)* may also be stimulating more of the parafoveal and peripheral vision, where rod cells are more prevalent. This means that in the larger text, significant rod contrast signals (Shepherd & Wyatt, 2008) may reduce the amount of contrast required for visual differentiation.

11. The research by Hall & Hanna (2004) involved 10 groups of 10 to 30 students. These participants read content in different web pages, which were designed to test readability. The experiments conducted by Ramadan (2011) utilised 40 male students, who were reading Arabic script characters on video displays.

12. See Section 1.3.1.1 in Appendix 1 for more information on this aspect.

13. This driver for arousal is discussed in Section 1.3.3.2 in Appendix 1.

the same way that higher luminance *(up to a point)* assists in generating legibility, it should also typically assist in optimising readability.

- ***Text Colour.*** Legge & Rubin (1986) identified that the colours selected to improve readability may be less important than other factors, such as those described in the preceding points. However, poor text colour selection can still make the content less readable (Macaulay, 1995). According to Hall & Hanna (2004, p. 192) the 'traditional black on white page was clearly the most readable'. However, the application of different text colours can also make key points stand out (Jones, 1997; Smaldino, et al., 2008). According to Wu & Yuan (2003), this type of text highlighting can even be more effective than other more overt techniques to create salience, such as flashing text, or reverse video. Text highlighting with colour *(e.g. highlighting in red or blue font to juxtapose key content from black text)* can therefore be a useful method for drawing attention to key points (Wu & Yuan, 2003).
- ***Long Wavelength Background Colour.*** Longer wavelength light *(e.g. red)* may suppress the magnocellular pathway[14] (Bedwell, Brown, & Orem, 2008; Breitmeyer & Breier, 1994; Pammer & Lovegrove, 2001). This is important, because the 'magnocellular pathway is the dominant visual pathway for text perception' (Chase, Ashourzadeh, Kelly, Monfette, & Kinsey, 2003, p. 1211). Therefore the presence of significant long wave light in the display *(e.g. a red background)* may suppress readability for many people (Chase, et al., 2003). However, in some cases *(particularly for people with reading difficulties induced by meta-contrast – e.g. dyslexia),* the suppression of the magnocellular pathway may actually improve reading (Edwards, Hogben, Clark, & Pratt, 1996).

However, there is also a conundrum presented by research on readability, in terms of reading speed. As illustrated in Figure 6[15]*(overleaf),* the negative polarity combination of white on blue, appear to make the text faster to read. For example, Ramadan (2011) found that white on blue *(~128 words per minute)* facilitated faster reading than black on white *(~120 words per minute).* This result appears to be counter intuitive, noting that previously cited research *(including Ramadan's (2011))* indicated that positive polarity enhances readability and comprehension.

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14. See Section 1.3.2.2 in Appendix 1 for more details on this pathway.
15. See Footnote 11 for background information on the research by Ramadan (2011). The experiments conducted by Wu & Yuan (2003) involved 136 participants, who read content on screens, which utilised various combinations of hue, saturation and luminance.

EXAMPLE 1

	Example	Foreground/ Background	Av Words Speed
1	Aa Aa	White / Blue	127.43
2	Aa Aa	Black / White	120.56
3	Aa Aa	Blue / White	113.52
4	Aa Aa	White / Black	95.75

Colour Key

Name	R	G	B
White	255	255	255
Blue	0	0	153
Black	0	0	0

Source: Ramadan (2011)
(Note: Provided as RGB in the research)

EXAMPLE 2

Foreground Luminance Higher than Background

	Example	Foreground/ Background	Av Reading Time
1	Aa Aa	White / Blue	53.27
2	Aa Aa	White / Green	54.00
3	Aa Aa	White / Black	56.39
4	Aa Aa	White / Yellow	56.72

Foreground Luminance Less than Background

	Example	Foreground/ Background	Av Reading Time
1	Aa Aa	Black / Green	50.93
2	Aa Aa	Black / Yellow	51.20
3	Aa Aa	Black / Blue	52.71
4	Aa Aa	Black / White	55.50

Source: Wu & Yuan (2003)
(Note: Colours assumed from description. Specific RGB codes not available)

Figure 6: Reading speed based on colour combinations

Polarity may not, however, be the most important factor causing this improvement in reading speed. Firstly, the effect appears to be most pronounced with a blue background. The more rapid processing may therefore be due to the stimulation of the koniocellular pathway[16] by the blue hue. This might also explain the significant difference between this negative polarity example, and white on black, which was significantly slower to read.

Wu & Yuan (2003) also identified similar findings for the white on blue combination, in situations where the luminance was higher in the foreground than in the background *(as illustrated in Figure 6)*. However, Wu & Yuan (2003) also found that when the foreground luminance or saturation[17] were lower than the same attributes in the background, the reading speed was higher. Differences in luminance and saturation may therefore be more important in terms of supporting faster reading.

1.1.2. Impressions from Aesthetics

Aesthetic factors related to foreground and background colour combinations can also have a significant impact on impressions and viewer intent (Gazbar & Pelet, 2011; Hall & Hanna, 2004; Norman, 2002). Additionally, aesthetic visualisations are more likely to draw attention (Roberts, 2007), and be looked at more carefully (Wang & Mueller, 2008).

16. See Section 1.3.2.3 in Appendix 1 for more information on the koniocellular pathway. The author was unable to find any specific research to support this postulation, so this should ideally be investigated in later research.
17. Wu & Yuan (2003) used the term chroma, which is a synonym for saturation in this context.

As illustrated in Figure 7[18], various research projects have delivered significantly different outcomes in relation to viewer preferences for different colour combinations.

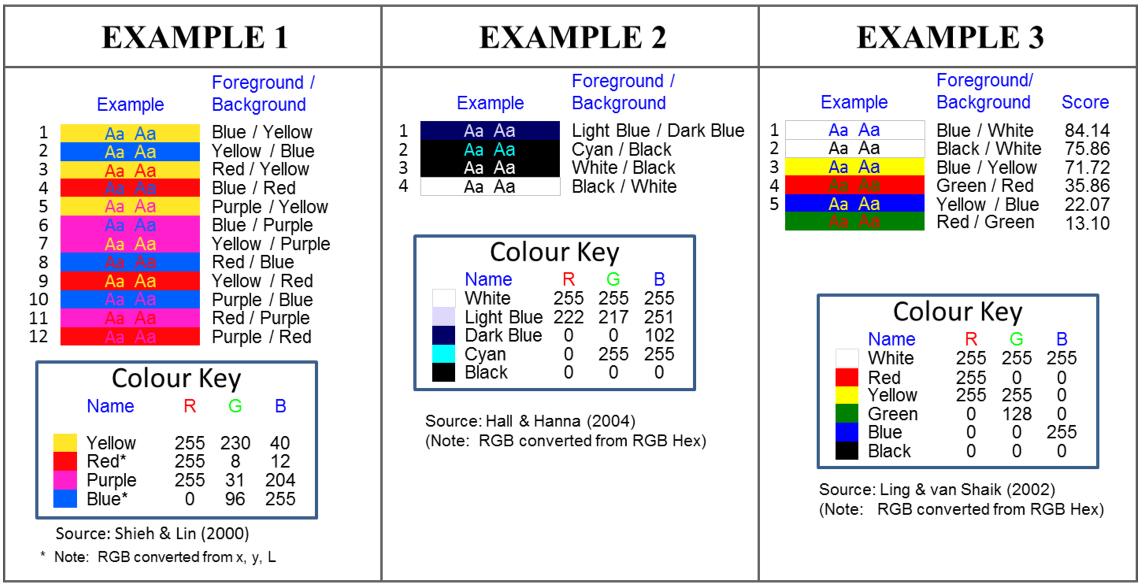

Figure 7: Aesthetic colour combination preferences

Therefore, aesthetics may not just be generated by specific combinations of hues. The following common rules have been recommended for integrating foreground and background colours, to enhance the aesthetic nature of the visual display:

- ***Employ colour, but use it carefully.*** The use of chromatic colours in the display is preferred over achromatic combinations (Hall & Hanna, 2004). However, the use of saturated, highly salient colours *(see the previous handout on Colour Psychology)* like red, yellow, green and blue can stimulate arousal (Ali, 1972; Hau, Miao, & Zhang, 2009; Jacobs & Hustmyer, 1974), and may even over-stimulate the neural processing in the brain (Küller, Mikellides, & Janssens, 2009). Therefore, 'an excessive amount of vivid colours is perceived as unpleasant and overwhelming', so saturated colours should be used sparingly, and as highlights separated by less saturated hues in the background (Wang, et al., 2008, p. 1740).
- ***Utilise colour harmony.*** The concepts explained in the previous handout on Colour Psychology should be applied when designing foreground and background colour combinations. Where possible, colours should also be selected to align with the viewer's preferences (Camgöz, 2000), and to trigger emotional inferences (Gazbar & Pelet, 2011) *(see the handout on Shaping Attention)*. Specific colour combinations also have a significant effect on preferences, with combinations such as blue on

18. See Footnote 3 for information on the research conducted by Shieh & Lin (2000). Background information on the research by Hall & Hanna (2004) is provided in Footnote 11. Ling & Van Shaik (2002) used 29 participants to read mock web pages to determine which combinations were faster to read, and which were rated more favourably. Ling & Van Shaik's (2002) research is useful because it utilises colour combinations that align to the three neural pathways, namely: parvocellular (red/green), magnocellular (black/white), and koniocellular (yellow/blue) *(see Section 1.3.2 in Appendix 1 for more information on these neural pathways)*.

yellow[19] yielding the highest preference and purple on red the least (Shieh & Lin, 2000). Some colour combinations, such as cyan on magenta, green on magenta, cyan on red, and green on red also create eye strain for the viewers (Humar, et al., 2008), which is likely to adversely impact on their impressions.

- ***Apply polarity in relation to context.*** Some studies have identified that negative polarity is more aesthetically pleasing than positive polarity displays (Hall & Hanna, 2004). Other research has shown that positive polarity is preferred (Ling & van Schaik, 2002). In other cases, such as the research conducted by Coronel-Beltrán & Álvarez-Borrego (2010), both positive *(black on white)* and negative *(white on blue)* polarity were identified as preferred combinations. The preference may therefore be aligned to context. For example, Beltrán & Álvarez-Borrego (2010) linked the preferences to the viewer's ability to read the text quickly. Therefore:
  - in situations where reading is required, it may be more appropriate to utilise positive polarity, which may not be as preferred, but assists in optimising readability (Buchner & Baumgartner, 2007); and
  - in other situations *(e.g. icons or graphics)* negative polarity can be used in a range of appropriate combinations (Ko, Shen, & Lee, 2010).
- ***Make the backgrounds simple.*** A plain light coloured background may be optimal (Smaldino, et al., 2008) to:
  - minimise visual complexity in the background, because this can interfere with the processing *(perception and cognition)* of foreground content (Crone, Parkes, & Ward, 1995; Kosnik, 1995)[20];
  - minimise colour interaction problems (Camgöz, 2000; Guimaraes, 1992; Macaulay, 1995) *(see the handout on Colour Psychology)*; and
  - avoid creating significant salience in the background, which might draw the viewer's attention away from important content (Farmer & Taylor, 1980; McDermott, Malkoc, Mulligan, & Webster, 2010).
- ***Applying foreground colours.*** The following guidelines should be applied to foreground colours:
  - use brighter, higher saturation colours in the foreground to draw attention (Macaulay, 1995), and apply a less bright, and/or less saturated background to optimise foreground background separation (Wang, et al., 2008);
  - coloured areas and symbols on a light background are typically perceived as more saturated than they would be on a dark background (Guimaraes, 1992); and
  - coloured regions may look darker and smaller against a white background, due to simultaneous contrast (Macaulay, 1995)[21].

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19. The linking of yellow and blue in a harmonious way typically implies utilising a triadic or tetradic colour combination *(see the previous Colour Psychology handout)*.

20. See Section 2.2 for more details on visual complexity.

21. 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

- ***Provide appropriately significant contrast.*** Higher contrasts between foreground and background elements are rated more highly for preference, particularly when the viewer is being asked to read (Ling & van Schaik, 2002). Most importantly, the luminance ratio between the foreground and background should be relatively large, as this approach appears to be preferred (Shieh & Lin, 2000).

1.1.3. Attention from Salience

Salience can be created by different combinations of colour within the foreground and background. For example, Ling & Van Shaik's (2002) identified that some colour combinations appeared to be more salient. As illustrated in Figure 8[22], yellow and blue combinations feature much more highly in target detection, and in particular the speed of detection, than mixtures of red and green[23].

SALIENCE IN SEARCH

	Example	Foreground/ Background	% Target Correct ID (Hits/Salience)
1	Aa Aa	Yellow / Blue	94.25
2	Aa Aa	Blue / Yellow	93.10
3	Aa Aa	Black / White	90.23
4	Aa Aa	Green / Red	90.23
5	Aa Aa	Red / Green	88.51
6	Aa Aa	Blue / White	79.89

SPEED IN SEARCH

	Example	Foreground/ Background	Reaction Time For Hits (ms)
1	Aa Aa	Yellow / Blue	1596
2	Aa Aa	Blue / White	1653
3	Aa Aa	Black / White	1690
4	Aa Aa	Blue / Yellow	1814
5	Aa Aa	Red / Green	1857
6	Aa Aa	Green / Red	2183

Colour Key

Name	R	G	B
White	255	255	255
Red	255	0	0
Yellow	255	255	0
Green	0	128	0
Blue	0	0	255
Black	0	0	0

Source: Ling & van Shaik (2002)
(Note: RGB converted from RGB Hex)

Figure 8: Salience of different colour combinations

Another key factor in creating salience is contrast, because attention is typically biased toward areas where the foreground and background provide the highest contrast (Camgöz, 2000; Engmann et al., 2009). As explained by Wang, et al. (2008) contrast can be created by differences in:

- ***Luminance.*** Luminance differentials between the foreground and background can be highly salient (Engmann, et al., 2009). When adjusting luminance to create contrast, the following rules should be applied:
  - in lower luminance situations only small differences are required *(e.g. small differences in blue luminance are well perceived)* (Wang, et al., 2008); and

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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).*

22. See Footnote 18 for more information on the research conducted by Ling & Van Shaik (2002).

23. The differentials identified by Ling & Van Shaik (2002) may be caused by the more rapid transmission of yellow and blue stimuli through the koniocellular pathway *(as discussed in Section 1.3.2.3 in Appendix 1)*. The next fastest pathway is the magnocellular system, which handles achromatic content *(see Section 1.3.2.2 in Appendix 1)* and appears to be responsible for handling the stimuli related to reading (Chase, et al., 2003). Finally, the slowest pathway is the parvocellular pathway *(see Section 1.3.2.1 in Appendix 1)*, which handles combinations of red and green hues.

- for higher levels of brightness, larger luminance differentials are required to create contrast *(e.g. large changes in luminance are required to create visual differentiation in brighter colours like yellow)*[(24)] (Wang, et al., 2008).

- ***Saturation.*** 'Brightness and saturation levels are more important than [the] hue component for attracting attention' (Camgöz, 2000, p. 115). Vivid *(e.g. bright and saturated)* colours, which are in contrast 'stand out, and guide attention to a particular feature, generating the pop-out effect' (Wang, et al., 2008, p. 1740).

- ***Hue.*** Camgöz (2000) and Camgöz, et al. (2004) identified that the use of foreground colours such as those shown in the peaks illustrated in Figure 3.8 in the previous Colour Psychology handout, were salient when used with differential background colours. For example, utilising a more salient *(e.g. red, yellow, bluish-green)* colour with a less salient colour can shape attention to the more saliently coloured object (Camgöz, 2000). Additionally, the use of cool colours in the foreground and warm colours in the background is more effective in generating separation than having warm colours in the foreground and cool colours in the background (Wang, et al., 2008). However, this effect appears to be due to the colour mixing, rather than the properties of the individual colours (Wang, et al., 2008).

- ***Size of the coloured area.*** Small regions of salient colours are typically less attracting than larger regions. Therefore, for smaller objects, higher differentials of contrasting hue, luminance and saturations are required (Wang, et al., 2008).

1.1.4. Identified Optimal Solution

As a result of this analysis, the optimal foreground/background combinations can be determined as follows:

- ***Slide Background.*** For the content slides a white or very light background is likely to increase the luminance of the screen, and apply positive polarity, to improve readability. Additionally, the white/light background is likely to reduce the risk of negative colour interactions. In title[(25)] and separator slides[(26)], a blue background can be selected, to make the changes in subject material more explicit. The blue colours you can select for these should have high levels of luminance and saturation.

- ***Text (Foreground) Colours.*** Black text should be used predominantly. However, full hue red and blue fonts can also be applied to highlight key words[(27)]. For example,

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24. Wang, et al. (2008) equate this to Weber's Law, which states that 'sensitivity to changes in magnitude along a given physical dimension decreases when stimulus magnitude increases' (Ganel, Chajut, & Algom, 2009, p. 1165). In practical terms, these changes are likely to be due to the activation levels of luminance for the cones and rods. See Section 1.3.1.2.1 in Appendix 1 for more information on this aspect.

25. The first slide in each control version of the experimental presentations gave the title of the module. This slide was designed to be informative and engaging.

26. A separator slide is used to flag changes in content *(e.g. on moving from one topic to the next in the presentation)*.

27. In a small number of cases other text highlighting colours can also be applied, to provide linkages between graphics and text.

red and blue can be selected to align with a standardised triad colour combination, as identified in Section 1.1.2.3 in the previous Colour Psychology handout *(e.g. yellow, red, blue)*.

- ***Graphics Combinations.*** Developed graphics *(e.g. graphs, relationship diagrams, etc.)* should utilise the selected triad colour combination. The selection of hue, saturation, luminance, and contrast in these combinations should align to the optimal approaches identified in the preceding Colour Psychology handout.

1.2. Conclusion

When read in conjunction with the previous Colour Psychology handout, this information can be applied to demystify the optimisation of colour use in screen design. Therefore, as much as this is focussed on PowerPoint® *(because this is the scope of the thesis)*, the concepts are useful for any visual display. Additionally, they are also likely to have a direct impact on all forms of graphic design optimisation.

The outcomes from my research are very clear. The optimised use of colour can have a significant effect on viewer comprehension, impressions and attention. I would therefore dedicate you to think about the colours you use, because they can make a very real difference.

1.3. For more information

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