# Spatial Effect of Target Display on Visual Search

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**Abstract.** The effect of spatial layout on visual performance and eye-movements characteristics was analyzed and the results would provide theoretical guidance for the ergonomics design of man-computer interface. A division method was proposed to divide the optimum visual field into nine regions based on the anatomical characteristics of human retinal and the horizon characteristics of quadrants, and corresponding software with the target displaying in different regions dynamically was completed for the experiment. Twelve subjects participated in the experiment and their reaction time and eye movement data were recorded. The significant differences and the prioritizations of different visual regions were analyzed. The results indicated that, there was significant time difference among the regions with different eccentricity, and the visual performance decreased along with the increase of eccentric distance; for the same eccentric distance, the visual performance of lower visual field was superior to the upper visual field, while the left visual field was superior to the right visual field, and the former difference was more apparent compared with the latter one. In the ergonomic study of display interface of man-computer, spatial effect of target display should be considered.

**Keywords:** Eye movement · Spatial effect · Visual search · Workload · Man-computer interface

## 1 Introduction

Vision is an important approach to gain information, from which 80 %∼90 % of the information external is obtained [1]. Information detection tasks form an essential part of a man-computer system, and these activities invariably involve visual search [2]. The vision working efficiency is affected by various extrinsic factors, such as the stimulus' shape and color, contrast, background color [3]. At present, there is less ergonomics research on spatial effect of target display on visual search. The space division way of visual field is only limited to previous research and has no further development [4]. RT (reaction time) and accuracy are important evaluation indicators of visual search performance, and are important reference for the analysis of vision ergonomics [5]. In order to explore the spatial effect of target display on visual search


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more deeply, a method synthetizing performance measurement and eye movement measurement was proposed in the study. The research result will be used for the interface layout design of aeronautics and astronautics human factors engineering, which could improve the work efficiency of man-machine interaction.

The purpose of this study is to explore the characteristics of pilots' attention allocation, workload change, and cognition by eye tracking of pilots' scanning behavior and the analysis of pilots' eye movement indexes. The work will provide some valuable reference to the design of aircraft cockpit.

## 2 Method

### 2.1 Subjects

Twelve college students participated this experiment voluntarily; their ages ranged from 20 to 28. They all had reported having normal or corrected to normal visual acuity. All were right-handed.

### 2.2 Experiment Design

There are mainly two division ways of visual field. One is based on the anatomy characteristics of retina, and the other is based on the absolute position of visual field. The visual field is divided into four regions through the former division way, and they are fovea region(circle with radius 6°), deputy fovea zone (circle with radius from 6° to 11°), peripheral visual zone(from the circle with radius 11° to optimal vision edge), and edge visual zone (the region beyond the optimal vision) [6, 7]. For the latter division way, the visual gaze center is considered as the origin, and the visual field is divided into four mathematical quadrants from the horizontal and vertical directions [8, 9]. With the combination of the two division ways above, a new division way of visual field is proposed. Meanwhile, combining the results of pretest, the final visual field was divided into nine regions, as shown in Fig. 1.

Software was designed based on the new division way (Fig. 1). The red square with blue arrows is considered as the target stimulus, randomly appearing in one of the nine regions. When the target appears, the subjects have to press the space key immediately. Meanwhile, the target disappears, and the subjects have to press the left or right mouse

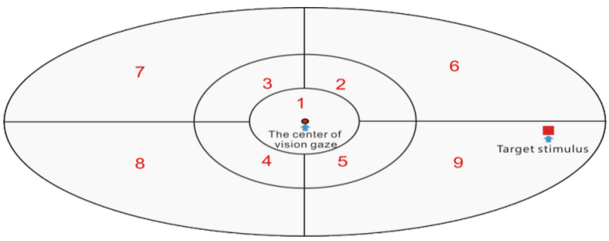


**Fig. 1.** Division of the visual field (Color figure online)

key according to the arrows direction. Avoiding the effect of fatigue, for each subject, the whole experiment is consisted of twelve sections, and each section has 25 trials. After each section finished, the subjects should have a rest. The RTs of correct operations are recorded by the software. RED eye tracker of iView series is used to record the eye movement data during the experiment.

## 3 Results and Discussion

### 3.1 RT Statistics and Analysis

One-way ANOVA was used to analyze the reaction time. The results showed that the difference at the nine regions was significant ($F = 122.53$, $P < 0.05$). Meanwhile, multiple comparative law was carried out, some conclusions can be obtained. Table 1 showed the average RT at different regions.

(1) Regions with different eccentricity

The RT of region 1 had significant difference with other eight regions (all in $P < 0.05$). Meanwhile, for the deputy fovea peripheral (region 2, 3, 4, 5) and peripheral zone (region 6, 7, 8, 9), there was significant difference between the regions in the same quadrant but with different eccentricity ($P < 0.05$). Table 1 showed the average reaction time at different regions and indicated that the RT of central fovea (region 1) is shortest, while the deputy fovea's (region 2, 3, 4, 5) is shorter than the peripheral zone's (region 6, 7, 8, 9).That is to say, farther the away from the visual gaze center, longer the reaction time and worse the visual search performance.

(2) Regions with the same eccentricity

In the zone of deputy fovea peripheral (region 2, 3, 4, 5), the difference of left-lower (region 4), right-lower (region 5) and left-upper (region 3) is not significant (all in $P > 0.05$). Right-upper (region 2) has significant difference to other three regions (left-lower, right-lower, left-upper) (all in $P < 0.05$) with about 20 ms average RT longer than them, which means that there is no visual advantage at the right-upper of deputy fovea peripheral. According to the average RT in Table 1, the priority order of the four regions is: left-lower (region 4) > right-lower (region 5) = left-upper (region 3) > right-upper (region 2).

In the peripheral zone (region 6, 7, 8, 9), left-upper (region 7) has significant difference with left-lower (region 8) ($P < 0.05$); right-upper (region 6) has significant difference with right-lower (region 9) ($P < 0.05$). That is to say, the visual advantage of lower horizon over upper horizon appears in the peripheral zone. Left-lower (region 8) has significant difference with right-lower (region 9) ($P < 0.05$). However, there is no significant difference between left-upper (region 7) and right-upper (region 6). According to the average RT in Table 1, the priority order of the four regions in

**Table 1.** RTs at different regions

| Visual region | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| RT(ms) | 513.1 | 656.2 | 630.04 | 613.8 | 627.0 | 696.9 | 688.8 | 657.9 | 672.2 |

peripheral zone is: left-lower > right-lower > left-upper > right-upper, which is consistent with the regions in deputy fovea peripheral.

Bumsuk Lee [12] pointed out that the left horizon was superior to the right horizon, while the lower horizon was superior to the upper horizon in the visual search. Yantao Ren [13] also gave the same conclusions, meanwhile he pointed out that the difference of upper horizon and lower horizon is larger than the difference of left horizon and right horizon, and the eccentric distance effect was very significant in visual search. In this division way of visual field, the results verified that the whole trend also conformed to these laws, and the whole the priority order is generally: 1 > 4>5 > 3>2 > 8>9 > 7>6.

### 3.2 The Average Fixation Duration

The eye movements of visual search are generally consisted of one planning motion and a series of correction motions. Figure 2 showed the eye movement trail of one subject when the target appeared at the 8-region, and the blue line represented the visual planning phase. When the saccades movement is lineal, the vision cannot reach the target directly but reach a position to correct the direction. There are two vision corrections before it reached the target, and the red lines represents the visual correcting phase. Larger the eccentricity is, greater deviation the saccade direction of planning motion would produce, which led to longer time of correction motions.

Figure 3 showed the eye movement contrail of one subject with the target appearing in the left and right horizons with the same eccentricity respectively. From the comparison figures, it can been seen that when the target was appearing in the left horizon,

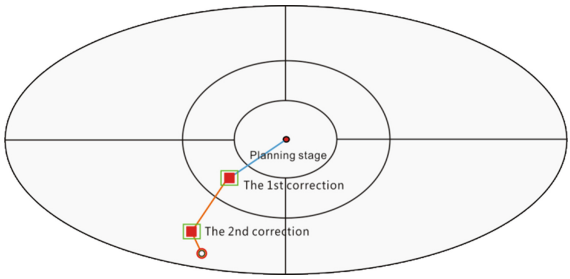


**Fig. 2.** Eye movement contrail of visual search (Color figure online)

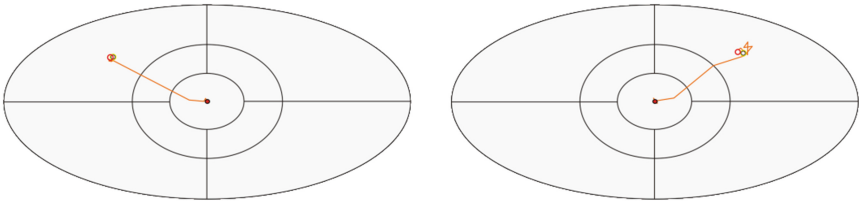

**Fig. 3.** Eye movement contrails in left horizon and right horizon

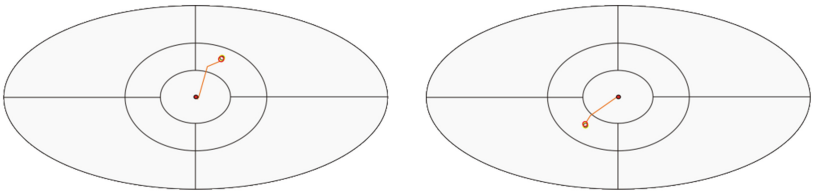

**Fig. 4.** Eye movement contrails in upper horizon and lower horizon

the eye movement contrail was more clear and there are less saccades in the phase of correction; while the contrail in right horizon was more messy, and there are more saccades in the phase of correction, resulting in longer RT. Meanwhile, comparing with the upper horizon, the contrail in lower horizon was clear and there are less saccades in the phase of vision correction (seen in Fig. 4).

## 4 Conclusion

The spatial effect of target display on visual search was researched by means of reaction time and eye-movement measurement. Based on the anatomy characteristics of retina and the absolute position characteristics of visual field, the visual field is divided into nine regions, and the following conclusions can be obtained: (1) The eccentricity effect of reaction time was very significant, and the reaction time increased following with the increase of eccentricity. Meanwhile the quadrant effect of RT was also significant: the RT of the upper horizon was longer than the lower horizon; the RT of the right horizon was longer than the left horizon; the difference of upper horizon and lower horizon is more apparent than the difference of left horizon and right horizon. (2) Eye movements of visual search are consisted of a planning motion and correction motions, and correction motions took longer time.

The results of the paper provide some reference for the future study of spatial characteristics in ergonomics. Meanwhile, the priority order of different visual regions can be used in the layout design of human-computer interface.

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