Measurement of Useful Field of View during Ocular Following Response

Kimihiro Yamanaka and Atsushi Minochi

Tokyo Metropolitan University, Tokyo, Japan
{kiyamana,minochi-atsushi}@sd.tmu.ac.jp

Abstract. There have been numerous studies related to useful field of view with regard to ensuring safety during activities and preventing recognition failures that can result in human error. As a result, the form of the useful field of view has been determined and methods for its measurement have been proposed. Most studies have assumed a fixed gaze, however, thus failing to consider the useful field of view during eye movement. The present research takes an experimental approach toward discovering the effects of eye movement speed and direction on useful field of view, limiting eye movement speed to 30°/s. As a result, the direction of gaze movement, increases in speed, and the direction of the recognized object with respect to the focal point cause variation in the narrowing of the useful field of view.

Keywords: useful field of view, eye movement, effects of binocular summation.

1 Introduction

Visual information processing is performed on information obtained from not only the center of the field of view, but also along its periphery. The range of visual information collection that can be effectively used during visual cognitive tasks is called the useful field of view (UFOV), and is an important visual characteristic for recognition of, for example, obstacles and markers [1,2]. There have been numerous studies related to UFOV with regard to ensuring safety during activities and preventing recognition failures that can result in human error. As a result, the form of UFOV has been determined and methods for its measurement have been proposed. Most studies have assumed a fixed gaze, however, thus failing to consider UFOV during eye movement [3-5]. Yet in actual working environments there are few tasks that workers perform with a fixed gaze; in most cases, necessary visual information will be collected during eye movement. It is therefore important to better understand the features of UFOV in unrestrained situations.

The present research takes an experimental approach toward discovering the effects of eye movement speed and direction on UFOV, limiting eye movement speed to 30°/s (the accepted maximal speed at which perception can occur).

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2 Experimental Outline

Fig.1 shows a diagram of the experiment and the path of the tracking markers. A participant was seated with the head secured by a chin rest (HE285, Handaya Co., Ltd.), and visual stimuli were presented via a rear projector (HD70MH700, Victor) at a point located 225 cm in front of the eyes. A program developed by us in Microsoft Visual Basic 2008 generated the visual stimuli. In the presentation, a white, circular marker with 1.25° diameter moves randomly in horizontal, vertical, and diagonal directions, and upon reaching the center of the screen a Landolt ring is randomly shown in the screen center and at the screen edge in one of three directions (horizontal, diagonal, vertical) at one of five distances (between 1.25° and 3.25°) from the center. The participant then presses arrow keys on a keyboard to indicate the direction of the center and edge Landolt rings. The tracking marker moved at one of three speeds (10, 15, or 20°/s) in one of three directions (horizontal, diagonal, or vertical). Lighting in the participant's visual area was 122.2 lx, verified according to the 5-point method in JIS C7612 (Methods for Measuring Illumination).

Ten university students aged 23.7 ± 1.1 with corrected or uncorrected vision of 0.8 or better participated in the experiment. An eye tracker (EMR-8, NAC Image Technology) monitored whether participants continued visual tracking during the experiment, and those who did not were excluded from analysis. We also simultaneously performed experiments with an unmoving focus point as a measure of UFOV with a fixed gaze.

3 Measurements of Useful Field of View

The purpose of this experiment is to measure the threshold of recognition when the response category changes from "possible to detect" to "impossible to detect" or vice versa. It is well known that the function linking the possibility of detection and the strength of the stimulus can be obtained as a psychometric curve [6]. Since the

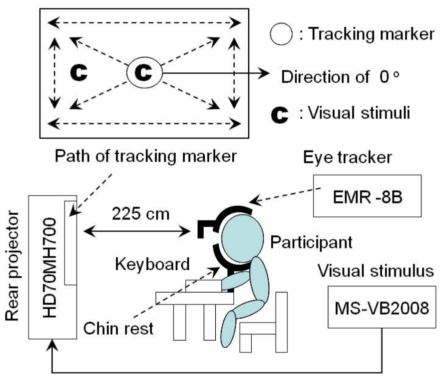

Fig. 1. Experimental setup

distance of the boundary between the "possible to detect" and "impossible to detect" categories indicates the threshold of recognition, the latter can be estimated by using a psychometric curve. Therefore, it may be possible to obtain the psychometric curves in any direction from the fixation point, and it is also known that the stimulus threshold can be obtained as a probabilistic percentile of this psychometric curve. One of the examples of this threshold with a 50% probability is the point of subjective equality (PSE), which is equivalent to the threshold of recognition. As shown in Fig.2, if we can assume that the region plotted within these stimulus thresholds is defined as UFOV, then the outer limit of the region connected with PSE for each angle is also defined as UFOV [7].

4 Experimental Results and Discussion

Table 1 shows average values for the edge of UFOV for all participants during eye movement in each direction. The results in that table show that for all directions, the range of UFOV decreases as tracking speed (eye movement speed) increases. Two-way analysis of variance with eye movement speed and direction with respect to focus point as factors reveals that as focal point movement speed increases, the visual field narrows in all directions.

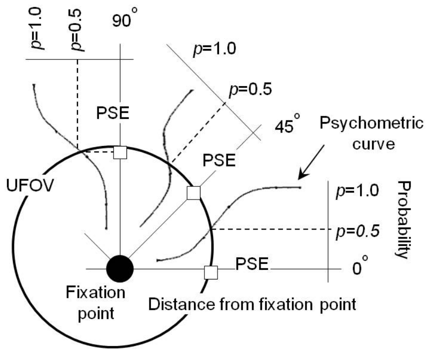

Fig. 2. Definition of UFOV

Table 1. Average values of UFOV (°)

		Horizontal eye movements			Diagonal eye movements			Vertical eye movements		
Eye movement speed (°/s)		10	15	20	10	15	20	10	15	20
Directions from fixation	Horizontal	7.74	6.23	5.44	6.77	5.94	4.43	6.46	4.75	3.75
	Diagonal	5.37	4.64	4.85	5.22	4.59	3.89	5.03	4.01	2.21
	Vertical	6.07	5.15	5.13	5.30	4.40	3.50	4.90	3.67	3.09

We next focused on the amount of narrowing of the effective visual field for each eye movement direction. Fig.3 shows eye movement speed and area of UFOV as estimated according to direction of the focus point. Fig.3(a)–(c) respectively show values during horizontal eye movement, diagonal eye movement, and vertical eye movement. The figures indicate that UFOV is reduced most during vertical eye movement, and least during horizontal eye movement, suggesting that the reduction of field of view varies with the direction of eye movement.

We next consider reasons for this remarkable narrowing during vertical eye movement. Numerous previous studies have reported that the forward field of view in humans has a greater horizontal range than vertical range. The reason for this remains unclear, but one possible explanation is the horizontal positioning of the eyes, which may broaden the range in which objects can be detected. While only one of the left or right eye detects objects near the horizontal periphery of the field of view, both eyes are involved in detection of objects near the vertical periphery. This means that detection thresholds are lower due to the effects of binocular summation. In other words, at the edge of the field of view for a single eye one can expect a higher sensitivity for object detection by both eyes in the vertical direction than in the horizontal direction. The effects of binocular summation means that functionality is increased for a pair of eyes rather than one alone, and there have been reports that when corresponding points in the retinas of both eyes are given equal stimuli the functioning of both is high, and that the functioning of both eyes decreases with increased imbalance in sensitivity between the nasal retina and the temporal retina [8,9]. This supports the idea that the expansion of the field of view may be greater in the vertical direction than in the horizontal direction due to the effects of binocular summation. In other words, for a given reduction with respect to the field of view for a single eye regardless of direction, vertical reduction of the field of view for both eyes may be more significant, because there was a larger increase in that direction due to The effect of binocular summation. This may also explain the remarkable narrowing of the field of view when the view is shifted vertically: the vertical rotational speed of the eye would increase, imparting a greater control load for eye movement than if the movement were horizontal. Verification of this hypothesis is a topic for future research.

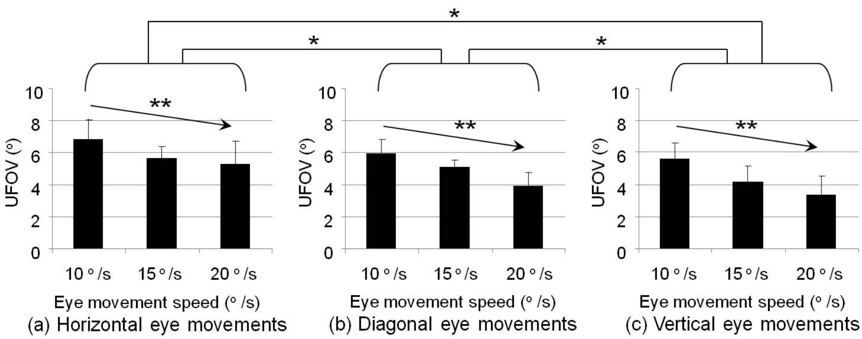

Fig. 3. Eye movement speed and area of UFOV (*:p<0.05, **:p<0.01)

5 Conclusions

In this research, experiments were conducted to investigate the effects of the speed and direction of eye movement on the effective field of view during ocular following response. Our investigation resulted in the following conclusions:

1. The direction of gaze movement, increases in speed, and the direction of the recognized object with respect to the focal point cause variation in the narrowing of the effective field of view.
2. The effect of binocular summation likely explain the phenomenon of remarkable narrowing of the field of view in the vertical direction.

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