PERIPHERAL VISION PATTERN DETECTION DYNAMIC TEST

João P. Rodrigues, João D. Semedo, Fernando M. Melicio
Institute Systems and Robotics, Technical University, Av Rovisco Pais 1 TN6.21, Lisbon, Portugal

Agostinho C. da Rosa
Laseeb-System and Robotics Institute, Technical University, Lisbon, Portugal

Keywords: Pattern Recognition, Peripheral Vision, Foveal Vision, Electrooculogram.

Abstract: This work proposes a test that evaluates how well a subject can recognize and relate objects in the peripheral and foveal field while focused on some different task and how well this subject can make decisions based on this visual information. Although there exist a few peripheral vision tests in ophthalmology for checking the homogeneity and the reach of the vision field, these professional or clinical grade tests need a fixing or resting system to immobilize the head and also to instruct to the subject to gaze on a reference point. This test doesn't evaluate the homogeneity of the visual field alone but also how well the information that is visually acquired is processed. Automatic detection of ocular movement is used to separate the results due to peripheral vision from those due to central vision. This test was applied to twelve junior soccer players and successfully identified those that used more peripheral vision, eye scanning or those that didn't want to collaborate and clicked randomly.

1 INTRODUCTION

The aim of this work was to develop a test that evaluates peripheral vision and how well it is used by athletes. Although peripheral field of vision tests are already available and can accurately measure the peripheral field of vision, they give no information about how this extra information is used. On the rare attempts to do so, there was no care in assuring that the test subjects were really using their peripheral vision and not performing eye scanning. This, added to the fact that decisions based in the peripheral visual field is one of the most decisive skill in the performance of some professional athletes, lead to development of a test platform able to efficiently infer about the quality of this skill.

1.1 Peripheral Vision

The human eye is constituted by some major components: cornea, iris, pupil, lens, retina, macula, optic nerve, choroid and vitreous. For the purpose of this article it is interesting to take a closer look at the retina and its relation to the peripheral vision.

The retina is a nerve layer lining the back of the eye composed by rods and cones, two types of photosensitive cells. Cones concentrate around the fovea and are responsible for color vision. The need to look directly at an object to sharpen the vision results from the positioning of cones in the retina, as this movement centers de image on the fovea - foveal vision.

The peripheral vision is mostly due to the rods, which are equally distributed around the retina, with the exception of the fovea, where only cones are present. Rods are very light-sensitive, working mostly at low intensities of light, as they become saturated in normal day conditions. They do not distinguish color and one of their most important features is the capability of motion detection. Although there is a higher percentage of rods than cones in the area of the eye responsible for the peripheral vision, there still is color information in this perception but not so evident. Besides lower color information, peripheral vision also lacks of spatial resolution, when compared to foveal vision.

The fact that foveal vision field richer in color and resolution may lead to a frequent underestimation and waste of the peripheral vision field by most

P. Rodrigues J., D. Semedo J., M. Melicio F. and C. da Rosa A. (2010).
PERIPHERAL VISION PATTERN DETECTION DYNAMIC TEST.
In *Proceedings of the 12th International Conference on Enterprise Information Systems - Human-Computer Interaction*, pages 242-247
DOI: 10.5220/0002977402420247

people. However, its characteristics suggest that it can play a crucial role in different types of tasks and taking it into account can be beneficial.

1.2 Objectives

The objective of this work was to develop a reliable test to determine how well a subject can recognize and relate objects in the peripheral and foveal field while focused on some different task. In other words, the test should measure how well a subject can be aware of his surroundings. This objective is because the target subjects of this test are mostly athletes (in this study, soccer players) that benefit from this skill. In soccer or basketball for example, this skill is of the utmost importance while players dribble along the field, focused on their dribble and, at the same time, distinguishing their team mates from the opponents or from the referee, choosing which team mate to pass, acknowledging field contours or targeting the goal. This way, it is important that this test accomplishes the following requirements:

- Display test images for the peripheral visual field.
- Display test images for the foveal visual field.
- Ask the subject for some response when a certain relation between the test images is met.
- Engage the subject in some task other than distinguishing the test images at the same time.
- Score the subjects performance in the test.
- Distinguish a response due to peripheral vision from eye scanning.

This last point is decisive for the quality of the results because it is possible that a subject eye scans the objects meant for the peripheral visual field thus, seeing them with the foveal visual field. This would violate the main objective of this test that is about how well the information present in peripheral and foveal visual fields is processed and related. Moreover, peripheral vision is probably the most important factor responsible for a players orientation in the field (Levi et al., 2002).

2 PLATFORM

There exist a few peripheral vision tests in ophthalmology for checking the homogeneity and the reach of the vision field. These tests needs a fixing system to immobilize the head and also instruction to the subject not to gaze on a reference point. Since the peripheral vision is a perceptual function, its assessment needs feedback from the subject self evaluation which is not reliable or more convenient through an indirect but objective response. In order that only peripheral vision is being used the experimenter has to control the existence of eye scanning by visual inspection. Initial works by Stiles measured the sensitivity to background lights with different wavelengths (Stiles, 1959) and lead to the emerging of new automated tests later called by Short Wavelength Automated Perimetry (SWAP). This test can be used to detect visual field loss in patients with glaucoma but still has the limitation of subjective observation of eye movement (Johnson et al., 1993).
In this work we proposed a simple test system based on a PC with a large screen for visual test delivery, but with an acquisition hardware and biologic amplifier for acquiring the electrooculogram (EOG), giving priority to the detection of horizontal scanning. Although different colors and shapes are stimulating the peripheral visual field, determining the individual thresholds for each wavelength is not in the scope for this test. This, and the fact that eye scanning can be detected, distinguishes this test from the previous. It is not supposed to be a medical diagnostic test but a way to measure information processing from different visual fields.

2.1 Test Structure

The general screen layout of the test is shown in Figure 1. It consisted of a flat LCD screen (size 102 cm in diagonal) and the subject is seated in front of it at a distance of 53 cm. This setup ensures a horizontal vision angle of 60º and a vertical vision angle of 33.75º.

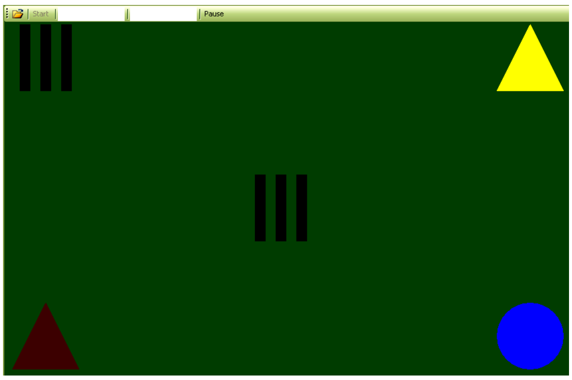


Figure 1: Test screen. The objects at the vertices should be captured by peripheral vision.

The test screen has four objects in each corner and a central object moving slowly. The stimuli are composed by different set of objects with a programmed duration or persistence. The sequence of stimulus is completely programmable by a script file that can be loaded into the system prior to the session starts.

There are two types of stimulus: the target stimulus is when the screen shows simultaneously at least three equal objects (including the center one). In order to ensure a sixty degree the target stimulus has always at least one object in the left and right side of the screen. Figure 2 represents the possible target configurations where the circles represent each object.

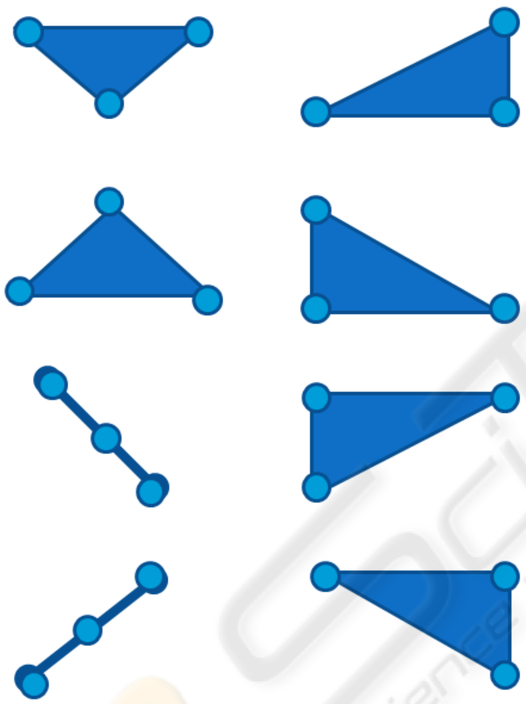


Figure 2: All possible configurations of objects that produce a target stimulus in the test.

In order to distinguish between responses with or without eye scanning the asymmetric outer cantus montage is used (see Figure 3). This particular montage configuration allows the capture of both horizontal and vertical eye movements and due to this specific placing it is more sensitive in the Horizontal axis than the vertical one allowing to filter out the eye blinks artifacts, mostly due to eye blinks that are dominated by vertical components.

In order to engage more, the test subject has to control a mouse pointer, tracking the central object and click on it whenever a target stimulus is

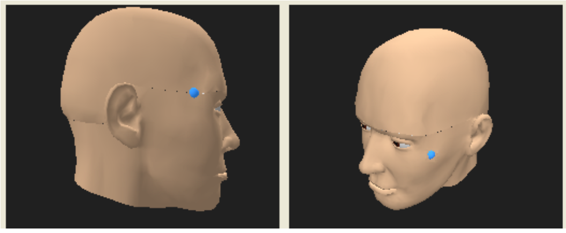


Figure 3: One eye electrode is placed 0.5 cm below the outer canthus, and the other electrode is placed 0.5 cm above the outer canthus of the other eye. Differential field effects of the retina-to-cornea dipoles recorded in these opposing electrodes provide data on the types of eye movements (Gerla et al., 2009).

perceived. Thus, the subject's response can result in a click or not.

To start each test, the user has to click in the start button, located in the upper left corner. The test begins two seconds after the click. The EOG that results from looking at the start button and looking back to the central object again can be used for calibration of an EOG detection algorithm. There is also the possibility of pause the test.

2.2 Eye Scanning Detection

The presence of eye scanning during tests is determined by the information present in the EOG channel. Eye movements are captured by the asymmetric outer cantus montage explained previously before being amplified. The amplified signal is then digitalized at a rate of 250 Hz and sent to the laptop where the test is running, via USB protocol, and recorded. There was no need for online EOG detection in this study because it was not planned to give feedback about it to the test subjects. However, every event that occurred during the test is attached to the recorded signal (see Figure 4) so that later it can be processed by any EOG detection algorithm. This is a better alternative because only raw data about the test is saved, together with the EOG. Further processing is done offline.

2.2.1 EOG Detection Algorithm

The EOG detection algorithm developed for this test was meant to be simple and did not take into account de direction of the eye movement (there is no distinction between left, right up or down eye movement). Nevertheless, because the raw data of the test session is available, it is possible to use an algorithm that distinguishes these movements to determine what was the object in the test that was being scanned with the foveal vision field.

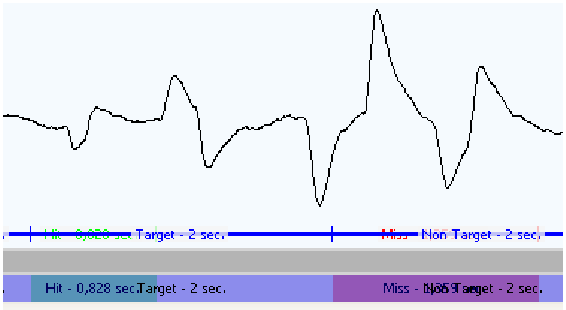


Figure 4: Signal labeled with the events that occurred during the test. The subject clicked 829 ms after the target stimulus and clicked again 1359 ms after non target stimulus.

For calibration sample, the developed algorithm can use the signal in the initial seconds of the test where the subject clicks the start button, any pre-selected region or the entire signal. Both calibration sample and the test signal to be processed are filtered by a low pass filter with a 5 Hz cut off frequency. Then, the absolute maximum *max* of the calibration sample is determined (there is no need to distinguish the direction of the movement) and the test signal is normalized by this value. Signal extremes are found when the first derivative of the signal is zero. Only the extreme with absolute value higher than a certain percentage *a* of *max* are considered as possible candidates for an EOG. In most cases this is enough to conclude that there was EOG present in the channel. However, if necessary, the algorithm can decide if the extreme found is from an EOG or not by looking into the distance *d* between the second derivative zeros around the maximum and comparing them with the results from the calibration sample as well as with the sum of the absolute values of the second derivative *s* between these zeros.

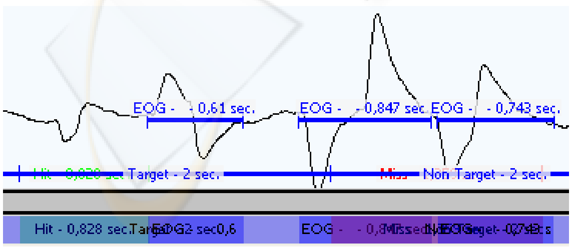


Figure 5: Signal labeled with test events and eye movements.

After this, each EOG is marked in the signal, where the information from the test was already marked (Figure 5). This way, it is possible to determine if the subject's decision to any stimulus in the test is based only on peripheral vision or helped by eye scanning. If EOG is detected after the beginning of a stimulus and before the subject's response, it is considered to be based on eye scanning.

2.3 Test Score

The results from the test are treated in three different ways: global results; only peripheral vision results; only eye scanning results. Global results are those that take into consideration the responses due to peripheral vision and eye scanning together. Peripheral vision results only have responses based in peripheral vision (without EOG) and eye scanning results only have responses based in eye scanning. For each set of results the following events are taken into account: True Positive (TP) stands for clicking a target; True Negative (TN) means the subject ignored a non-target; False Positive (FP) is accounted whenever a non-target is clicked; False Negative (FN) stands for ignoring a target. These events are used to calculate the indexes that evaluate the performance in this test. Again, for each set of results a score is calculated by Equation 1:

$$score = \frac{1}{2}\left[\left(\frac{TP}{T} - \frac{FP}{NT}\right) + \left(\frac{TN}{NT} - \frac{FN}{T}\right)\right] \times 100 \quad (1)$$

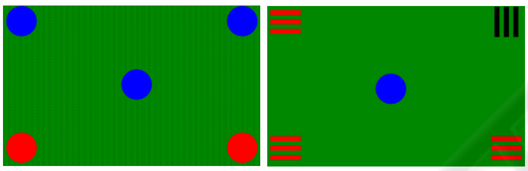
Where T is the total number of targets and NT is the total number of non targets. This index is calculated for the global, peripheral and eye scanning results, resulting in three different indexes. This score ranges from -100% to 100%. If the subject doesn't click in any target or clicks in all (correct and false) the score is 0%. If the subject only clicks in correct targets and doesn't miss any one the score is 100%. If the subject clicks in every false target and doesn't click in any correct one the score is -100%.
The average response time is also given for each set of results, so it is possible to check if peripheral vision responses are in average faster or slower than eye scanning. An example is shown in Table 1

Table 1: Average response time associated to each test.

Target Type	*Target time (ms)*	*Response*	*Response time (ms)*
NonTarget	3984,38	Clicked: Peripheral	1656,25
NonTarget	4015,62	Peripheral	
NonTarget	3984,38	Peripheral	
Target	4000	Clicked: Peripheral	1187,5

3 TEST PROTOCOL

Twelve junior soccer players with varying field positions and average ages of seventeen were tested by this application. The test setup only requires the placement of the electrodes that took about three minutes for each player. After that, the test objectives and functioning were explained in the same way for all twelve players. Then, they were allowed to start the test when feeling prepared. Before the tests, each player was informed that no eye scanning was allowed.
Each session consisted of two pre-programmed set of stimulus of approximately one minute duration each. In the first set the objects are plain colored circles while in the second one the objects may have mixed colors and shapes making it much harder to differentiate. In order to add additional difficulty to the test, the frequency of the stimulus increases along each session in both tests. Figure 6 shows a frame from the first test while figure 7 shows a frame belonging to the second test.



Test1 Test2

Figure 6: Test objects only vary in color in Test1 while in Pattern Test vary in color and shape.

4 RESULTS

Table 2 shows the results from the two tests for four players. Columns *Global 1%* and *Global 2%* represent the global score for Color Test and Pattern Test respectively and *TG%* the average of both. Columns *Pher 1%* and *Pher 2%* are the scores from the peripheral responses for Color Test and Pattern Test respectively and *TP%* their average. Columns *Scan 1%* and *Scan 2%* are the scores from the eye scanning responses for Color Test and Pattern Test respectively and *TS%* their average. From the examples present in Table 2: the highlighted subject (last row) appeared to be clicking randomly and the score reflected his lack of dedication to the test; the subject in the first row was the one that used more eye scanning and a very few peripheral vision; the subject from second row has the opposite situation and the subject in the third row uses both peripheral and eye scanning.

Table 2: Test results.

Subject	Global 1 %	Global 2 %	TG %	Pher 1 %	Pher 2 %	TP %	Scan 1 %	Scan 2 %	TS %
1	23,81	47,68	35,75	-3,57	3,57	0,00	27,38	44,05	35,72
2	52,38	59,52	55,95	39,29	53,57	46,43	13,1	5,95	9,53
3	50	52,38	51,19	41,67	11,9	26,79	8,33	40,48	24,41
4	-16,67	7,14	-4,77	-16,67	3,57	-6,55	0	3,57	1,79

5 CONCLUSIONS

Despite the request for avoiding eye scanning, almost every subject used it more than once. Interestingly, in most cases, the average delay for the eye scanning response is higher than the average delay from peripheral vision response. There are obvious cases of subjects that score higher in both global and peripheral scores. During both tests one subject seemed to be clicking randomly and his results were very close to 0% in both. This way, this test shows promising results to be a good indicator of a persons' capability of deciding according to his surroundings while performing a different task. It also discriminates between two ways of acknowledging their surroundings: by peripheral vision or eye scanning. With a stable and precise evaluation tool for this skill it is possible to experiment new methods to improve it.

ACKNOWLEDGEMENTS

This work was partially supported by Fundação para a Ciência e a Tecnologia (ISR/IST plurianual funding) through the POS_Conhecimento Program that includes FEDER funds.

REFERENCES

Gerla V., Paul K., Lhotska L., Krajca V. (2009) Multivariate analysis of full-term neonatal polysomnographic data. Trans Info Tech Biomed 13:104-110.
Johnson C. A., Adams A. J., Casson E.J., Brandt J. D. (1993) Progression of Early Glaucomatous Visual Field Loss as Detected by Blue-on-Yellow and Standard White-on-White Automated Perimetry. Arch Ophthalmol 111:651-656.
Levi D. M., Hariharan S., Klein S. A. (2002) Suppressive and facilitatory spatial interactions in peripheral

vision: Peripheral crowding is neither size invariant nor simple contrast masking. J. Vis 2:167-177.
Stiles W. S. (1959) Color vision: the approach through increment-threshold sensitivity. Proceedings of the National Academy of Sciences of the United States of America 45:100-114.