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# *Kits, colours and confusion: a pilot study of vision and football*

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# Vision & Football

Association football (soccer) is a major global business involving huge sums of money, much of it from television. But watching football is a complex, dynamic visual task: who is moving where ? - who's offside ? - where are the defenders ? - how many attackers in the box ? Hence if there are visual factors that enhance or hinder perception by viewers and by players, then these factors could be important to the success of the sport and the business of football. Our repeated armchair experience has been that some combinations of kit colours promote good 'reading' of the game, perhaps by enabling rapid visual search and visual segregation of one team from the other. Other kit combinations seem to make matches confusing and almost unwatchable by preventing easy search and grouping of players. Fig. 1(a) suggests that if the two teams wear different but uniform colours (e.g. all-red vs all-white; Liverpool vs Real Madrid) then the segregation and ‘readability’ of the pattern of play is very good, while Fig. 1(b) suggests that if the two teams wear similar colours, albeit in opposite combinations (e.g. red-white vs white-red; Manchester United vs Southampton), then the readability may be very poor. [See supplementary Fig. 1 for a real example from the 2003-4 season.]

The literature on visual search (mainly for single targets) tells us that simple colour differences 'pop-out' readily (Bauer et al 1996; D'Zmura 1991; Duncan 1989), while conjunctions of colour and form typically do not (Treisman and Gelade 1980). One general theory proposes that search is slow and difficult when targets are similar to distractor items, or when distractors are dissimilar to each other, or both (Duncan and Humphreys 1989). Thus we suspect that some football matches (perhaps inadvertently) take advantage of ‘pop-out’ and grouping by colour, while others create confusion. Surprisingly, the *Laws of the Game* [www.fifa.com/refs/laws_E.html] (Law 4) make no prescription at all about kit colours, but different competitions and leagues have a variety of rules about what shall be done when kit colours clash. The English FA Cup rules, for example, state that "Where the colours (shirts, shorts or stockings) of the two competing Clubs are similar, both Clubs must change…", but similarity appears to be undefined. Many of the other kit rules are concerned with commercial rather than psychophysical impact. In practice, referees may check that the shirt colours are different, and that the shorts are different, and then suppose that all will be well. From real matches and from schematic examples like Fig. 1(b) we doubt that this is a sound strategy, but we need experimental evidence, rather than anecdote. We used response time as a measure of difficulty in a visual search and counting task, and removed the possible influence of many extraneous variations such as camera angles, lighting conditions, crowd effects and so on, by using schematic, still pictures.

## Experiment: Count the players

The experimental task was based on a combination of visual search and counting, using simplified static images with coloured, shaded rectangles to represent the players against a textured green background. On each trial, 8 'players' were shown in random locations without overlap (Fig. 1). The task was to indicate by a key-press whether 3, 4 or 5 of 'your team' (indicated before each block of trials) were present. Selectively gathering this kind of spatially distributed information is likely to be vital in 'reading' the match. Response time (RT) and accuracy were recorded. Instructions emphasized both speed and accuracy. A ‘referee’ and ‘ball’ were present, but were to be ignored. The key experimental factor was whether the teams wore different, *uniform* colours (eg red-red, vs white-white; Liverpool vs Real Madrid) or *crossed* colours (e.g. red-white vs white-red).

Images (Fig. 1) were generated as 8-bit TIFFs on a Macintosh computer in Matlab 5.2, displayed on a 19" RGB monitor using PsychToolbox software (Pelli & Brainard, 1997). The image was on until the subject responded with a key press. The green ‘pitch’ subtended 9.5 x 6.4 deg (about the same as a 25" TV set, viewed from 10 feet), set in a larger (full screen) green background. Player size was 30 x 16 pixels (28.4 x 15.1 min arc), with shirt length 19 pixels, shorts length 11 pixels. Chromaticity and luminance of the test colours, measured with a Minolta CS-100A Chroma meter, are given in Table 1. Observers were allowed free, binocular viewing from a distance of 125 cm, with no fixation point.

The experiment had a 4-factor (3x2x3x2) repeated measures design:

- Number of target players [3,4,or 5]
- Type of colour combination [uniform vs crossed] (eg. fig 1(a) vs fig 1(b))
- Colour pair [ (blue,red), (blue, white), or (red, white) ]
- Target team [1 vs 2] (left or right on the instruction screen)

Different sets of images with different randomizations, were used for each observer. Each image was used just twice: once for target team '1', and once for team '2'. Number-of-targets varied within a block of trials, while other factors varied in random order between blocks. Data for the ANOVA were median RTs from 8 repetitions of each condition within a block. Subjects were 5 male, and 5 female volunteers (age 20-35; median age 21). Short practice sessions were given before the main blocks of trials

## Results

Crossed colours are bad. Fig. 2(a) shows that when teams wore crossed colours (e.g. red-white vs white-red), it was much more difficult to count the players than when kits were of uniform colour (e.g. red-red vs white-white). Average response time to count the players in the target team was 750 ms slower with crossed colours than uniform colours [$F(1,9)=49.4$, $p<0.0001$]. All observers showed the effect consistently. Across individuals the smallest difference was 340 ms and the largest was 1370 ms (mean 752 ms; median 690 ms).

Not surprisingly, counting 3 targets was significantly quicker than counting 4 or 5, by about 140 msec [$F(2,18)=18.4$, $p<0.0001$], irrespective of colour combination. There was no significant interaction between these two factors [$F(2,18)=2.00$, $p>0.1$].

Fig. 2(b) shows that the crossed-colour disadvantage was found for all 3 pairs of colours tested, and that it was worst for the blue-red pairing where the crossed-colour penalty rose to almost 1000 msec. This interaction between colour pair and type of combination was highly significant [$F(2,18)=26.5$, $p<0.0001$].

Unlike the RT measure, accuracy (% correct trials) was not a useful measure of difficulty, because error rates were not high. Most effects in the ANOVA were not significant, although there was lower accuracy for crossed colours with 4 or 5 targets present - a significant interaction between number of targets and type of colour combination [$F(2,18)=8.01$, $p<0.005$].

## Discussion

**Penalty!**

We have found that it is much more difficult to 'read' the spatial layout of an image resembling a football match when the 2 teams wear crossed colours (the same pair of colours but with opposite ordering of shirt and shorts) than when they wear completely different, uniform colours. The response time penalty averaged 0.75 sec, and was even greater (1.0 sec) for the red-blue pairing. These are huge delays, implying great difficulty in the crossed-colour condition.

Such effects are consistent with the literature on visual search for single targets, and with the factors that enable or impede texture segregation. The crossed colour condition probably prevents target 'popout', and so impedes the localization and counting of target items. In a recent overview, Pashler (1999, chapter 3) concluded that "Targets defined by spatial arrangements of parts can yield strikingly difficult conjunction searches". Heathcote & Mewhort (1993), for example, studied single target search in a situation analogous to ours. Target items were squares divided into black/white or red/blue halves, while the seven distractor items were white/black or blue/red respectively, in different groups of observers. Response times to detect the target were very slow, and averaged about 1 second (though they gradually improved with intensive practice on the same condition). In our crossed colour condition, the two teams also differed only in the spatial ordering of their colours, and so the observer was presumably forced to use an item-by-item search which can be painfully slow. The observer probably also gets a much weaker sense of the pattern and spatial arrangement of the players. Thus with crossed colours, viewers (and players?) are effectively blind to much of the information needed to make sense of the game.

We chose to compare the uniform and crossed colour conditions because they may represent the best and worst cases, but other common combinations of kit colours (eg blue-white vs white-black; Everton vs Fulham) are likely to present analogous difficulties where the colour pairings defeat the processes underlying grouping and popout.

Lack of realism might be an issue in our displays, and it would be interesting to use real video clips instead of schematic stills. But there the introduction of cluttered backgrounds, real human forms, overlapping and rapidly changing positions might only make the task even more difficult. Supplementary Figs 1 and 2 [*insert Perception URL for these*] are video stills from real matches, and the crossed colour case (Supp. Fig. 1) seems to us informally to be as difficult as the schematic images used in the experiment.

**Real football**

If such difficulties and delays also exist when viewers watch real matches (and we suspect it is not infrequent), it would imply that viewers can suffer great confusion in some matches. Who is where? How many attackers in the box? Where are the defenders? Was van Nistelrooy offside? This kind of global spatial information is needed rapidly, with rapid updating, if the viewer, official or player is to make sense of the match and make vital, quick decisions. Although our experiment relates most directly to TV viewers, it seems likely that players and officials might also be confused or delayed by impoverished information, and if so the impact on the game itself could be substantial. Poor choice of kit colour combinations, even if less severe than the crossed-colour case, are likely to be detrimental. Games often turn on a few critical moments where players make the right or wrong decision, and in top-level games, players have to decide and act very quickly with no time for scrutiny, so even a 300 msec delay could be disastrous.

To our surprise, we see many poor examples in real matches every season. This suggests that the authorities and broadcasters do not have adequate procedures for regulating the combination of colours in matches. As far as we can discover, it is the referee who makes a decision about whether two kits clash. For example, Fifa World Cup rules [http://fifaworldcup.yahoo.com/en/] state that "If, in the opinion of the referee or the match commissioner, the colours worn by two opposing teams might cause confusion or prove unsuitable for television broadcasts, they shall be modified, using either the entire reserve outfit or a combination of both". The basis for the referee's opinion is unclear, but it seems likely that this decision will be based mainly on the colour and pattern of the shirts, viewed from close-up. In our view it would be safer to ensure that the two kits differ more fundamentally, in ways that are visible in peripheral vision, and at long distance, and are rapidly available to early visual processes without slow, detailed scrutiny. Where the two teams wear a single colour from head to toe (eg red vs blue; Liverpool vs Chelsea) all these requirements are met. Difficulties arise when the teams have one or (as here) two colours in common. When teams wear striped or patterned shirts, the spatial frequency dependence of pattern and colour vision will also have to be considered. For example, the black & white stripes of Newcastle and the desaturated light blue of Manchester City may look very different close to, but at a distance, in motion, or in peripheral vision the two may be quite similar as Newcastle's stripes blur to a mid-grey. In short, then, better guidance could be formulated by applying visual science to football.

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## Table 1

Luminance & chromaticity of the kits, pitch and surrounding screen

| | Luminance cd/m$^2$ | CIE Chromaticity co-ords x | y |
|---|---|---|---|
| Red | 19.3 | 0.521 | 0.336 |
| White | 96.4 | 0.286 | 0.325 |
| Blue | 14.4 | 0.163 | 0.121 |
| Green pitch | 52.9 | 0.284 | 0.477 |
| Green surround | 42.6 | 0.300 | 0.471 |

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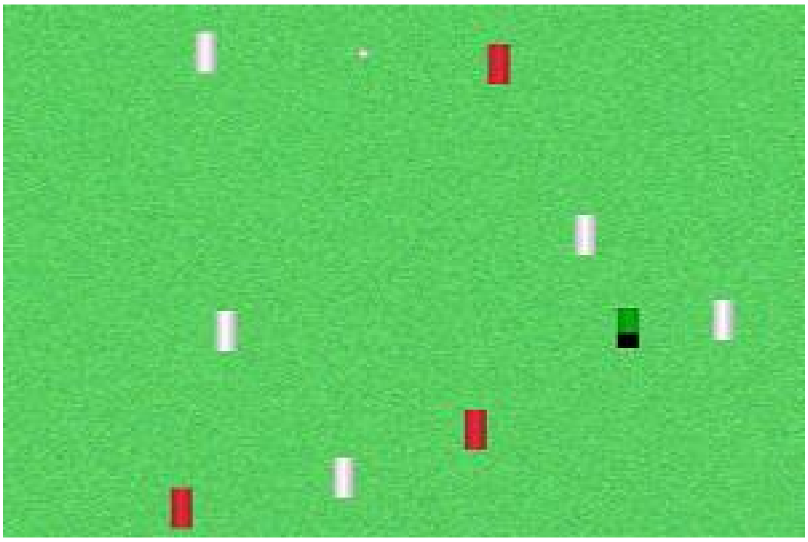
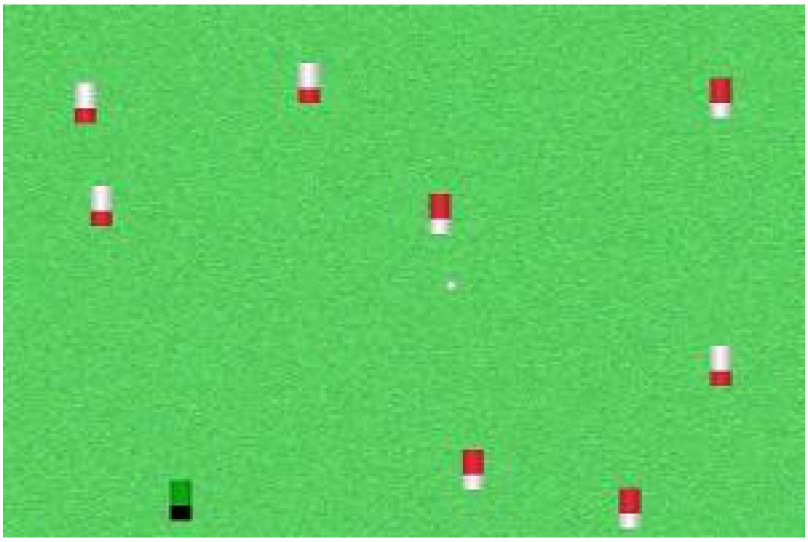
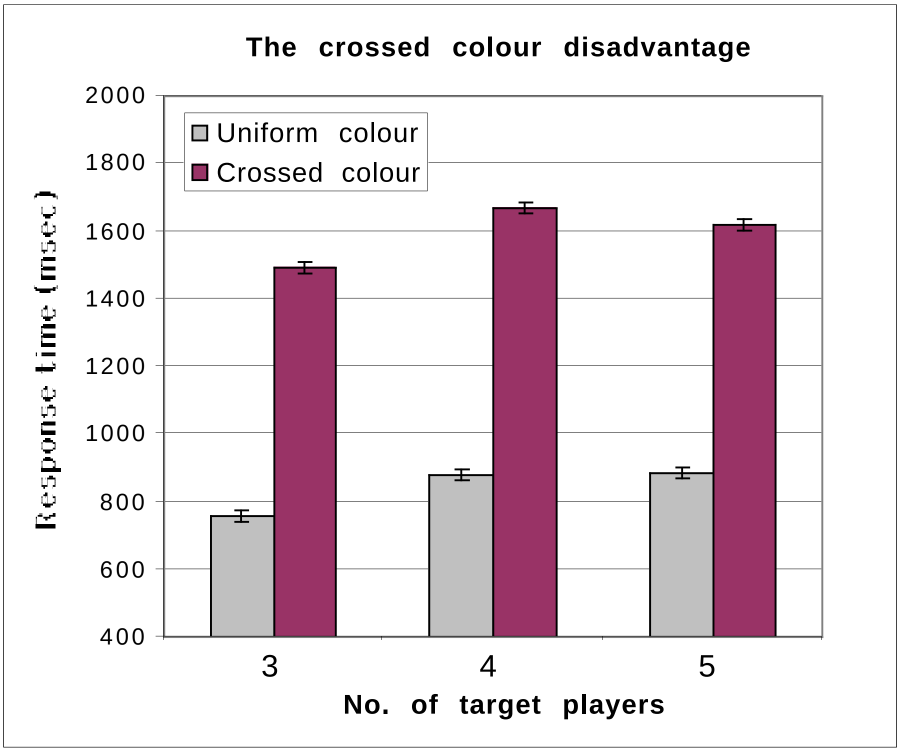


(a)

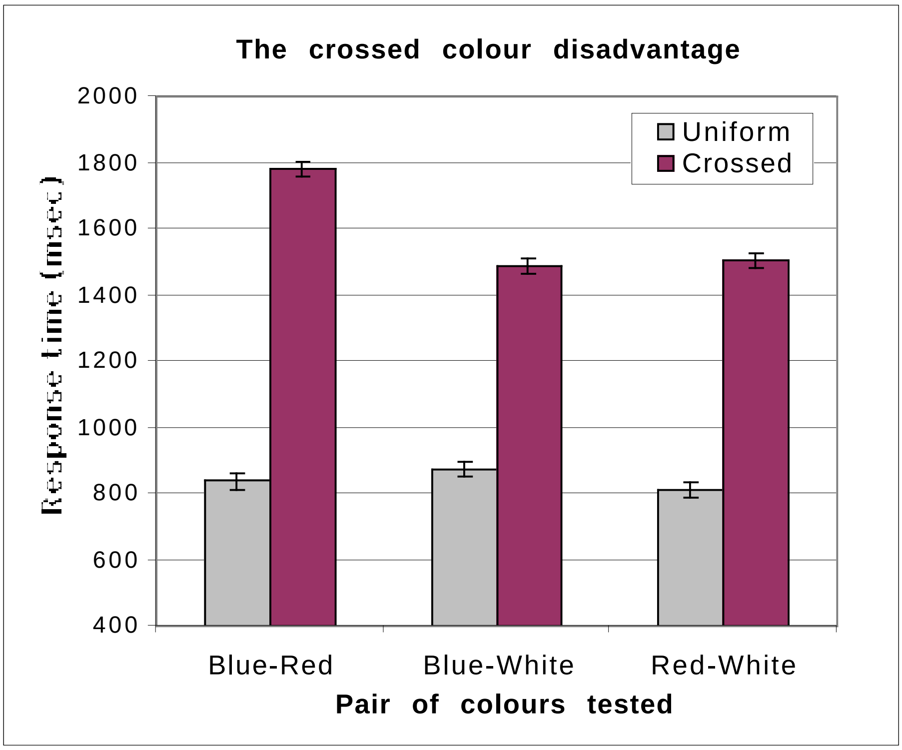


(b)

Fig1. (a) Uniform Colours. Liverpool v Real Madrid (all-red vs all-white, on a green background) Verdict ? Excellent. See online [ insert URL here] for colour versions of all figures. (b) Crossed Colours. Man Utd vs Southampton (red top & white shorts vs white top & red shorts). This combination has been seen for at least the last 3 seasons. Many others like this can be seen. Verdict? Very poor.




(a)




(b)

Fig.2 (a) Mean response times (±1 s.e from the ANOVA) plotted against number of target players, for the two kinds of colour combination (pooled over the three pairs of colours). (b) Mean response times (±1 s.e) plotted for each pair of colours.


Supplementary Fig. 1.  FOR ONLINE ACCESS

Everton vs Chelsea: A real example of crossed colours from the 2003-4 season. How many Everton players (blue shirts) on the pitch ?  Perceptual segregation of the two teams is difficult and slow.


Supplementary Fig. 2. FOR ONLINE ACCESS
Manchester United vs Portsmouth: A real example from the 2003-4 season. With no colours in common, team segregation is easy.

Supplementary Fig.3. FOR ONLINE ACCESS

Examples of the experimental images for each colour pairing and type of combination