Colour and Pattern Composition to Blend Objects into a Natural Environment

Johannes BAUMBACH
Council for Scientific and Industrial Research (CSIR), South Africa

ABSTRACT

Three experimental patterns, having the same colours, were developed to better understand colour, form and texture perception by the human cognitive system. It was found that at short distances small elements (highly textured pattern) are almost three times more effective than a pattern with large elements, while at long distances the pattern with the larger elements was three times more effective than the textured pattern. Colour differences in the pattern, caused by the human eye's integration where the individual elements could not be resolved, were not obvious.

1. INTRODUCTION

Successful blending with the natural environment (also known as camouflaging) depends on a huge number of factors. For an object to be successfully camouflaged it needs to closely match the environment's colours, shapes and textures in order to reduce the detection probability by a possible observer. In the majority of cases an observer scans an area of interest with his eyes. Successful detection of a camouflaged target in a natural environment also depends on the physical properties of the observer's eyes, i.e. eyesight and possible colour deficiencies. A second aspect, which is mostly under-estimated, is the psychological aspects of human vision.

The key question to our research is: "What is the contribution of form, brightness and colour of the pattern on camouflage performance?". In this paper we describe these three psychophysical aspects of human vision. An experiment has been designed to test these aspects, using three different camouflage patterns (all three have the same colours).

2. PSYCHOPHYSICAL ASPECTS OF HUMAN VISION

One of the first basic principles of effective camouflage is to disguise the shape/form of a target. An observer will be able to immediately detect the shape of an uncamouflaged human in a natural environment. The purpose of camouflage patterns is therefore to divide this telltale shape into indistinguishable "parts". The human cognitive system is, according to Kosslynn (1995), a very opportunistic system. Depending on the task, clues provided and the observer's abilities, different kinds of information in the scene are exploited for interpretation.

Figure 1 shows three of the seven "Gestalt principles", which were originally defined by Max Wertheimer, a German psychologist practicing in the early 1900's (see Paré (2007)). These three are proximity, similarity and closure. Elements near each other (proximity) appear to be grouped together. Likewise, elements that look similar (similarity) also appear to be grouped together. These two aspects are exploited with the Concept 2 and Concept 3 patterns, as explained later. The third principle, where the human brain completes the triangles even when some information is missing, is called closure. Even with different coloured elements, Figure 1c is perceived as a white triangle on top of a coloured triangle. This concept will be exploited in future pattern concepts. From a psychophysical viewpoint all of the above are defined as “form perception”.

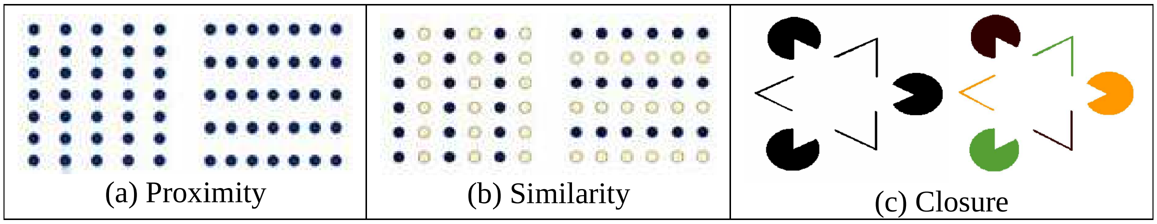
(a) Proximity (b) Similarity (c) Closure

Figure 1. Gestalt Principles: Proximity, Similarity and Closure.

The second psychophysical aspect is brightness perception. The perception of brightness of an area is determined by the elements with the lowest spatial frequency, as discussed by Perna and Morrone (2007). Although they used greyscale images in their research, the same effects were observed during our own evaluations. When patterns with small elements are observed at increased distances, the high frequency elements (the small elements) starts to disappear. This is due to the spatial resolution of the eye, which can’t resolve the elements anymore. In this particular case, the brain starts to fill in missing information, “assuming” the missing parts are the same colour as that of the low frequency (larger) patterns (Concept 2 and 3 patterns).

Colour perception is the most complex of all of the psychophysical aspects of human vision. Context of presentation has a huge effect on the perceived colour. Colours with low chromaticity (more neutral/grey) are especially prone to contextual perceptions. One of the most striking examples is the coloured cube, developed by Lotto and Purves (2000).

3. CAMOUFLAGE PATTERNS

In order to better understand the role psychophysics play when designing and evaluating camouflage patterns, we designed three different patterns, which were printed on fabric and uniforms made. A single baseline pattern was used as reference (and starting point) for the three experimental designs. The colours used for all of the experimental patterns were the same. The reason for this is that we are interested in the influence of the pattern and by keeping the colour the same we reduce the number of variables. The baseline and the three experimental patterns are shown in Figure 2.

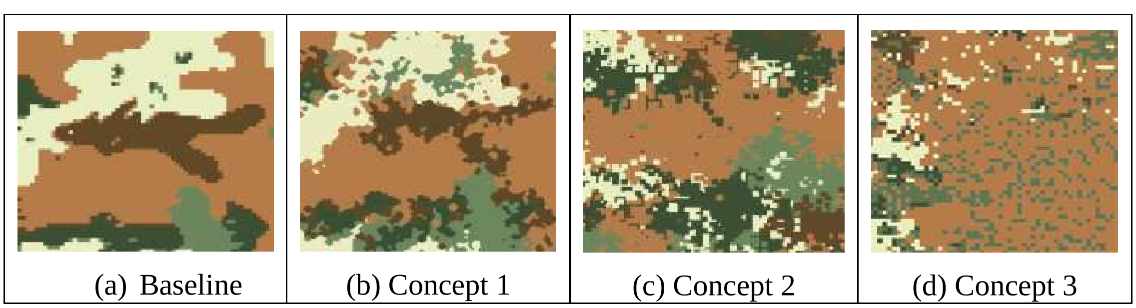
(a) Baseline (b) Concept 1 (c) Concept 2 (d) Concept 3

Figure 2. The baseline pattern, together with the three experimental patterns.

The baseline pattern, which does not have a large number of small elements (texture), was designed to be effective over longer distances (150m-300m). The Concept 1 pattern was designed to retain the long-distance properties, but by introducing smaller elements, have short-distance properties as well. Therefore, for each of the colours the contrast threshold function (CTF)[1] was used to calculate the element sizes that would be visible up to 100m, assuming daylight conditions and the light-brown as the background colour. Starting off with the baseline pattern, edge elements not larger than the calculated size were "displaced" within a pre-defined distance from the original edge. The effect of this was that the edges of the pattern became diluted, and the patterns appear to have a lot more texture. The area ratios between the different colours remained the same.

It was decided that the Concept 2 and Concept 3 patterns would be typical digital patterns (i.e. patterns constructed by means of square elements). Again, the element sizes were calculated using the CTF, assuming daylight conditions and light-brown as the background colour. The element sizes for Concept 2 were defined for resolvability at 100m, while for Concept 3 it was defined at 30m.

All three experimental patterns were printed on fabric. A jacket and pants made of each were used for field evaluations.

FIELD EVALUATION AND DATA ANALYSES

The three concept uniforms were evaluated in the field, using the analytical hierarchy process (AHP) developed by Saaty (1980), which is a pairwise comparison method. Seven observers scored the uniforms in terms of their relative performances in the field, both on short distance (30m) and long distance (160m). The evaluation results are shown in Table 1. Scaling is linear between 0 and 100, and larger values indicate better performance.

Table 1. Evaluation results for 30m and 160m.

Uniform	**Distance: 30m**	**Distance: 160m**
Concept 1	15	63
Concept 2	22	14
Concept 3	63	23
Total:	*100*	*100*

The data shows that at a distance of 30m the digital patterns performed better than the larger pattern. This was as expected, since the small elements provide much better texture match with the environment. Due to the gradual change from one colour to the next the digital patterns also have "soft edges", which make them less prominent at close range. One the other hand, Concept 1 performed the best at 160m. The digital patterns lost all detail at the long

[1] The CTF defines the threshold at which a specific spatial frequency (pattern size) would just be resolved by the human eye, given a certain light level and a specific contrast ratio between the elements. Although defined for a monochrome sine-wave function, it was assumed that it would not yield dramatically different results in the colour domain. See Barten (1999) for a detailed discussion on CTF.

distances, and the fabric appeared to be of uniform colour, void of any detail to aid in blending with the environment. The predicted resolvable element size at different distances, calculated using the CTF, was found to be on the conservative side. A given element size could be resolved at a distance approximately 10% further than the theoretical value.

As soon as the human eye can't resolve the texture elements, an average colour for an area is perceived. The area with the brown background and the green elements shown on the right-hand side of the Concept 3 pattern needs to be mentioned (Figure 2d). Theoretically the calculated colour difference between that area's "average colour" and an adjacent brown area has a dE = 6. During our evaluations this difference could only be seen by a person familiar with this phenomena and actively searching for it. This is caused by colour and brightness perception, as discussed earlier.

CONCLUSIONS AND FUTURE WORK

Through this work we have gained significant understanding into the psychophysics of human vision, and its influence on successful blending of patterns with the natural environment. Future work will include aspects of colour perception (lightness, whiteness and chromaticness), depth perception (as introduced by shadows and texture) and contrast perception.

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Address: Johannes Baumbach, CSIR, Defence Peace Safety Security (DPSS),
PO Box 395, Pretoria, 0001, South Africa
E-mail: jbaumbac(a)csir.co.za