Object Recognition Test in Peripheral Vision: A Study on the Influence of Object Color, Pattern and Shape

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Abstract. As an important factor for central vision preview, peripheral vision is a crucial ability for most ball game players in motion detection. A critical problem with peripheral vision is object recognition which has not yet been given much attention. This paper presents an experimental study to evaluate the influence on object recognition in peripheral vision due to different patterns, colors and shapes of the objects. More specifically, four types of shapes (including circles, triangles, horizontal stripes and vertical stripes) with various colors presented in different patterns were applied during the peripheral vision test. The results show that different patterns and colors indeed affect object recognition in peripheral vision in terms of accuracy and response time, while different types of shapes do not vary the performance significantly.

1 Introduction

Human vision system is composed of not only central vision but also peripheral vision. According to the constitution of human eye, retina is made up of two types of photoreceptor cells which are rod cells and cone cells. Cone cells are mostly concentrated in the central area of the retina, while rod cells are distributed in the outer edges of the retina and peripheral vision employs mainly rod cells. Due to the higher density of cone cells at fovea and less density populated at periphery, peripheral vision is characterized as poor spatial resolution [2]. Owing to the feature of rod cells, in peripheral vision humans are good at detecting motion but weak in distinguishing colors and shapes.

As a part of vision, peripheral vision provides a rich source of visual information outside the central field. While perceiving an object in periphery, people make the direction and span of leading eye movements by using visual information from peripheral vision. Thus, peripheral vision has been suggested important in the feature recognition and object identification as it directs the eye movements of neutral search tasks in real world sense [1]. In particular, peripheral vision is important for many people, especially for most of ball games players. For instance, in a football game, if a player wants to pass the ball to his teammate, he should not look at his teammate

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directly and make a heel-dragging decision, otherwise he may lose the control of the ball as defenders will identify and prevent the passing through the detection of opponent's eye gaze. Therefore, the player has to use his peripheral vision to gather information from the environment (goal, teammates, etc.) and keep focused without revealing his intention, to avoid defending actions by his opponents.

Previously, a number of studies have examined why the performance of peripheral vision is weaker than that of central vision. Several factors (including age, distance, form and condition) have been found affecting the identification of a stimulus in peripheral vision without the usage of eye movements [3]. In addition, perceptual research also provides strong evidences that young children have poor peripheral vision ability compared to the adults [4], but it can be improved along with the growth of age [5]. Furthermore, it is observed that peripheral sensitivity will decrease along with enlarging of eccentricity [6], while forms and conditions of stimuli also affect the performance of peripheral vision (for instance, the size of stimuli target).

A recent study [11] has proposed a suprathreshold discrimination method to investigate natural-scene information processed in central and peripheral vision, using a set of stimulus images made from colored photographs of neutral scenes and their variants (in different colors, shape orientations). The method requires subjects to give a magnitude estimate rating of the perceived target and the changes. The results show that observers' rating of color changes in periphery is higher than that of peripheral orientation changes, implying that human's peripheral vision is indeed more sensitive to specific types of stimuli targets.

To the best of our knowledge, there is no study on the impact of football players' peripheral vision performance in relation to different patterns, colors and shapes. Because of the poor ability of peripheral vision, it is necessary and meaningful to further investigate the mechanism of peripheral vision or more precisely in this work, human's peripheral vision is more sensitive to which types of stimuli targets, this may help ball game players identify their teammate in periphery easily.

In our recent study [12], we have proposed a new peripheral vision evaluation index which can reveal the underlying correlation between global peripheral vision performance and personal sports ability, but the number of subjects is limited and no analysis is provided about the influence on colors, shapes and patterns. Therefore, in this study, the pattern recognition in peripheral vision based on the aforementioned work will be studied to evaluate the influence on peripheral vision performance in football players due to different patterns, different colors and different shapes.

2 Methods

2.1 Participants

A total of 62 football players (aged 14-19 years: mean=16.44, SD=1.5) with normal or corrected-to-normal vision participated in this experiment and all the subjects have reported no color blindness history. The protocol was in accordance with the declaration of Helsinki (World Medical Association. 1996) and approved by the Research Board of "Academia do Sporting Club de Portugal".

2.2 Experiment Set Up and Peripheral Vision Measurement

A resolution of 1920x1080 dots with diagonal size of 102 cm LCD display was used to present the stimuli objects. Subjects were seated in front of the screen with away from 53 cm. The distance of 53 cm ensured that the horizontal vision angle and vertical vision angle was 60° and 33.75° respectively. Fig. 1 shows the test screen of the experiment, the background color simulated the football field environment and five objects were presented at the central and four corners of the screen. Experiment was conducted in a comfortable room and illuminated by incandescent lights. A comfortable chair with adjustable height was used to keep subjects' eyes leveled with the screen.

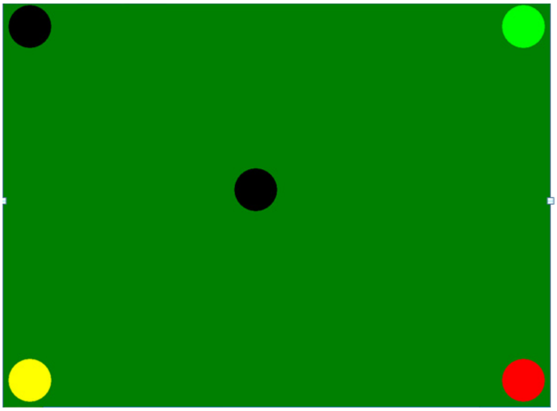

Fig. 1. Test screen

Four types of shapes (including circles, horizontal stripes, triangles and vertical stripes) in seven different colors (including black, blue, brown, green, red, white and yellow) was used as stimuli objects in the experiment and each displayed objects were framed in a square with diagonal of 6.5 cm. The combinations of all the different stimuli objects composed the two types of object sets which were the targets and non-targets. In the target sets, three of the five objects must equal in color and shape, otherwise it was considered as non-target sets. The target sets could be produced by ten different types of target patterns (see Fig. 2 where a dot represented an object) which cover different visual fields. The whole experiment was divided into two parts: the first part, Test 1, included 56 different patterns with 13 target patterns and 43 non-target patterns, and this part was designed for the impact due to different colors and patterns (all the objects were circles with different colors); the second part, Test 2, included also 56 different patterns but with 14 target patterns and 42 non-target patterns, this part was designed to cover all situations with different colors, shapes and patterns. In both tests, target patterns appeared in a predefined order as shown in Fig. 3 (the horizontal axes).

When the experiment started, subjects were required to track with a mouse pointer on the central object binocularly and use peripheral vision to perceive the changed objects in the periphery. During the experiment, the central object first moved slowly and then faster while different types of stimuli objects were presented in periphery, thereby different patterns could be shown in the test screen. The sequence and exposure time of the stimuli objects were determined by a script file which was programmed and loaded into the system before the experiment. If the subjects noticed that any three equal objects (including the central one) were the same, they were required to click as fast as possible on the central object to identify it as a target. Subjects were instructed to avoid the usage of eye scanning and concentrate on the central object tracking its movements with the mouse pointer.

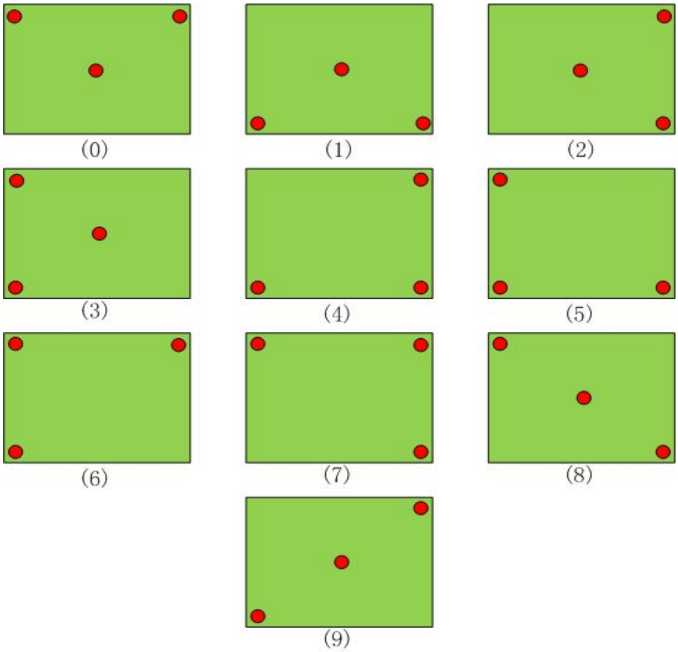

Fig. 2. All of the target patterns used in the tests

2.3 Peripheral Vision Performance Evaluation

To evaluate the performance in the peripheral vision test, true positive (stands for clicking a target) and false positive (accounts whenever a non-target is hit) associated with the reaction time was recorded over each pattern. To detect eye movements, combined horizontal and vertical electrooculogram (EOG) was recorded at the outer canthi of eyes [12], one above an eye and one below another. The EOG measurement was used to distinguish whether the subjects were using pure peripheral vision instead of eye scanning to perceive the changes. There were totally four types of responses which were "target clicked" (subjects identified the pattern as target in peripheral vision), "target non-clicked" (subjects did not identify the pattern as target in peripheral vision), "non-target clicked" (subjects confused with the pattern as target in peripheral vision) and "non-target non-clicked" (subjects identified the pattern as non-target in peripheral vision). Moreover, the reaction times corresponding to four types of responses were distinguished in the session reports.

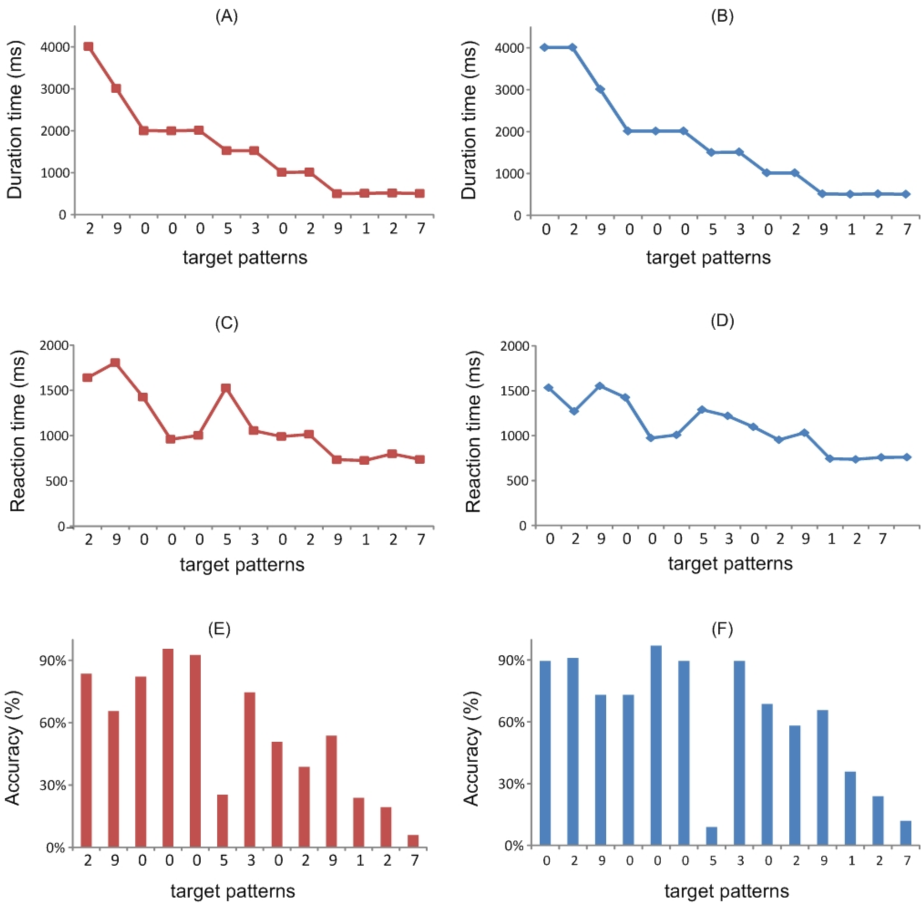

Fig. 3. Performance in accuracy, duration time and reaction time for each target pattern. (A), (C) and (E) show the results from Test 1 while (B), (D) and (F) show the results from Test 2. (A) and (B) present the performance of each target pattern which identified by the subjects. (C) and (D) show the duration time while (E) and (F) show the reaction time for each target pattern.

3 Results and Discussions

3.1 Influence Due to Patterns

Fig. 3 presents the accuracy, duration time and reaction time over each target pattern. The peripheral vision test did not cover all the target patterns in order to reduce the test duration. More specifically, target pattern types 4, 6, 8 (see Fig. 2) were not used in this test, since they were symmetrical to patterns 5, 7 and 9 respectively. Some of patterns had been tested many times (with different shapes and colors of objects), for instance, target pattern type 0. Fig. 3A and Fig. 3B show that different target patterns resulted in significant differences in performance. The easiest target patterns were types 0 and 3, for which 80.22% and 80.09% subjects had successfully recognized them in peripheral vision respectively. Type 9 was relatively easy to identify, 64.55% subjects had recognized it correctly. However, some target patterns had shown a greater difficulty than the others for all the subjects to identify, for example only 17.16% and 8.96% subjects were able to recognize the target pattern type 5 and type 7 correctly. For target pattern type 9, the poor performance may be due to the short duration presentation time of this pattern. Even subjects had recognized the target pattern in peripheral vision, they probably did not have enough time to react and click on the central object (time allowed to respond is the pattern duration plus 300ms). But for the target pattern type 5, even with the same duration time (compared with type 3), the accuracy of target pattern type 5 was still 64.93% lower than that of target pattern type 3. It was probably due to the larger visual-span [14] required for target pattern type 5 as subjects needed to cover the upper and lower visual field at the same time (target pattern type 6 may have the same results). These findings confirm that the ability of peripheral vision of human is weak, and if the stimuli objects cover a larger visual span, the performance of peripheral vision would get worse. To summarize, different patterns do affect objects recognition in peripheral vision.

In addition, a correlation was observed between the duration time and reaction time: the Pearson correlation coefficient is 0.81, which implies a significant correlation ($p<0.01$). As shown in Fig. 3E and Fig. 3F, a shorter duration time can produce a faster reaction time, subjects needed to react fast during a short presentation time. The fastest reaction time was obtained from target pattern type 1, which was 724.95ms including 510.03ms of stimuli presentation time. The slowest response time was observed in target pattern type 9, which was 1805.68ms with 3011.17ms of stimuli presentation time (if subjects click on the central object before the completion of duration time, reaction time will shorter than duration time). The results seem consistent with the habit of human's behavior: when the test is more demanding, subjects need more concentration on the peripheral changes to respond more quickly. The accuracy for targets with duration below the vicinity of 2 seconds also follow the inverse trend (with respect to duration) as response time, that is, the shorter the duration the lower the accuracy.

3.2 Influence Due to Colors and Shapes

In Test 1, the same kind of shapes (all objects are circle) with seven different colors were used to present in the central and peripheral vision. As shown in Fig. 4, different color objects resulted in significantly different performances in the peripheral vision test. Green and brown showed a higher accuracy than the other colors in the test. The highest accuracy was obtained from the objects in green, for which 83.58% subjects had identified it in peripheral vision correctly. However, red had caused a great difficulty for all the subjects, that only 15.67% subjects had successfully identified the stimuli objects in red. It seems that object identification in peripheral vision did not benefit from a high contrast color (red). By comparison with red, low contrast or similarity to the background color (green) has a positive contribution to object recognition in peripheral vision. The results prove that human's peripheral vision is indeed more sensitive to some specific colors. More importantly, the objects with these specific features may be easier to attract subject's interest in terms of human's peripheral vision.

In Test 2, different types of shapes were used in the peripheral vision test. Based on the independent-samples t test, there are no significant difference between the results of Test 1 and Test 2 (p=0.51). It shows that circles, triangles, horizontal stripes and vertical stripes had not much influence on identifying the target patterns in peripheral vision. It suggests that the subjects were able to distinguish different types of objects in peripheral vision.

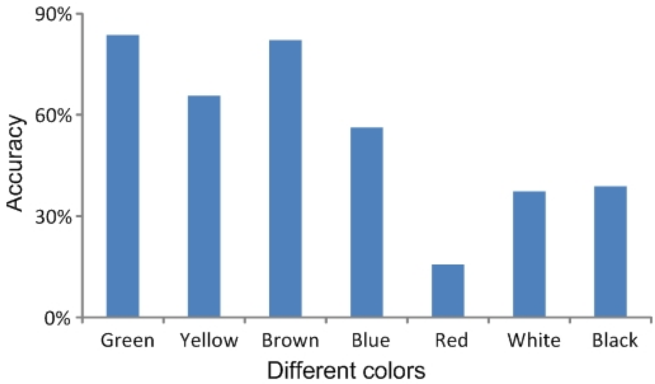

Fig. 4. Performance in accuracy of different colors

3.3 Difficult Situations

Interestingly, there were some object color combinations of non-target patterns which can confuse the subjects. Ten of the most confusing color combinations of non-target patterns are presented in Fig. 5. As shown in Fig. 5, the combinations of red and brown of non-target patterns had presented a great difficulty to identify as non-target during the test, for which 61.19% subjects were confused by this type of non-target. Also, the combinations of green and red confused many subjects, more than 55% subjects had misperceived them as target patterns. This result confirms the lack of color discrimination in the peripheral vision due to the low density of cones cells. Colors with the same grey level contribute greatly for this confusion.

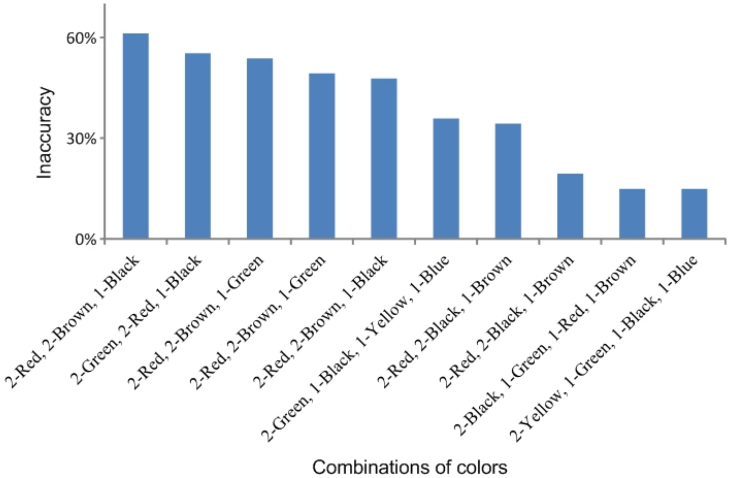

Fig. 5. Top 10 confusing color combinations. The horizontal axes represent the color combination of the non-target patterns, for instance "2-Red, 2-Brown, 1-Black" means that the non-target pattern is composed of two red objects, two brown objects and one black object.

4 Conclusions

This paper presents an object recognition experiment for the impact of peripheral vision due to different patterns, different colors and different shapes. Four types of objects (including circles, horizontal stripes, triangles and vertical stripes) with seven different colors (including black, blue, brown, green, red, white and yellow) presented in different patterns were applied in the experiment. The results show that target pattern types 0 and 3 were easiest to be recognized in peripheral vision, for which 80.22% and 80.09% subjects had recognized them respectively. In addition, different colors led to significant different performances in peripheral vision, but different shapes of objects do not. For instance, green was the easiest color as 83.58% subjects had identified the objects with green in peripheral vision while no significant difference was observed between Test 1 and Test 2 which implies no influence due to object shapes.

These findings provide an evidence for instructing how to design a compelling and recognizing symbol. For instance, the team jersey is better in green or brown instead of red which is the lowest sensitive color, so that football players can easily identify their team members during games. Furthermore, the traffic signs should be placed on the same side, because drivers have difficulty to recognize the traffic signs which are placed on both sides (the performance of peripheral vision get worse when the objects cover a large visual span). On the other hand, a comprehensive study would be desired, to cover all types of target pattern with different colors and shapes, which can provide us a better understanding of the visual ability on peripheral vision and help us enhance our perception and improve ergonomic design of products.

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