The effect of contrast in camouflage patterns on detectability by human observers and CAMAELEON

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ABSTRACT

Evaluation of signature properties of military equipment is very important. It is crucial to apply the proper method out of many possible approaches, based on amongst others ranking by probability of detection, detection time, and distance to target, which have been carried out by various countries. In this paper we present results from camouflage pattern assessments utilising two different approaches, based on human observers (detection time) and simulations (CAMAELEON). CAMAELEON ranks camouflaged targets by their local contrast, orientation and spatial frequency, mimicking the human eye's response, and is a rapid and low cost method for signature assessment. In our camouflage tests, human observers were asked to search for targets (in a natural setting) presented on a high resolution pc screen, and the corresponding detection times were recorded. In our study we find a good correspondence between the camouflage properties of the targets in most of our unique tests (scenes), but in some particular cases there is an interesting deviation. Two similar camouflage patterns (both were random samples of the pattern) were tested, and it seemed that the results depended on the way the pattern is attached to the test subject. More precisely, it may seem that high-contrast coloured patches of the pattern in the target outline were significantly different detected by humans compared to CAMAELEON. In this paper we discuss this deviation in the two signature evaluation methods and look at potential risks.

Keywords: Camouflage, CAMAELEON, Human observers, Detection time, Detectability range.

1. INTRODUCTION

Understanding the nature and function of the human visual system in complex natural scenery is inextricably intertwined with progress within the fields of camouflage and concealment. The visual system allows for detection and subsequently identification of objects at a distance, depending on a broad set of parameters, generally involving acuity of the system, the system's field of view, what types of light levels it operates under, the way spectral information is being extracted from the visual environment and how spatial information is being processed and then interpreted [1].

Several models have been reported, mimicking the human visual system in different ways, often with the aim of model the eye's probability of detecting a camouflaged target in natural backgrounds [2-6]. Based on how the human eye's receptive filter banks respond to a target's contrast, spatial information and orientation a software tool – appropriately named CAMAELEON – was developed [2], verified [7,8] and made commercially available during the 1990's, claiming to distinguish between a target and its local background similarly to the human eye. Hence, CAMAELEON is a signature assessment tool valuable in a process of developing, testing and evaluating camouflage.

Although being verified and found to predict human performance in search processes for camouflaged targets in overall [7], it is still very interesting to test the computational modelling of human vision against real observer data from human observers. There is not very much literature on visual function in natural environments [1]. Hence it will be of interest to try to find sub-areas of human search performance, founded in visual search tasks in natural environments that are thought to be difficult to model, and then compare it with one or more computational human vision models.

Based on our results from an extensive trial, where human observers were searching for camouflaged targets in natural scenery, we found some interesting "performance anomalies" when comparing two near-identical targets, resulting in significant differences in target performance given by their corresponding detection times distributions. In this study we want to study one particular anomaly (i.e. contrast patch located at the head outline) in more detail by evaluating the same two targets in the same natural scenery also by CAMAELEON, to study further if CAMAELEON picks up the same anomaly effect, and finally to compare results from human observers and CAMAELEON. We give possible explanations to the deviations that we observe, when comparing human vision and a computational model of human vision.

2. METHODS

Two near identical camouflage patterns, from now on referred to as target 1 and target 2 and shown in Figure 1, were roller printed (HolTex, Germany) onto cotton textile (225 g/ m^2), similar to that used in military clothing, and then sewn into two mannequin suits consisting of torso and head. A styrofoam mannequin was dressed up with the two suits, one at the time, and the two camouflaged targets were then recorded in 6 various natural backgrounds (scenes) in Rhodes in August 2013. The scene images were all intended to be used in camouflage assessment with i) CAMAELEON and ii) human observers in a search by photo observer trial.

Figure 1. The camouflage patterns used in this study. In a) and b) we see the patterns of target 1 and target 2, respectively, with no head. In c) and d) we see the same two targets, target 1 and 2, respectively, with head. Note that in c) the head of target 1 is nearly half-filled with a highly contrasting dark green patch on the right side.

Image capture in natural backgrounds

The scenes were chosen to contain different types of local backgrounds around the target. We recorded the targets in as identical conditions as we were able to, considering, target orientation, position, area exposed, and as stable illumination conditions as possible. Our aim was to assure that the target's camouflage patterns were assessed solely based on their relative camouflage effectiveness. To achieve that, we carried out a near-continuous (within minutes) recording of the targets in each scene. This was done by a digital camera (Nikon D5200). Furthermore, only one target was recorded per image to avoid confusion about what is actually to be assessed by the human observer during the trial.

Targets were located randomly in the image frame (never centered) in order to avoid observers' expectations on where to start to search. The physical distance to the targets in the field was varied between 17 m and 70 m in the 6 different scenes. We recorded the scene images with the intention that it was actually possible to detect the target, whenever the observer's eye focus was at the target's spot in the image frame. Hence, a detection of a target by a human observer was to reflect camouflage effectiveness and not to be based on observer's making guesses about too far objects. In 3 of the in total 6 scenes the target was recorded with both torso and head (Fig 1), whereas in the 3 of the remaining scenes only the target's torso was recorded by photography. A collage of close up-images of the targets in the 6 different scenes is shown in Figure 2.

Figure 2. Close-up images of the 6 different scenes used in this study, both for CAMAELEON-analysis as well as in the search by photo camouflage assessment by human observers. The images show one of the two targets, either target 1 or target 2, and its local background. The 6 images are all 256 by 256 pixels prepared for further CAMAELEON-analysis of detectability. During the observer trial with humans, however, the scene images were much larger (2560 by 1600 pixels), suitable for detection times within the seconds range.

2.1 CAMAELEON simulations

We performed analysis by the CAMAELEON software (licensed by IABG, Germany) on the two targets (target 1 and target 2) in all of the 6 scenes [2]. In short, the CAMAELEON software allows for estimates of detectability (given in meters) of a target in a natural scene. As shown in Figure 3, the target had to be marked (in red) along its outline as delicate as possible. This was done by drawing a free-hand line by an operator in the research team. Thereafter, a background had to be chosen, to which the target was compared regarding statistical overlap of local contrast, spatial frequency and local orientation [2]. Hence it was of great importance that the target was defined correctly as well as the backgrounds to be used in a comparison among target's camouflage effectiveness were identical.

In order to find the two target's detectability ranges and thereafter compare the calculated figures/numbers of target 1 *relatively* to target 2, we developed a procedure trying to minimize the sensitivity of the target marking on the final results. Each target was marked (as accurate as possible along the target outline) twice in every scene. Although the two targets were placed as identical as possible when recording the scenes by photography, their relative position in a particular scene deviated within a few centimetres. This was due to the fact that the targets appearance was never 100 % identical as the targets consisted of (soft) cotton fabrics, and hence deviated slightly due to small folds in the fabric etc. Therefore, in 5 of the 6 scenes it was not possible to use the markings of target 1 also for target 2 in the CAMAELEON calculations of detectability. Hence, the markings of target 1 and target 2 had to be drawn independently. Finally, we performed calculations of detectability of each of the target markings, using 5 different local backgrounds. An example is shown in Figure 3. This means that a total of 10 values of detectability were gained per target in each of the 6 scenes. We chose 256 by 256 close-up images of all of the scenes in the calculations of target detectability as CAMAELEON required 2^n pixel images. This means that the only the relevant (and zoomed in) parts of the whole scene image was used in our CAMAELEON analysis.

In addition we performed calculations on target detectability in all scenes for at least one target, with the aim of studying the sensitivity of the different (drawn by human) target markings on the estimated detectability distance for a fixed background. Based on the results we found, we were able to avoid markings of the targets in our study which would lead to extreme detectability range values.

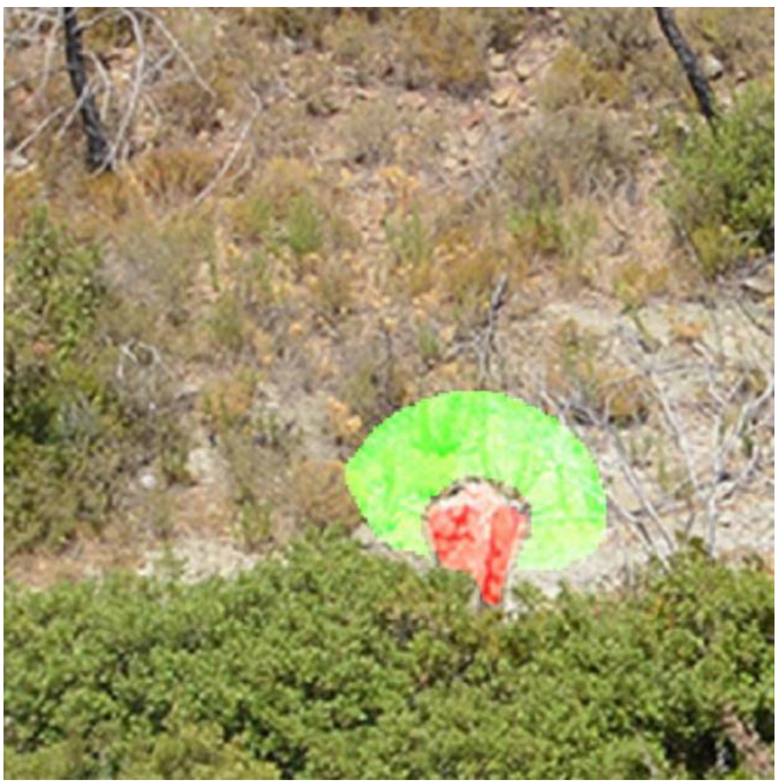


Figure 3. Illustration on how one of the targets was marked (red) in scene 2 for further use by CAMAELEON. The green halo above and to either side of the target shows one of our 5 differently chosen local backgrounds, to which the targets were to be compared, in order to find an estimate on the targets detectability, given in metres.

2.2 Search by photo trial with human observers

The number of human observers that were used per scene varied between 24 (scene 3 and 5) and 36 (scene 1) in our observer trial. This was due to the fact that the observer results to be presented in this paper were a part of a larger camouflage study where a total number of 148 observers were used to assess 9 or 12 (some targets did not facilitate the use of a hood) unique targets per scene. However, the number of observers was the same for both target 1 and 2 (to an accuracy of one single observer) in each of the 6 scenes presented in this paper, and hence allows for a relative comparison of camouflage effectiveness per scene.

Preparation of human observers

Prior to the observer trial each soldier was given a word by word *identical* introduction to the observer trial by an instructor. Each observer was then adjusted to have an optimal and identical distance to the widescreen (ca. 40 cm), as the screen was intended to fill most of the observers' field of view Also, the observer's eyes were approximately leveling the center of the pc-screen. Thereafter, each of the observers conducted a test run consisting of two images similar to those in the main trial. During this test run, the observers were allowed to ask questions to the instructors, reducing the risk of misunderstandings before the main trial started. During trial itself, observers were not allowed to ask questions, but left to find targets solely by themselves. Finally, the observers were free to choose their own search strategy during the trial.

Conducting the observer trial

During the observer trial each observer was shown a randomized sequence of photographs of the 6 different scenes, one at the time in a high definition (HD) wide screen (2560 x 1600 pixels) in a dimly lit room. Each photograph represented a scene with either one or no target. The observers searched for a target and indicated detection by mouse-clicking at the target as soon as he or she felt confident that it was a proper target and not an anomaly (e.g. a target-shaped bush). There was a small tolerance surrounding each target. Hence the observer had to click close to the target to indicate a "hit", but not necessarily spot on the center of the target. Of importance was that each human observer was exposed no more than one single target per scene, as targets were identically positioned in each scene.

The total duration of each scene image presentation was limited to 60 s in order to give the observer reasonable search time, but on the same time avoid a reduction of the observer's concentration through tedious searches for a well hidden target. Whenever our fixed time limit was exceeded, the target (in that particular scene) was stored as a non-detection". Furthermore, we used a self-developed software tool, showing the scenes in a randomized order and keeping data in a sorted manner for further analysis.

2.3 Statistical analysis

CAMAELEON-data

For the CAMEALEON study we were not able to use exactly the same target masking for target 1 and target 2 in 5 of the 6 scenes. To estimate the uncertainty which was introduced by different selections of the target area, we calculated 10 detectability ranges for one target for each scene by choosing 10 different target markings while keeping the marked background area the same. From these 10 detectability ranges we calculated an average detectability range and the standard deviation (Tab. 1). The obtained standard deviations assured that comparing the two targets by applying the described procedure lead to meaningful results.

Observer trial data

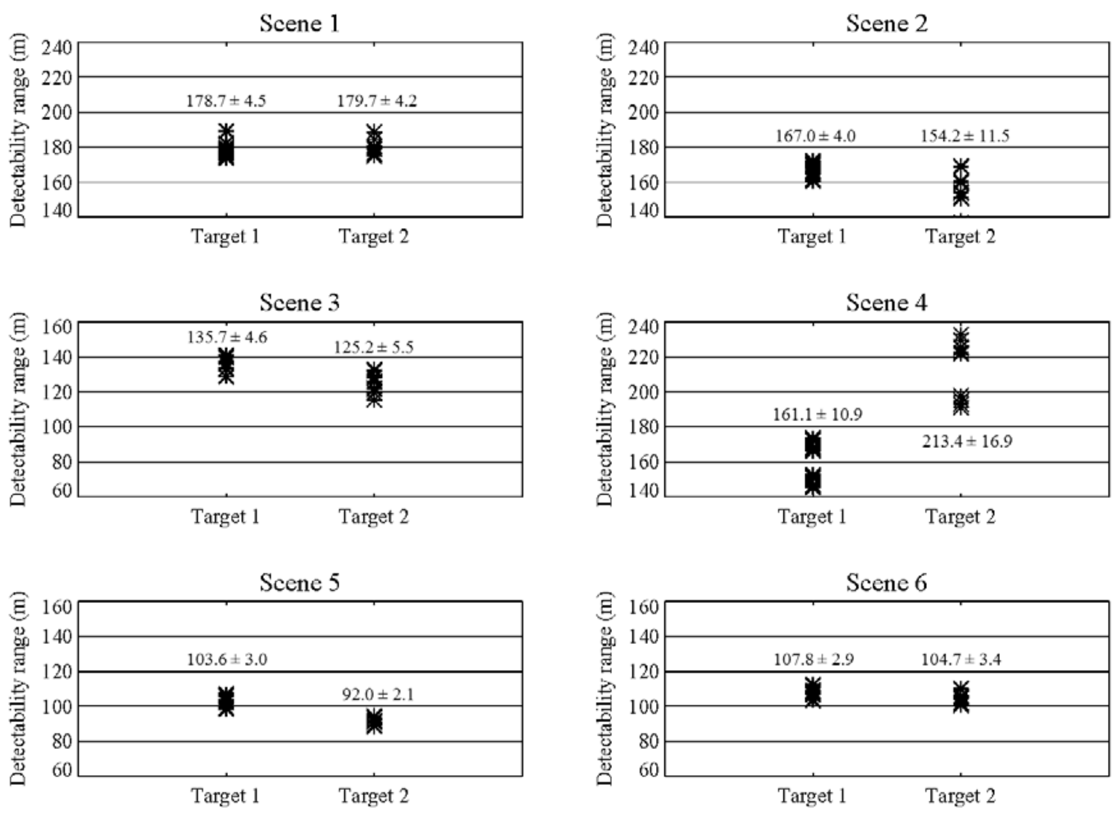
The detection time data from the observer trials, using humans, were inspected further in order to look for significant differences between the two target's camouflage effectiveness in each of the 6 scenes. We first carried out a Jarque-Bera test for each target per scene, testing whether the corresponding distribution of detection times was normally distributed or not. Whenever at least one of the target's detection times, in a particular scene, failed to fulfill normality we carried out a Wilcoxon on rank test (Mann-Whitney U-test) as such a non-parametric test has shown to be more trustworthy than the parametric counterpart (such as ANOVA) in such cases [9,10]. Also, the Wilcoxon's rank test, being non-parametric, has the ability to account for non-detections (i.e. detection times larger than the search time limit set to 60 s) that appeared for some of the target's in some scenes during the observer trial. In total, we then gained p-values describing the degree of similarity in camouflage effectiveness between target 1 and target 2 for each of the 6 scenes. A further description on how to handle trial detection data, including the non-detections, can be found in a recent study on camouflage assessment methodologies [11].

3. RESULTS

The two near-similar camouflage pattern targets were evaluated in 6 scenes by utilizing both CAMAELEON detectability range calculations and based on human observers in a search by photo observer trial.

3.1 CAMAELEON results

The results calculating similarity measures (i.e. detectability ranges) with CAMAELEON for target 1 and 2 in the 6 scenes are shown in Figure 4. For each scene we selected five different, but relevant background areas. All five backgrounds were selected in close vicinity to the target. Three of the backgrounds surrounded the target and differed only in size. One background mask was chosen without including any foreground (such as Fig. 3), while the last one did not include any foreground and in addition was marking the most relevant background on only one side of the target. These 5 backgrounds were used for detectability range calculations for both targets. Besides, each target was marked twice in an as similar as possible way in each scene. This resulted in 10 different detectability ranges for each target and each scene, which are plotted in Figure 4. Detectability ranges varied from 89 m to 233 m. The 10 calculated detectability ranges for one target in one scene spanned different intervals. The spread of the calculated detectability ranges in-between the highest and the lowest value varied from 6 m for target 2 in scene 5 and up to 42 m for target 2 in scene 4. The average detectability ranges together with the standard deviations for each target in each scene are given above or underneath the data points.



Figur 4. The 6 plots show the obtained 10 detectability ranges for the 10 combinations of target (two different target masks) and background (five different background masks) markings for each target and each scene, together with the average detectability range and standard deviation.

The role of target markings on the results

Different markings of the target and background resulted in different detectability range values, as each pixel of the image contributed to the calculation of measure of similarity. To estimate the influence of the target markings we calculated detectability ranges for 10 target masks while keeping the background mask unchanged. This was done for one target and one background in each scene. Table 1 lists the obtained average detectability ranges with the corresponding standard deviations. These results were used in two ways. First to assure that the 2 markings of the targets for the calculations presented in Figure 4 would result in detectability ranges with low deviations. Furthermore, did the results indicate that the uncertainty introduced due to the different target masks did not lead to meaningless results for the study comparing the two targets.

Table 1. Average detectability ranges calculated for target 1 for each scene with 10 different markings of the target and one determined background mask.

Scene	Detectability range (m)
1	174,28 ±3,1
2	165,1 ±2,2
3	139,6 ±0,6
4	168,5 ±2,9
5	106,5 ±3,4
6	105,5 ±3,4

Table 2 gives an overview over the detectibility ranges for target 1 and target 2 in the 6 scenes together with their distances to the camera, and if they were used with head/hood or without. The last column of the table presents the relation between the detectability ranges of the two targets. In 2 of the 6 scenes (scene 1, 6) both targets performed almost equal (Target 1/ Target 2 values close to 1). In scene 2, 3, and 5 target 2 performed slightly better than target 1, while in scene 4 target 1 performed much better than target 2.

Table 2. Detectability ranges for target 1 and target 2 in the 6 scenes together with their distances to the camera and if they were used with head or without. The last column presents the relation between the detectability ranges of the two targets.

Scene	hood	Distance to target (m)	Detectability range (m) Target 1	Detectability range (m) Target 2	Target 1/ Taget 2
1	with	41	178,7 ±4,5	179,7 ±4,2	0,99 ±0,05
2	without	39	167,0 ±4,0	154,2 ±11,5	1,08 ±0,11
3	without	41	135,7 ±4,6	125,2 ±5,5	1,08 ±0,09
4	with	17	161,1 ±10,9	213,4 ±16,9	0,76 ±0,11
5	without	70	103,6 ±3,0	92,0 ±2,1	1,13 ±0,06
6	with	17	107,8 ±2,9	104,7 ±3,4	1,03 ±0,06

3.2 Observer trial results

The results obtained from the study with human observers was detection times for each target in each scene [11]. The median values for the detection times are given in Table 3, together with the number of observers for each scene and the number of non-detections. In case an observer didn't detect the target at all the detection time was set to 60 s (i.e. the detcetion time limit). The two targets showed different performances for each of the scences. To determine if the differnces in the median detection times for the two targets were significant the Wilconxon rank test was applied. For scene 2, 3, and 5 no sifnificant differnces in the performance of the two targets was found, in contrast to scene 1, 4 and 6, were the targets performed significantly different.

Table 3. Median observation times as result of the human observer trial for each target in each scene, together with the assessment of the significance of the obtained differences. Furthermore, the number of observes for each scene and the non-detections are listed.

Scene	No. of observers	Target 1 Median detection time (s)	non-detection	Target 2 Median detection time (s)	non-detection	Significant different
1	36	28,6	8	8,2	1	yes
2	27	23,6	2	27,7	3	no
3	24	5,3	1	9,8	1	no
4	35	38,0	7	15,3	2	yes
5	24	16,4	1	15,0	2	no
6	32	60	12	16,5	3	yes

3.3 CAMAELEON versus Observer trial results

A comparison of the results for the two applied methods to study the performance of the two targets in the 6 different scenes is presented in Table 4. CAMAELOEN assessed the performance of both targets as very similar in 5 of the 6 scenes. Only in scene 4 CAMAELEON predicted a better performance of target 1 in comparison to target 2. For this scene also the human observer trial resulted in different median detection times with target 1 having a near significant longer median detection time than target 2. The human observer trial revealed in addition a significant difference in median detection times for the 2 targets in scene 1 and 6, in which the targets were used with head (hood). Target 1 performed significant better in both these scenes, too.

Table 4. Comparison of the relations of detectability ranges (given with standard deviation) from the CAMAELEON study and the observer times (with significance) from the human observer trial for target 1 and target 2.

Scene	Detectability Target1/Target2	SD	Observation times Target1/Target 2	Significance
1	0,99	±0,05	3,49	yes (p=0,027)
2	1,08	±0,11	0,85	no (p=0,864)
3	1,08	±0,09	0,54	no (p=0,248)
4	0,76	±0,11	2,48	yes (p=0,064)
5	1,13	±0,06	1,09	no (p=0,707)
6	1,03	±0,06	3,64	yes (p=0,001)

4. DISCUSSION

In this paper we have studied how signature assessments induced by a simulation tool (CAMAELEON), mimicking the early stages in the human visual sensory system [2] correlate with human observers' assessment of two camouflaged targets in natural settings. We found good correlation. In some cases, however, which seem to have been connected with the way the pattern was distributed within the target, the camouflage effectiveness of the targets were very much differently assessed by CAMAELEON and human observers.

4.1 CAMAELEON results versus human observers

In Figure 4, which represents the main finding in this study, we see that the two targets were assessed by the CAMAELEON software tool to be similar or near similar in camouflage effectiveness in 5 of 6 scenes. In scene 4 it seems that target 1 was assessed by CAMAELEON to have shorter detectability range (and hence better camouflage properties in that particular natural scenery) than target 2. The results derived from human observers, assessing the same two targets in the same 6 natural scenes; show that the targets were assessed significantly different, given by their median detection time, in 3 of the 6 scenes.

A careful inspection of the 3 scenes, in which the two (near identical) targets were assessed to pose different camouflage effectiveness by CAMAELEON and the human observers, shows that the targets were always with head (hood) in these scenes. In the remaining 3 scenes, both targets were exposed with no head to the human observers and CAMAELEON. The two targets, in this study were near similar, but not exact copies of one another. This holds also for the two hoods, seen in Figure 1 c) and d). A further visual inspection of the two target heads shows that target 1 had a large dark green patch in the pattern filling most of the right part of the head, whereas target 2 did not have such a large distinguished pattern. This large dark patch in the pattern may have had an important effect on how the human observers perceived the two targets. In the following section we try to give an explanation to the observed difference on how the targets were assessed (to be similar) by CAMAELEON and (to be different) by human observers, regarding their camouflage effectiveness.

The CAMAELEON simulation tool assesses any target, relatively to its background based on similarity measures based on local contrast, spatial frequency and local orientation [2]. Hence, CAMAELEON may not necessarily respond to minor variations, regarding how the camouflage pattern elements are distributed within the target, as long as the three above mentioned parameters are unchanged in overall. The human visual perception – from its first sensory system to the cognitive understanding on similarity of shapes - is likely to be more delicate than represented by the three parameters contrast, spatial frequency and orientation [12]. Studies on visual search processes indicate that the observer normally has some (pre-induced) representation on the visual properties of the target to be searched for and, furthermore, some description on its physical properties, allowing the observer to distinguish the target from a complex background [1]. Hence, the high contrast pattern patch on the head of target 1 may have altered its properties in a way that affected the detection time significantly. It has been reported that edges are a salient feature of target detection processes [13], and the high contrast marking may have disturbed this feature, inhibiting detection.

It has further been reported that detection through some organic visual perception mechanism, consists of four stages [1]. The steps are i) detecting an anomaly in the background, ii) identifying the region of a target, iii) describing its contours, and iv) verifying the target being real. Step iii) involves the observer being able to describe and perceive the contour of the target. In our study, we found that target 1, with a contrasting marking at its head contour, had significantly longer detection times compared to its near-similar counterpart, target, 2, but with no such large marking. We believe this has to do with step iii) by some affection on the observer's ability to locate the targets outline in a search process.

Finally, it has been reported [14] that the human visual system is optimized for capturing the spatial information of natural visual images, and it would be interesting to know more on how such a high contrast patch, as was found in target 1 in our study, may have disturbed the observer's attention when the area where the target was eye scanned during the search process.

4.2 CAMAELEON results

Figure 4 presents the 10 detectability range calculations, belonging to 5 different background elements (masks) and 2 different target masks, for each target in each scene. Comparing the distribution of the detectability ranges in all 6 scenes it seems like there is an overall tendency that target 2 performs slightly better than target 1, with the exception of scene 4. In scene 4 target 2 performed significantly better than target 1.

The role of local background to the estimated detectability range

The detectability range distributions, caused by the use of 5 different background masks, revealed different characteristics in the different scenes. For scene 1 and 3 the values for the 10 detectability ranges for one target spread over intervals of 12-17 m with no significant difference in the performance of the two targets. However, we want to stress that in scene 1 the two targets were assessed by CAMEALEON to perform equal. For scene 5 and 6 the 10 detectability ranges could be found in intervals of 6-9 m. In these two scenes (Fig. 2) the backgrounds consisted mainly of stones and rocks. This represented a background with little variation in color, size or structure. Also the contrasts (local energy) exhibited a homogenous distribution due to distinct illumination differences between sunlit and shadow areas. Hence, these backgrounds were quite uniform with regard to local contrast, spatial frequency and local orientation [2]. Scene 6 consisted in addition of larger regions in the shadow. For the background masking we only used small amounts of these shadow areas. Accordingly, the 5 background masks in these two scenes resulted in similar detectability ranges for one target in one scene due to the uniformity of the background. The detectability ranges for scene 2 and 4 differed from the rest of the scenes because of their less compact distributions for both targets. This can be explained by the background mask choices. In both the scenes the foreground right in front of the targets was quite different to the background around the target. These foregrounds (scene 2 green bushes and scene 4 sunlit grass) were included in different amounts in the background masks, ranging from not accounted for to about a third of the mask. In addition did the distribution of the detectability ranges for target 1 vary less than for target 2 (Fig. 4) in both these scenes. In scene 2 the target is used with head (hood) and in scene 4 without. This means that the calculations of measure of similarity suggested that the camouflage pattern of target 2, independent of the pattern distribution on the hood, was more sensitive to the background elements chosen for the different background masks.

Scene 4 differs from all the other scenes in a number of aspects. The average detectability ranges for both targets had the largest standard deviations, or in other words showed the widest distributions. The presumed reason for this is discussed above. Furthermore, we find that the detectability ranges for one target accumulated in two groups. The grouping was due to the choice of background elements. 2 of the 5 background masks did not include the sunlit grass in the foreground. For the according 4 calculations obtained detectability ranges group around 25 m lower values than the other 6 detectability ranges. It should be noted, that his is also the only scene where the targets were placed in the shadow. At last, in this scene, as the only scene with such a result, the difference in the performance of the two targets seemed to be significant.

The study showed that the choice of background had a large influence on the detectability range calculations. For comparison of the performance of different camouflage pattern in the future the same background element therefore has to be applied.

The role of target marking to the estimated detectability range

The marking of different parts of the images both for the target (object marking) and the background changes the received detectability ranges. For the comparison study of the effectiveness of the camouflage pattern of target 1 and target 2 the target masking was different for the two targets, with one exception, namely scene 5. As the different masks did not introduce large deviations in the obtained detectability ranges we feel confident that the differences in the results of the CAMAELEON study and the human observer trial are not a consequence of the choice of target masks.

4.3 Possible future follow-up studies

The comparison of the performance of the two targets utilizing the two evaluation methods (CAMAELEON and human observers) showed in some scenes significant differences in the evaluation results. The in this paper presented study is based on an interesting “performance anomaly” we found during a camouflage study when comparing two near-identical targets. Different findings on the influence of markings overlapping edges of a target are reported in studies on disruptive coloration and background pattern matching in reducing detectability [15-18]. To verify the presented preliminary results we suggest a follow-up study using one distinguished camouflage pattern applied in varying ways, in terms of pattern patch distribution, to the target. In case of our target mannequin the high contrast color patch can be applied to a part of the hood as well as a shoulder. A carefully selected number of varying scenes could allow studying different aspects of target placing, e.g. the influence of the target being placed in the shadow, on the comparison study results.

CAMAELEON calculations suggested that the blurred pattern of target 1 was less sensitive to changes in the background. This could also be worth more extensive exploration in a later follow-up study.

5. CONCLUSION

We have seen, in this study, how the human visual perception may be sensitive to small – but important – deviations within a camouflage pattern, deviations that simulation tools mimicking the eye’s sensory response will not necessarily pick up. Contrast patches in the camouflage pattern located differently particularly with regard to the outline of the target seemed to have an influence on detection times for human observers.

Camouflage pattern developed the last years tend to favor small pattern structures, e.g. pixel structure of the US Universal Camouflage Pattern. This study shows that there may be potential pitfalls whenever pattern structures are too small, and that our reported effect of camouflage pattern contrast patches should be kept in mind.

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