Psychophysics of Human Vision: The Key to Improved Camouflage Pattern Design

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ABSTRACT

Camouflage is one of the methods a soldier in the field employs to increase survivability, and decrease probability of detection. A camouflage pattern can only be effective if it matches the spectral properties (amongst others, colour) as well as the spatial properties (i.e. patterns) of the background scene. It is usually very easy to detect flat-surfaced objects in nature. This means that the camouflage pattern on uniforms, nets and vehicles need to have local and global three-dimensionality (or at least the perception there-of), in order to be effective.

One of the methods to achieve depth perception on a flat surface is by using textured gradients. Depth perception could also be enhanced by the appropriate usage of colour. This study investigated the different mechanisms of human vision, and how perceptual effects could be used to develop better camouflage patterns. A camouflage pattern, based on these principles, was developed and evaluated in order to verify the research.

1. Introduction

Camouflage is one of the methods a soldier in the field employs to increase survivability and decrease probability of detection. Camouflage patterns, as printed on fabric and painted on vehicles, are aiding the soldier to blend better with his operational environment. Camouflage patterns are not a "quick fix" for survivability; training and doctrine are also crucial factors for increasing survivability.

Various factors need to be taken into account during development of a camouflage pattern. The relationship between these factors are shown schematically in *Figure 1*. The first consideration is the environment in which the pattern will be deployed. The colours used in the pattern (spectral properties of the pattern) will depend on the vegetation and geology of the envisaged area of operation. That is: mostly brown colours wil be used in desert and semi-desert areas, while greens will be the dominant colour in tropical areas. The size of the different elements in the pattern (spatial properties of the pattern) is determined by three factors: the most probable engagement distance (doctrine), the sensors to be used by the opposition (human eye or electronic detectors) as well as the spatial distribution of different elements in the operational environment.

The need for a unique pattern is also determined by corporate image (e.g. to be identified as a South African Defence Force member). During engagement with opposing forces it is also important to be uniquely identified as part of own forces (Identify Friend or Foe (IFF)).

The manufacturing technology and manufacturing capability also plays a role in the pattern design, albeit to a lesser extent.

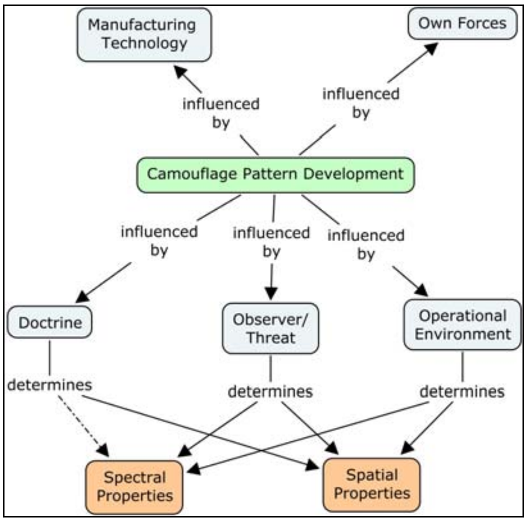


Figure 1 Camouflage pattern development

The spectral and spatial properties are not only determined by the factors mentioned above, but also by the (possible) observer/enemy. The human visual system (which includes the brain) is one of the most powerful observation systems. This paper examined the eye-brain interaction, and how these properties could aid camouflage pattern development.

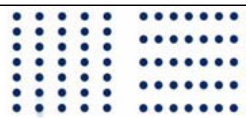
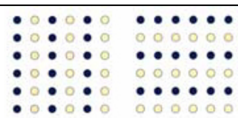
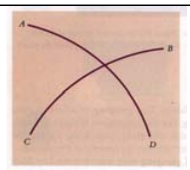
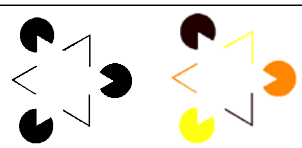
2. The Human Visual System

The human visual system is very complex, therefore this study was undertaken in order to better understand the human eye-brain interaction. It also assisted in forming a better understanding of how a human perceives a scene, and how the information in the scene is processed and analysed in the brain.

The Gestalt Principles, as defined by the German psychologist Max Wertheimer [1, 2], describes form and shape perception. These principles are often hailed as too simplistic and inadequate, but we have found that it helps a lot towards a better understanding of the human's subconcious view of the world around him. The four Gestalt principles discussed below is shown in Table 1.

The first Gestalt principle is called proximity. Wertheimer suggested that elements close to each other appear to be grouped together: the blue dots appear to be grouped together in a line, due to their spacing. Likewise, similar elements appear to be grouped together (this is called similarity). Although the spacing is the same in this case, similar elements appear to belong together, again forming a line. The third principle is continuity: The brain prefers straight lines (A-D, C-B) over ones with a discontinuity (A-C, D-B). The fourth and last one discussed here is called closure: the brain completes the figures even with some information missing. Even with different coloured elements (as in the last figure of Table 1), it is still perceived as a white triangle on top of a coloured triangle.

Table 1.Gestalt principles

Proximity	
Similarity	
Continuity	
Closure	

The human visual system can sometimes be tricked into seeing an environment in a way that looks different from what is actually presented.

A good example is the cubes as described by Purves [5], as seen in *Figure 2*. These cubes describe the effect called colour constancy. The blue squares on the top surface of the cube in the yellow environment (left) and the yellow squares on the top surface of the cube in the blue environment (right) actually are the exact same colour!

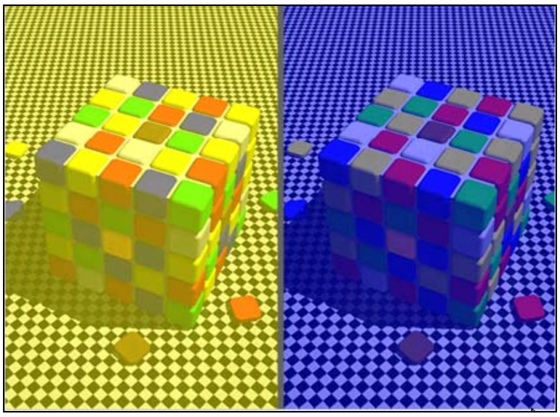


Figure 2 Purve's cubes

3. Depth perception

It is usually relatively easy to detect flat-surfaced objects in nature. This is because we (humans) live in a three-dimensional (3-D) world, and flat surfaces do not occur frequently in nature. Therefore, camouflage needs to be three-dimensional to be effective. It needs to be 3-D on a local scale (i.e. have some texture) or on a global scale (i.e. have depth). If physical three-dimensionality cannot be achieved, then at least a perception of depth will already help to increase camouflage effectiveness.

Textured gradients are one of the methods to achieve depth perception on flat surfaces [3, 4]. The best illustration of this effect is Gaussian blur, which is used to depict curvatures on flat surfaces. This is illustrated in *Figure 3*. A blue circle is shown on the left, but with the gradient areas (as on the right), it is perceived/interpreted to be a sphere illuminated by a light source.

A much similar principle can be observed in photographs with shallow depth-of-field. Everything out-of-focus is perceived to be in a different plane than the in-focus parts.

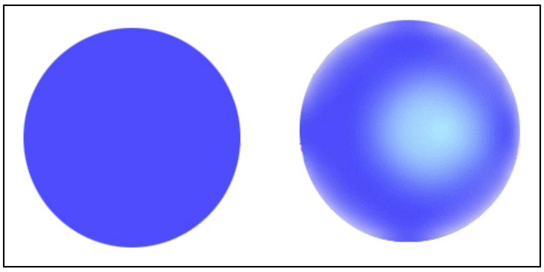


Figure 3 Depth perception, using Gaussian blur

The Cornsweet effect [6, 7] is another interesting phenomenon (*Figure 4*). The centre of the figure has a sharp transition from white to black. On the right the black fades to a grey, while on the left the fading is from white to grey when looking from right to left. The grey parts have the perceptual effect of different colours, but in fact it is exactly the same colour (blank the centre part of the figure to verify).

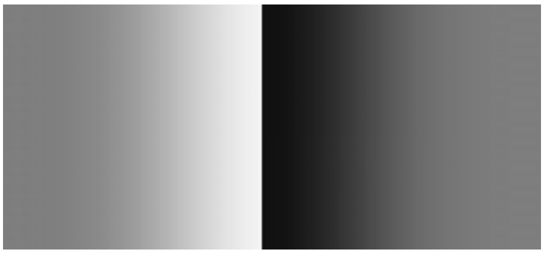


Figure 4 Cornsweet effect

The Cornsweet effect can be enhanced by providing additional "clues" in a scene, as shown in *Figure 5*. These are:

- Several cubes are shown in the figure, all of them having a darker side as well as a lighter side.
- The different cubes give perspective (depth) to the figure.

- The shadows casted by the cubes on the floor surface clearly indicate the presence of a light source, illuminating the scene from the top left-hand corner.

However, only when the centre part (transition) of the cube in the middle is blanked, one realises the colours on the opposing faces of the cube are the same.

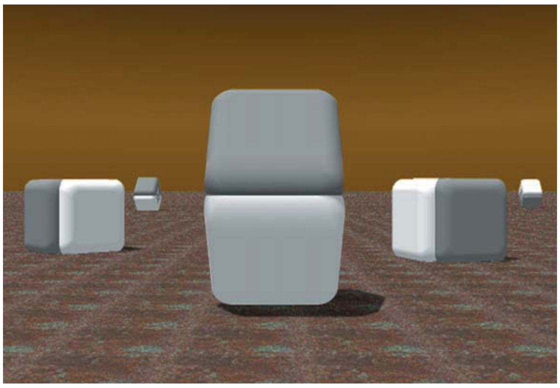


Figure 5 Complex figure: Cornsweet effect

4. Pattern developed

A camouflage pattern has been developed in order to determine if all of abovementioned phenomena could be observed in a real-life situation in the field. If these phenomena could be observed, it would improve the effectiveness of current camouflage uniform patterns.

The first requirement was a pattern having depth perception. The principle of focus depth and Gaussian blur was incorporated with this aspect. A background pattern, consisting of three colours, was developed. Two contrasting colours, namely a brown and a green, were selected. The third colour was a dark grey, to be used as a "shadow" colour. All three colours blurred into each other, with no sharp edges. The size of the elements were designed to be effective at long distances.

Super-imposed over the fade-pattern, was a pattern consisting of smaller elements, which had the purpose of being the texture-elements. This pattern had sharp edges, and as the spatial resolution of the human eye decreases with distance, these patterns blended into each other to form larger patterns (short-distance to medium-distance pattern). Also, with the edges being hard, the patterns would have the perception of being closer than the faded background pattern. A section of the pattern is shown in *Figure 6*.

Figure 6 Pattern developed

Crye developed the Multicam pattern (used by the USA [9]), as well as designing the new British camouflage uniform [10]. These patterns have similar foreground/ background properties than those described here. Due to a lack of published information on the websites and open literature it could not be established if the pshychophysical aspects of human vision was considered during the design process.

5. Discussion

Two versions of the pattern were made, namely a light-coloured version (called "FadeLight") as well as a darker version (called "FadeGreen"). The patterns were printed on fabric, and uniforms for evaluation were made. Firstly, a qualitative evaluation of the patterns were made. The uniforms were observed at distances ranging from 5m up to 50m. The evaluation was done in November, which is the wet season, when the grass and foliage is generally very green.

The first observation was that the overall lightness of both patterns was too high: the patterns were much lighter than the background. Secondly, there was too little lightness contrast between the different background colours (green and brown). This meant that the fading effect could not be readily observed at longer distances.

The third observation was that the smaller darker elements were also too light. These elements were supposed to act as the disruptive elements, which it did not. At a distance of 30m the uniforms appeared to have a relative homogeneous colour. However, the smaller elements did merge into larger patterns, because the human eye could no longer resolve all the small elements. The uniform is shown in *Figure 7*.

Figure 7 Uniform in the field

The Analytical Hierarchy Process (AHP) was used to evaluate the pattern quantitively [8]. The current South African National Defence Force (SANDF) pattern served as the reference pattern. A fourth pattern was also used in the evaluation, which was a concept pattern that performed well during a previous evaluation (which was called “Concept-X”).

The AHP scores, as well as the standard deviation of the observers’ results are shown in Table 2. The low consistency ratio scores (CR) confirmed that all observers performed the evaluation consistent. A graphical presentation of the results is shown in *Figure 8*. The blue triangles are the data points for the AHP scores, while the red bars are the respective standard deviations.

Table 2.AHP evaluation results

First Evaluation		
Uniform	**AHP-score**	**Std.Dev.**
FadeGreen	13	4.3
Reference	30	11.0
Concept-X	51	8.7
FadeLight	5	0.9
CR	4	
Second Evaluation		
Uniform	**AHP-score**	**Std.Dev.**
FadeGreen	12	2.9
Reference	30	7.0
Concept-X	54	6.5
FadeLight	4	0.9
CR	7	

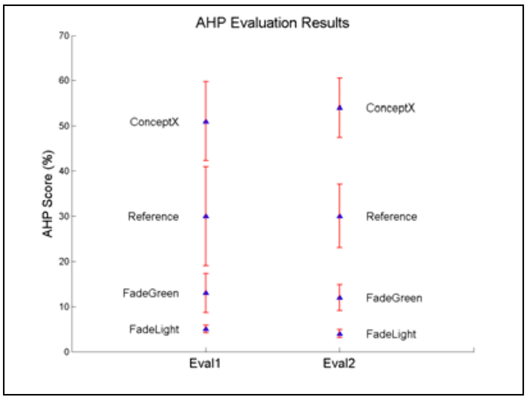


Figure 8 Graphical presentation of the AHP results

The AHP evaluation confirmed the initial qualitative evaluation, namely that the new patterns were too light, and did not blend very well with the environment. Hence, it received very low scores.

6. Conclusions

The aim of this study was to apply certain psychophysical aspects of human vision during camouflage pattern design in order to create depth perception on a flat surface (uniform), thereby improving camouflage effectiveness. Unfortunately, depth perception (and improved effectiveness) was not obtained with the patterns developed; the primary reason being the low contrast between the two background colours. A second reason was that the disruptive patterns did not have enough contrast with the background pattern. A revised pattern will be evaluated in October 2010.

7. References

[1] RJ Sternberg, R.J., "*In Search of the Human Mind*", 2nd Edition, Harcourt Brace College Publishers, 1998, ISBN 0-15-504025-1, p 50

[2] Kosslyn, S.M., Koenig, O., "*Wet Mind – The New Cognitive Neuroscience*" The Free Press, New York, 1995, pp 74-77

[3] Paré, M., "*The visual system*", Lecture at Queens University, Canada, as published at http://brain.phyg.queensu.ca/pare, downloaded July 2007

[4] Landrigan, D.T., "*Illusions Gallery*", University of Massachusetts Lowell, Psychology Department, as published at http://dragon.uml.edu/psych/depth2.html, downloaded August 2007

[5] Lotto, R.B., Purves, D., "*An empirical explanation of colour contrast*", Proceedings of the National Academy of Sciences of the USA (PNAS), Vol97, No 23, November 2000, P 12834-12839

[6] Purves, D., Shimpi, A, Lotto, R.B., "*An empirical explanation of the Cornsweet effect*", Journal of Neuroscience, Vol 19, No 19, October 1999, P 8542-8551

[7] Purves, D., Williams, S.M., Nundy, S., Lotto, R.B., "*Perceiving the intensity of light*", Psychological Review, Vol 111, No 1, 2004, P 142-158

[8] Baumbach, J., "Using the Analytical Hierarchy Process to Evaluate Target Signatures", Proceedings of the Land Warfare Conference, Brisbane, Australia, 27-31 October 2008, P29-34

[9] http://www.multicampattern.com/about, accessed 5 August 2010

[10] http://news.bbc.co.uk/2/hi/technology/8422942.stm, accessed 16 January 2010