News Article ID: 4028 Fire international
23 April 2003

Firefighter safety: How visible is your protective clothing?

TNO Human Factors Research Institute has developed a method to determine visual conspicuity of firefighting garments, write Dr F. L. Kooi and A. Toet. This method predicts human visual search and detection performance and can be determined in the field, as well as being determined from photographs or digitised imagery.

Summary
The conspicuity of six different firefighting garments was measured, from the back and from the side, and at two different positions. The experiment serves as a demonstration of the newly developed technique to quantify conspicuity. The results show that the conspicuity of firefighting garments is indeed measurable. The conspicuity of the six garments differs by up to a factor of two. The conspicuity also depends strongly on the visual environment - three times more shading resulted in a two to three times decrease in visual conspicuity. The TNO conspicuity method is a powerful tool to quantify the effective visibility of firefighter garments.

INTRODUCTION

To optimise the visual distinctness or conspicuity of objects such as firefighting garments a measure is needed to assess the degree to which they stand out from the background. Visual object distinctness is usually assessed through search and detection experiments with human observers. However, search performance inherently shows a large variance, and depends strongly on prior knowledge of the perceived scene.

A typical search experiment therefore requires a large number of observers to obtain statistically reliable data. It would require many subjects and an extensive experiment to measure the search performance for firefighter garments. It is for this reason that the TNO Human Factors Research Institute has developed a method to determine visual conspicuity which 1) predicts human visual search and detection performance, 2) can be determined in the field, and 3) can be determined from photographs or digitised imagery.

We made use of the TNO visual conspicuity meter to measure the effect of garment design on visual conspicuity. In this study we demonstrate the procedure and value of the TNO conspicuity meter.

VISUAL OBJECT CONSPICUITY

This section introduces the concept of visual conspicuity and explains the associated measurement procedure. Visual conspicuity refers to the discrepancy between the visual signatures of an object and its local background that attracts the attention of an observer. Visual conspicuity has previously been operationally defined as the peripheral area around the central fixation point from which specific object information can be extracted in a single glimpse (*Engel, 1971, 1974, 1977*).

The size and shape of the conspicuity area or 'visual lobe' have been measured for a range of static objects in static scenes (*Bloomfield, 1972; Bowler, 1990; Cole & Jenkins, 1984; Engel, 1971, 1974, 1977; Geisler & Chou, 1995; Jenkins & Cole, 1982*). It is found that the conspicuity area is small if the object is embedded in a complex background (a surround with high feature variability) or if the object is surrounded by irregularly positioned 'distracters' of high similarity (a surround with high spatial variability).

The conspicuity area is large if the object stands out clearly from a homogeneous background. The abovementioned definition of object distinctness therefore leads to results that agree with the intuitive notion of object detectability. However, the psychophysical procedures that were used by *Engel and Geisler & Chou* to measure the visual lobe are rather intricate and time consuming.

An operational definition of visual object conspicuity

The TNO Human Factors Research Institute has been in the process of developing a simple psychophysical procedure

to quantify the visual conspicuity of an object in a complex scene.

In this approach, object conspicuity is operationally defined as the maximal lateral distance between object and eye-fixation at which the object can be distinguished (*Wertheim, 1989*). This conspicuity measure can quickly be determined in situ, and can be used with full prior knowledge of the object and its location in the scene. It characterises the extent of the conspicuity area along the virtual line through the fixation point and the centre of the object.

The conspicuity area of an object is defined as the region around the centre of the visual field where the object is capable to attract visual attention, because it is perceived as significantly distinct from its local background.

We operationally define visual object conspicuity as the maximal lateral separation between object and eye-fixation at which the object can be identified (*Wertheim, 1989*). This separation is given either as the distance (in metres) in the fronto-parallel plane through the object, or as the corresponding visual angle (in degrees).

Conspicuity measurement procedure
The psychophysical conspicuity measurement procedure is as follows. First, the observer visually inspects (foveates) the target object to become familiar with it. Next, the observer fixates a point in the scene that is at a large angular distance from the object location. The target object should be positioned so far in his peripheral visual field that it can not be distinguished from the background.

The observer then successively fixates locations in the scene that are progressively closer to the object location, until he can perceive the object in his peripheral field of view. The successive fixation points are along a line through the initial fixation point and the centre of the object. The angular distance between the fixation location at which the object is first noted and the centre of the object is then recorded. Experienced subjects are usually able to make a setting within one minute. The distance thus obtained is adopted as the characteristic spatial extent of the distinctness area of the object.

The measurement procedure is simple and can be performed in the field or in complex environments. For objects in a cluttered environment only a few experienced observers (typically two to three) are needed to achieve sufficient accuracy. The resulting measure characterises the extent of the distinctness area along the virtual line through the fixation point and the centre of the object (*Engel, 1971, 1974, 1977; Geisler & Chou, 1995*). An optical instrument, the `conspicuity meter', has been developed at TNO to facilitate outdoor measurements.

Conspicuity and search time
When examining a scene, an observer usually fixates various points in the scene in rapid succession. The eye movements made during a rapid visual examination of a complex scene are performed automatically in response to the spatial features (layout) of the scene (Mannan ea, 1995). Details of the scene are examined during a fixation, and peripherally perceived information is used to select the next fixation point.

This visual interrogation process is not yet fully understood. However, one thing is evident: the more an object stands out from its background, the easier it will be detected, and the quicker it will be found. Visual conspicuity is therefore, though not the only, a main determinant of the chance that a road worker or firefighter will be detected in time.

The relationship between the conspicuity measurement as described above and search time has been examined for military vehicles (*Kooi and Toet, 1998; Kooi and Toet, 1999*). The results indeed show a clear, though not perfect, relationship between visual conspicuity and search time. Moreover, the TNO conspicuity meter has the advantage that the measurement can easily be repeated, which is not the case for search measurements.

FIELD MEASUREMENTS
The most time consuming aspect of visual conspicuity measurements is to control the experimental conditions. The conspicuity of an object depends on the surroundings and the meteorological conditions just as much as on the object itself.

Visual conditions

Our goal is to measure the conspicuity under "daytime conditions in a representative rural setting". It is therefore imperative to choose visual conditions that are representative as well as critical. If non-representative conditions are chosen, the results may also be non-representative. As far the critical aspect, it is for example possible that the conspicuity of the garments may not differ in well lit conditions while they may greatly differ in adverse lighting conditions. The following parameters need to be chosen:

- the distance from the viewer to the object (the garments)
- the type of background
- the light conditions (straylight, atmospheric transmission, light level
- the local clutter

We chose a location on the TNO grounds in Soesterberg, shown in Figure 2. The 'target' person with garment was standing at one of two positions, at a distance of respectively 129 m and 131 m. The two positions differ in the amount of shading. The closer location, position 1, has a medium amount of shade, the further location, position 2, is shaded more heavily. The background is a dark brown/green foliage. In order to make the lighting condition more objective, the illuminance was measured at four locations shown in Table 1. Position 2 is three times more shaded than position 1 (8 lux versus 27 lux). The light measurements of Table 1 with the scene layout shown in Figure 2 describe the visual condition. The light condition was overcast and diffuse during the first measurement day and during the morning of the second (demonstration) day.

	Location	Orientation	Lux	%
1	At the conspicuity meter	facing the target	56	100
2	At garment position 1	facing the meter	27	47
3	At garment position 2	facing the meter	8	15
4	At garment position 1	facing the background	6.8	12

Table 1. Light level measurements documenting the location of the conspicuity measurements. Both locations are dark w.r.t. the meter location (measurements 2 and 3 w.r.t. measurement 1). The 'far' position is three times more shaded than the 'near' position (measurement 3 w.r.t. measurement 2). The background of the garments is very dark (measurement 4).

Jacket 1

Jacket 3

Figure 2 (Jacket 1 and Jacket 3). The location of the conspicuity measurements. The back of a person wearing two of the garments in the near location is shown.

Experimental design

We measured the conspicuity of six different firefighting garments from the back and from the side. The six garments are shown close-up below. During the experiment the person wearing the garments wore black trousers. We counterbalanced the order of presentation of the six garments between the observers. During the first test day and the morning of the second test day the lighting conditions were constant (evenly overcast). The second afternoon was slightly sunny; the side of the garments at the 'far' position was measured under this lighting condition.

Figure 3 (below). The six garments shown up close from the back. The garment number is shown below each picture.

Jacket 1

Jacket 2

Jacket 3

Jacket 4

Jacket 5

Jacket 6

Experimental results

The measurements were undertaken by four TNO employees. The results below are the average data, collected over the two days. Garment 6 was not available during the first measurement day. The experimental results are shown in Figures 4 and 5 (Tables). The values are the average distances (in metres) that the observers could look beside the person and just detect the garment in the peripheral visual field. The six conditions refer to the six garments shown in Figure 3. Four trends are visible.

1) The garments differ up to a factor of 2 in conspicuity (Fig. 4). Garment 4 has the highest average conspicuity and garments 3 and 5 the lowest (For a finer ordering of garment conspicuity that is statistically significant, more data is required).

2) The conspicuity of the back-view at position 1 is slightly better than the conspicuity of the side-view (Fig. 5). For position 2, this comparison is not meaningful because of the change in lighting conditions.

3) The conspicuity in position 1 is better than the conspicuity in the more heavily shaded position 2 (Fig. 5). Three times more shading resulted on average in a 2.8 times decrease in conspicuity for the back-view. The decrease in conspicuity for the side-view is less due to the change in lighting condition.

4) Except for garment 1 the conspicuity from the side turns out to be good when the conspicuity from the back is good. The correlation coefficient for the position 1 data is 0.98 when garment 1 is excluded and 0.83 when it is included. The conspicuity of garment 1 is poor from the side while it is good from the back. A probable explanation is that the visible area of this short garment from the back is reasonably good but from the side the visible area is rather small.

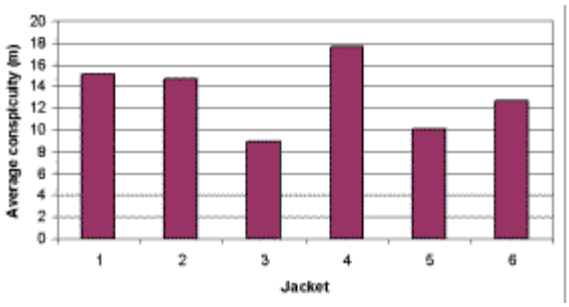

Figure 4. The conspicuity of the six garments averaged over the back ands side views. The unit (meter) indicates the distance that the observers could look beside the garment and just notice it in the peripheral visual field.

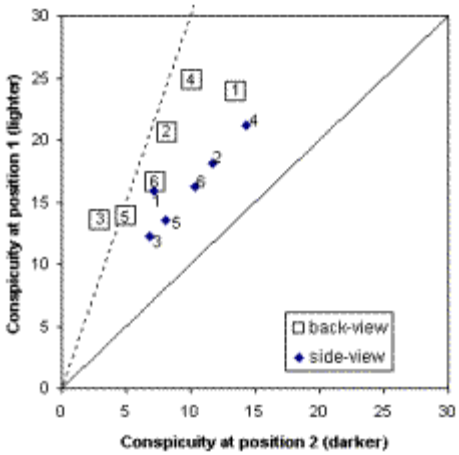

Figure 5. The garment conspicuity at the lighter position 1 compared to the more shaded position 2. The large squares are the data for the back view, the smaller triangles denote the side-view data. The solid line denotes equal conspicuity at the two positions; the broken line denotes a three times higher conspicuity at the lighter position.

CONCLUSIONS

The experiment has demonstrated that it is possible to quantify the conspicuity of firefighting garments on an outdoor location with the TNO conspicuity meter. The results show a two-fold conspicuity range for garment type. The conspicuity also depends strongly on the visual environment. The more shaded the location, the less conspicuous the garment. Three times more shading resulted in a 2.8 times conspicuity decrease for the back-view.

In order to more completely understand the conspicuity of fire fighter garments, it is necessary to measure the conspicuity in a variety of visual environments and from a range of viewing distances.

TNO Human Factors is a market-oriented research and scientific institute based in the Netherlands. Part of TNO Defence Research, TNO-HF's primary mission is to develop and apply human factors expertise in a high-tech military environment and to promote efficient deployment of personnel and materials. It also focuses on specific civil markets. Click here for more information.

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