

# PC-Based Measurement System of Useful Visual Field at Driving Situation by 3D Movie

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**Abstract--** In order to evaluate human error, the PC-based experimental system was developed in order to evaluate the useful field of view at driving situation replayed by 3D movie edited by PC. It was studied that the region of useful field of view was measured corresponding to effective factors by the proposed experimental system. As a result, the region of useful field became to be narrower, when the complexity of traffic situation is accumulated. EEG (electroencephalograph) was also measured with response time in the experiment to find the target mark in foreground scene overlaid on the background scene that is the 3D movie of driving a load vehicle.

**Index Terms--** EEG, Human Factors, Three-Dimensional Vision, Vision (Biological)

## I. INTRODUCTION

The human error is one of the important factors why the structural safety and reliability have not been improved until now [1-3]. The psychological method for the human error has not been advanced because of many complicated factors inherent, so that it must be clarified how to occur and what the principle factors are [8],[9]. In this paper, the human response is studied when one recognizes visual stimulus. One of the aims of this work is to offer the PC-based experimental system in order to measure the useful field of view experimentally and to clarify the mechanism of the phenomena of visual tunneling at driving situation.

It is examined by the experiment to evaluate the relation between the visual attention and physiological signal in load vehicles when the driver recognizes a target mark as a visual stimulus produced by PC. Experiments were performed in the shield room with the CRT that displays the 3D movie edited by PC in line with experimental purposes as a driving situation. In the experiment, the physiological signal and

response time are measured to evaluate a human behavior when one can find a target mark in foreground superimposed on the scene of 3D movie of driving a load vehicle. These experiments were performed along with the combinations of factors by the orthogonal table for experimental design. The sensitive factors were selected based on the analysis of variance (ANOVA) with 1 and 5 % significance level. It became to be possible by the experimental system to measure the region of useful field of view and EEG during driving a load vehicle in the laboratory.

## II. PC-BASED EXPERIMENTAL SYSTEM FOR USEFUL FIELD

### A. Experimental Equipments and Procedures

Fig.1 shows the schematic aspects of experimental devices. The response time and physiological signal are measured when the target mark displayed in CRT could be recognized by the examinee in the electromagnetic shield room. The 21 inches CRT (SONY, GDM-F500) was equipped with 600mm distance from the eye of the examinee. A visual stimulus consists of foreground scene and background scene. In the foreground scene, the target mark appears at random spatially and temporally programmed. As shown in Fig.2, the foreground scene is superimposed on the background scene by overlay unit in Fig.1. The driving scene is edited as background scene for the combination of velocity and traffic demand as shown in Fig.5.

The output data of NTSC signal from overlay unit is converted into RGB signal by the up-scan converter in Fig.1. All the scenes were transformed into 3D movies by NuVision's stereo display system (MacNaughton Inc, NuVision 21SX) consisted of liquid crystal modulator shutter, synchronizer, and stereo glasses. The shutter is a liquid crystal modulator that works in conjunction with stereo glasses to present the appropriate image to the left and right eye. The synchronizer accepts many video, input configurations and automatically synchronizes the shutter with the display of stereo image on CRT. In order to watch 3D stereo image, the examinee must wear stereo glasses. In the experiment, it is tried to measure the region of the field of view by the response of a target mark in the foreground scene. On the other hand, in the background scene it is used to give a visual task with a situation of driving an automobile that works the noise for the recognition of target marks in the foreground scene.

Two kinds of experiments are carried out. One is to measure the region of the useful field that is the range to detect a simple white circle as a target mark  $S_2$  in foreground scene.

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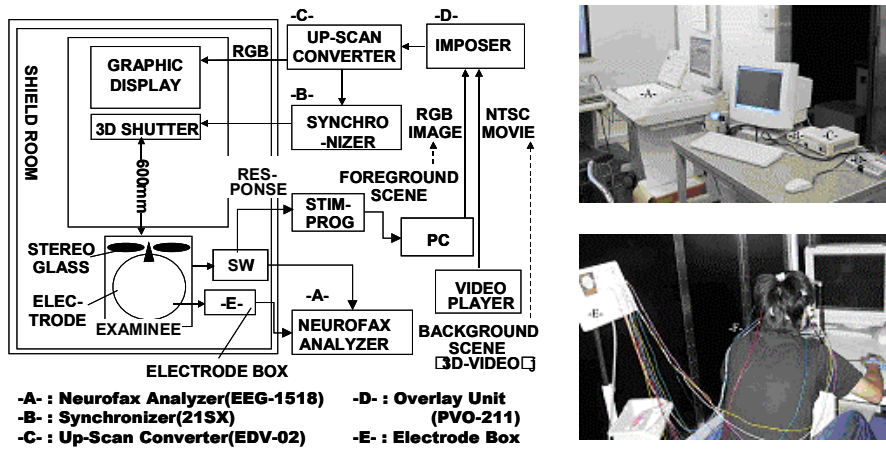


Fig. 1. Schematic aspect of experiment.

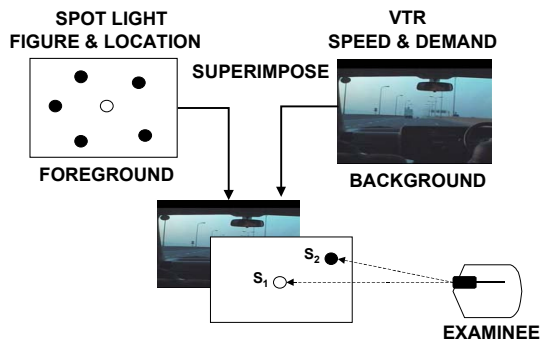


Fig. 2. Foreground and background scene.

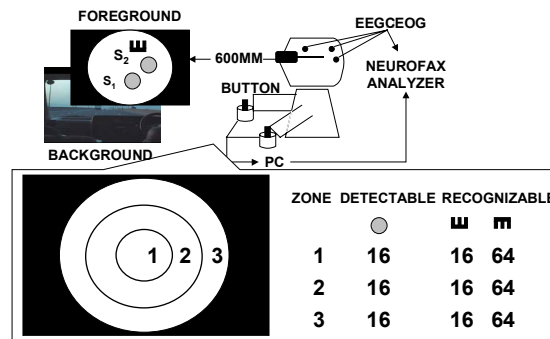


Fig. 3. Appearance zone of target marks.

The region measured by this experiment is called as “detectable field of view”. Therefore this is “the experiment of a detectable”. The other experiment is to measure the region of the useful field that is the range to be able to recognize a specific shape in Snellen’s chart as a target mark among the standard marks of similar shape. The region measured by the latter experiment is called as “recognizable field of view”, and this experiment is called as “the experiment of a recognizable”. Both the regions are equivalent to the working conspicuity field in psychophysics [6]. In the experiment, the examinee must continue an additional task to fix a one’s visual attention to the signal  $S_1$  on the center of foreground scene as shown in Fig.2.

The two kinds of buttons were given to the examinee in his or her hands as shown in Fig.3. The examinee must push the button of right side as soon as possible, when he or she can detect or recognize the target mark  $S_2$  in the foreground scene. On the other hand, the examinee must put the mark of  $S_1$  on by his or her left side button when  $S_1$  disappears in order to fix the visual attention into the center of the scene. Two kinds of visual task for the detection or recognition of  $S_2$  and putting  $S_1$  on were done at the same time during the experiment. The signal of the left side click was saved in the PC. The duration time from the appearance of  $S_2$  to the reaction by examinee was also saved in PC.

The brightness was 18.1 lx in front of the CRT. The 3D movies are used for the background scene of the additional

perceptive stimulus as shown in Fig.2. Several kinds of physiological signals was also measured by NeuroFax EEG-1518 (Nihon Kohden Inc.) such as EEG and ENG (electronystagmograph). In this experiment, the university students from 20 to 24 years old was selected as candidates of examinees who have regular class automobile licenses with normal vision or corrected normal vision.

### B. Foreground scene

The foreground scene plays a role to display a visual stimulus as a target mark. In the foreground scene, two kinds of marks of  $S_1$  and  $S_2$  are used as signals to measure the region of useful field of view as shown in Table 1.  $S_1$  is used to keep the visual attention of examinee on the center.  $S_1$  is a simple white circle with the size of  $0.48^\circ$ . The duration time between  $S_1$  and  $S_2$  is 1700msec as shown in Fig.4. In this experiment, the mark of  $S_1$  appears during the specified duration time so that the examinee must put on the mark of  $S_1$  by his or her left side button when  $S_1$  disappears. This is an additional task to recover the disappearance of mark  $S_1$ .  $T$  is the factor of this additional task. There are two kind of duration time  $T_1$  and  $T_2$  of  $S_1$  specified previously as shown in Table 2. The difference of  $T_1$  and  $T_2$  means the frequency of disappearance of  $S_1$ .  $S_2$  appears within the zone (radius:  $0^\circ \sim 14.03^\circ$ ) at undetermined coordinates whenever  $S_1$  is appearing. There are two kinds of target marks of  $S_2$ . The former is a simple white circle with  $0.48^\circ$ , and the latter mark is a specified shape in Snellen’s

Table 1. Two kinds of experiment and visual stimulus signal.

	DETECTABLE		RECOGNIZABLE	
	SHAPE OF SIGNAL	INTERVAL	SHAPE OF SIGNAL	INTERVAL
$S_1$	○ 0.48 °	15cycles/min 53cycles/min	○ 0.48 °	15cycles/min
$S_2$	○ 0.48 °	---	■ TARGET ■ STANDARD	---

Table 2. Conditions of factors.

	1	2	SCENE
T: TASK	$T_1$ : 15cycles/min	$T_2$ : 53cycles/min	FOREGROUND SCENE
V: AUTOMOBILE SPEED	$V_1$ : 40km/h	$V_2$ : 80km/h	BACKGROUND SCENE
D: TRAFFIC CONDITION	$D_1$ : NON-CROWDED	$D_2$ : CROWDED	

chart as shown in Table 1.

In the experiment for detectable field, a simple white circle is used in the target mark of  $S_2$ . In the experiment for recognizable field, a specified shape in Snellen's chart is used in the target mark of  $S_2$ . Two kinds of the specified shape are used for recognizable field of view such as a standard and a target listed in Table 1. In the experiment of a recognizable field, the examinee must put on his right side button when the target mark of  $S_2$  appears. The details of this time chart on the duration time of  $S_1$  and  $S_2$  are shown in Fig.4. In the experiment of a detectable,  $S_2$  is displayed 48 times per experiment. In the experiment of a recognizable,  $S_2$  is displayed 256 per experiment, the standard mark of  $S_2$  is 208 times and the target where is 48 times. In the experiment, the mark  $S_2$  appears the same times per zone, as shown in Fig. 3.

### C. Background scene

Several kinds of driving scenes are used as a background scene for the disturbance effect on the visual attention. Each image is recorded in actual road by 3D video camera KS55Z (Kastam, KS55Z). The patterns of driving scenes are listed in Table 2 where V and D mean the factors of the speed and traffic demand. The recorded scenes consist of two kinds of level for factors V (velocity of automobile:  $V_1=40\text{km/h}$ ,  $V_2=80\text{km/h}$ ) and D (demand of traffic:  $D_1=\text{non-crowded}$ ,

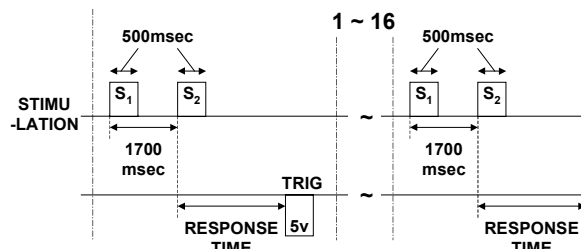


Fig. 4. Time chart of  $S_1$ - $S_2$ .



Fig. 5. Background scene.

$D_2=\text{crowded}$ ) as shown in Table 2. Background scenes were edited from original VTR source into scenes with two kinds of level for factors by the DV capture board and software DV-Editor (Canopus, DV-Editor). Fig.5 displays all patterns of the background scene for the combination of  $V_1$  (low),  $V_2$  (high),  $D_1$  (non-crowded) and  $D_2$  (crowded).

## III. DISCUSSION

### A. Definition of useful field of view

There are various kinds of definitions for field of view, because of the differences of the professional field. The width of stationary field of view can be illustrated as Fig.6 [6]. All regions in this figure are measured with a constraint of fixation of eye. As shown in this figure, the biggest region is called as static/kinetic field in psychology that is called as stationary field in medical science. This field means the region where one can find the unique circle mark (corresponding to the shape used in the experiment of a detectable) with uniform background. From Fig.6, the more the visual task is, the narrower the region is. The distinction between visibility and conspicuity field is in the condition of background. The former field is measured under uniform background, the latter field under complicated background. The distinction between conspicuity and working conspicuity field is in additional

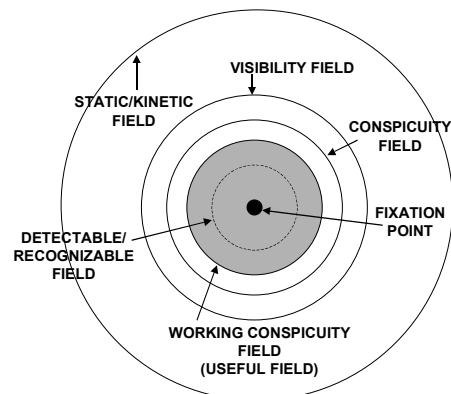


Fig. 6. Width of field of view [6].

Table 3. Classification of stationary field [5].

PROPOSAL		CONVENTIONAL CLASSIFICATION (MEDICAL AND PSYCHOLOGICAL SCIENCE)		
180-210 deg	PERIPHERAL FIELD		PERIPHERAL VIEW (MEDICAL AND PSYCHOLOGICAL SCIENCE)	FIELD OF VIEW (MEDICAL AND PSYCHOLOGICAL SCIENCE)
4-20 deg	DETECTABLE FIELD	[VISUAL SENSOR, VISUAL RECOGNITION] USEFUL FIELD (BEDERMAN ET AL.) / DETECTABLE AND RECOGNIZABLE FIELD (MIURA)		
	RECOGNIZABLE FIELD	RESPONSE PERIPHERAL FIELD (MIURA)		
	FIXATION ON CENTER	[MEDICAL SCIENCE] FOVEAL VISION (UNDER 1°) PARAFOVEAL (2-3deg) (KAKISAKI, 1957) / FOVEAL VISION (5.2deg) PARAFOVEAL (8.6deg) (IKEDA, 1975)	FOVEAL VISION (MEDICAL AND PSYCHOLOGICAL SCIENCE)	

visual task. From these definitions it is seen that the field of view measured in this experiment is equivalent to the working conspicuity field as shown in Fig.6 and Table 3 [6].

It is a problem that there are no standards of the way of measurement of the field within the visibility field. However, the useful field is the most important region which is of interest, since the characteristics of this region are strongly dependent upon the kind of visual task with high order function of brain such as driving automobile, train, aircraft and operation of control equipment of nuclear power plant and so on. Therefore, there are various kinds of terminology for useful field, that are called as useful field of view, functional visual field, range of cue utilization, conspicuity area and attention field [5].

From the reasons mentioned above, in this paper the new definitions of useful field are utilized in order to distinguish the meaning of useful field, as shown in Table 3 and Fig.6, such as a detectable and a recognizable field, though both fields are equivalent to a working conspicuity field in psychophysics [6].

### B. Experimental results of useful field of view

Table 4 shows the summary of the experimental results on effectiveness of factors that is evaluated from the experiment of a detectable and a recognizable. The second row in Table 4 shows the results of the table of variance by ANOVA, where the response time is selected as an objective variable. The notation such as E\* means 5% significant factor by statistical judgment. It was seen that T was more effective factor and D and T×V are the effective factors in the experiment of a detectable. On the other hand, in the experiment of a recognizable, it was also seen by ANOVA that D and D×V were more effective factors. The third and fourth rows in Table 4 are also the effectiveness of the factors from the subjective evaluations for response time and visual field. It was suggested that the factor D was the most sensitive factor from total consideration on Table 4.

The results of qualitative analysis on response time and width of the region of the field of view were listed in Table 4 for the conditions of V and D. From this table, it was remarkable that the response time in experiment of a

Table 4. Effectiveness of factors.

DETECTABLE	T	V	D	V×D	T×D	T×V
ANOVA	E*	N*	E	N	N	E
RESPONSE TIME	N	E	E*	□	□	□
MEASUREMENT OF VISUAL FIELD	E	N	N	□	□	□

RECOGNIZABLE	□	V	D	V×D
ANOVA	□	N	E*	E*
RESPONSE TIME	□	N	E*	□
MEASUREMENT OF VISUAL FIELD	□	E	E	□

E\* MORE EFFECTIVE  
 E EFFECTIVE  
 N LESS-EFFECTIVE  
 N\* MORE LESS-EFFECTIVE

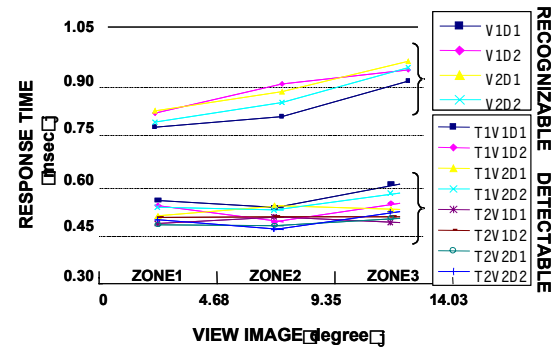


Fig. 7. Response time for appearance region of S<sub>2</sub>.

detectable was smaller than that in a recognizable for every combination of conditions of V and D. On the other hand, it was also found that the region of visual field in a recognizable was narrower than that in a detectable. It is interesting that the difference on the response time were from 230 to 290 (msec) and that on the width of visual field were from 1.50° to 3.15° as shown in Table 4.

Another results of the behavior on response time were represented in Fig. 7 for the appearance region of target mark S<sub>2</sub>. From this figure, in the experiment of a detectable, it was seen that there were no differences among the appearance region of target mark S<sub>2</sub> (zones 1, 2 and 3). However, in the experiment of a recognizable, there was a typical tendency that the wider the appearance region of target mark S<sub>2</sub> becomes, the longer the response time was as shown in Table 4.

### C. Useful field of view and visual tunneling

It is called as visual tunneling, perceptual narrowing or tunnel vision that the region within the visibility field is narrower, when the additional visual task increases. In order to explain the mechanism, Miura [4] has proposed a new hypothesis on visual attention from the viewpoints of cognitive and psychophysical science. In this hypothesis, the reason of occurrence of visual tunneling is due to two kinds of rules:

R1: When the visual demand is more than the ordinal visual task, the distance of moving visual attention is out of the region of useful field.

R2: When the visual demand is more than the ordinal visual task, there is less amount of overlapping of functional field.

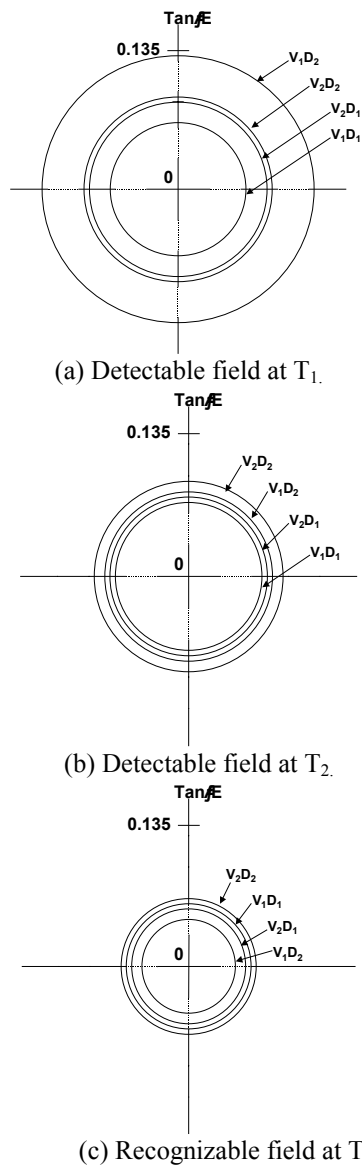


Fig. 8. Useful field of view by detectable and recognizable experiment.

In addition, in the hypothesis a new concept called cognitive momentum was also proposed by Miura [5], which means the active characteristics for information processing. From this concept, the reason why the visual tunneling occurs when the visual demand is more than the ordinal visual task is not due to the degradation of information processing, but due to adaptation to the change of situation for information processing. In other word, cognitive momentum means adaptation and optimization under the change of situation of information processing because of partition of resources on information processing.

Fig. 8 shows the measured useful field of view by the experiment of a detectable and a recognizable. Fig. 8(a) and (b) are regions of useful field for detectable field. From these results it is seen that the region of useful field at  $T_2$  becomes to be narrow at  $T_1$ . The additional visual task at  $T_2$  must be more

accumulated rather than at  $T_1$ . This is the reason why the region at Fig. 8(b) is smaller than that at Fig. 8(a). On the other hand, Fig. 8(c) is a region of useful field for recognizable field. From this figure, the region of recognizable field is smaller than those of detectable field.

#### D. Useful field of view and Information processing model

Fig.9 shows the path of the visual information processing in brain [7], where two kinds of channels of information processing are designated by dotted lines. One is the channel of processing on cognition of the motion and the other is that of character of an object. The routes for these channels in brain are illustrated in Fig.10 that is derived from Fig.9.

From this physiological knowledge, a visual information process model is proposed in Fig.11, where two kinds of channels correspond to recognize foreground and background scenes respectively. As shown in the figure, the process for both experiments such as a detectable and a recognizable are parallel processing in the path.

In order to verify the validity of the model, the event related potentials (ERP) were measured in the experiments, since it is seen that ERP is the potentials related to the specified cognition process. Especially, for the verification of the existence of the channels in the proposed model, P300 was studied. Fig.12 shows an example of obtained potentials P300 on  $C_z$ . Since the character of P300 designates how much concentration happens under the psychological uncertainties, this signal enables to measure the depth of information processing when one must judge the whether the mark appears during recognizable experiment under the visual information delivery.

Table 5. Response time and visual field.

RESPONSE TIME [msec]				
	D <sub>1</sub>	D <sub>2</sub>		
V <sub>1</sub>	0.575	0.564	DETECTABLE	RECOGNIZABLE
	0.805	0.858	RECOGNIZABLE	
V <sub>2</sub>	0.558	0.597	DETECTABLE	DETECTABLE
	0.824	0.850	RECOGNIZABLE	
				230 ± 290 [msec]
VISUAL FIELD [degree]				
	D <sub>1</sub>	D <sub>2</sub>		
V <sub>1</sub>	6.439	7.718	DETECTABLE	DETECTABLE
	4.941	4.569	RECOGNIZABLE	
V <sub>2</sub>	6.664	6.715	DETECTABLE	RECOGNIZABLE
	4.782	5.110	RECOGNIZABLE	
				1.50 ± 3.15 [degree]

Table 6. Comparison of response time for each zone.

RESPONSE TIME [msec]			
	ZONE1	ZONE2	ZONE3
DETECTABLE	0.418	0.414	0.425
	100%	99%	102%
RECOGNIZABLE	0.692	0.734	0.802
	100%	106%	116%

