

# VISUAL SEARCH STRATEGIES DURING AUTOMOBILE DRIVING

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## Abstract

*This study examined the visual search strategies during automobile driving. In an experiment, we measured eye movements when participants drove using a driving simulator. The results showed that the eye movements depended on driving road scenes. In situations where there were few objects to be attended to (e.g., at a straight road), the eye movement frequencies were smaller and the fixation durations were longer, than in situations where there are many objects (e.g., at a crosswalk). The results suggest that visual search strategies during automobile driving vary, depending on the driving road situations.*

To drive an automobile safely, we are required to perceive visual stimulus, such as pedestrians and vehicles, quickly and accurately. Since visual sensitivity generally decreases with increasing the retinal eccentricity (e.g., Millodot, 1965; Osaka, 1976), eye movements play an important role in perceiving the visual stimulus during automobile driving by capturing a peripheral stimulus on the fovea. Several studies measured eye movements during driving and found that frequencies of saccades and fixation durations decreased with increasing the number of the visual objects (Chapman & Underwood, 1998; Miura, 1992). To our knowledge, however, there were few studies examining eye movements during driving with conditions controlled experimentally (e.g., driving road situation).

The aim of the present study was to examine the eye movements during some driving road situations, such as driving near a blind corner or merging section. For this aim, we measured eye movements when participants drove using a driving simulator, and analyzed the eye movements in the context of selected driving road situations.

## Method

### *Participants*

Ten undergraduate students (mean age of 22.6 in the range of 20-24) and four volunteers (mean age of 54.75 in the range of 31-65), all males, participated in this experiment. Five of the students had practiced driving using a driving simulator for more than 10 hours before this experiment, while the others had no experience of driving using it. Prior to the experiment, the purpose and procedures were explained to the participants and their informed consents were obtained. All participants had normal or corrected-to-normal vision.

### *Apparatus and stimuli*

A driving simulator with a motion base system (HONDA Motor DS-DA1102) was used to simulate the driving work with automatic transmission. The simulator was controlled by five

networked computers, which also generated vehicle dynamics, traffic scenario and scene images of driving from the driver's point of view. The dashboard instrumentation, steering wheel, shift lever, side brake, accelerator pedal and brake pedal were positioned, similar to those in an automobile.

The visual scenes during driving were presented on a frontal screen (138 × 27 deg in width and height) and three 6.5-in. monitors located at positions of right and left side-view mirrors and a rear-view mirror of the simulator. The frontal screen was viewed binocularly from an approximately 150-cm distance. In this study, urban road and expressway courses installed in the simulator were used (see Figure 1). These courses consisted of several parts of road situations: a straight road, curving road and cross section into which dangerous events were inserted (e.g., a vehicle suddenly cut into a driver's lane). The urban road course virtually extended over 840 × 720 m, and the expressway course did over 840 × 1440 m. The texture mapping, various buildings, and objects (e.g., pedestrians and vehicles) gave the realistic appearance of the urban road and expressway.

During the experiment, participant's eye was recorded by eye movement recording system (SR Research EyeLinkII) controlled by a personal computer (Dell Dimension 3000). The system had a temporal resolution of 2 or 4 ms (sampling rate of 500 or 250 Hz), and was able to measure eye movements linearly within a range of ± 30 in horizontal axis and ± 20 deg in vertical axis, with a spatial resolution of less than 0.01 deg of visual angle (eye movements of three participants were recorded with a sampling rate of 500 Hz).

### *Procedure*

Participants were seated on the seat of the driving simulator. After the participants practiced driving on the urban road and the expressway courses (see Figure 1), an experimental session was conducted. In the experiment, the participants were instructed to drive on the driving courses safely. There was one trial for each driving course.

### *Eye Movement Recordings and Analyses*

In this study, horizontal and vertical eye movements of the participants were recorded from both the right and left eyes. Before beginning the experiment, the participants were asked to fixate on nine points presented on the monitor of the recording system to calibrate the eye

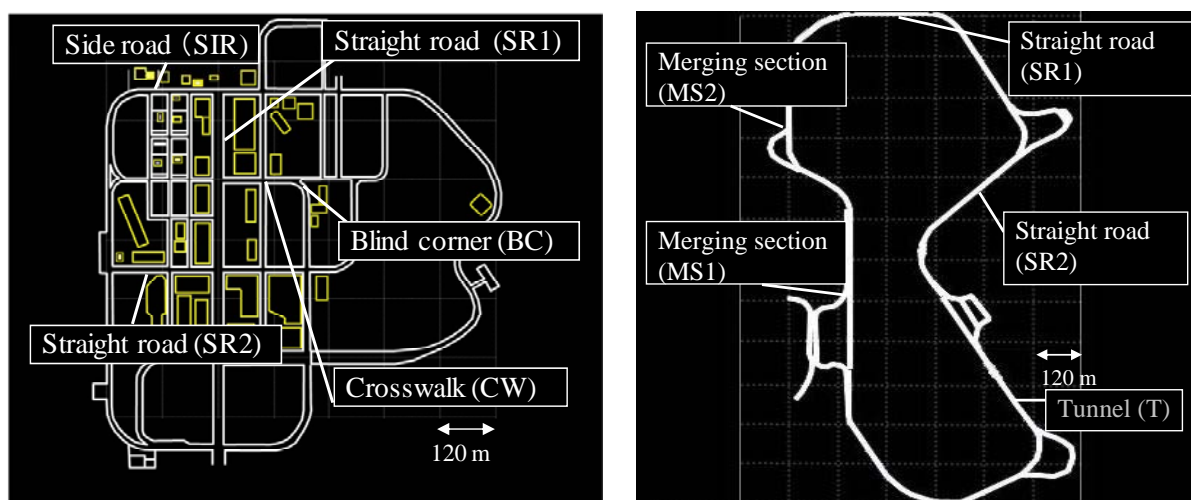


Figure1. Urban road (left panel) and expressway courses (right panel) used in this study.

tracking system. All data were stored on the computer and analyzed offline by a computer program that drew scan paths of eye movements and calculated the total distances of the eye movements and the fixation durations.

From the eye position data for each participant, we drew scan paths of the eye movements during five driving road situations (see Figure 1). Three of them (situations except for the straight road) contained a number of potentially dangerous events such as a vehicle cutting into driver's lane or a pedestrian walking across a road (an event situation). In the event situations, eye position data 2 seconds before and after the participants made saccades toward a vehicle or pedestrian to be perceived were used to draw the scan paths. The total distance of the eye movements was calculated by the differences between the eye positions. A fixation was defined as eye movements of less than 30°/sec velocity for more than 100 ms. A fixation duration was calculated by the difference in time between two successive saccades before and after the fixation, defined as eye movements of more than 30°/sec velocity.

In the straight road situations (see Figure 1), there were a few objects and there was no event. The analyses were identical to those in the event situations except for that eye position data 2 second before and after the participant's automobile reached at the middle of the straight road.

## **Results**

### *Scan Paths of Eye Movements*

Figure 2 shows representative scan paths for one participant during one event situation and straight road situation in the urban road course. For the event situation (left panel), the participant's eye moved frequently in various directions. For the straight road situation (right panel), the participant's eye positions were less variable than those at a crosswalk. Similar tendencies were observed in other event and straight road situations. Figure 3 shows representative scan paths of the same participant on the expressway course. A pattern of the results were quite similar to those in the urban road course.

### *Total Distance of Eye Movements*

Figure 4 shows mean total distance of eye movements (in degrees) during the event situations and the straight road situations in the urban road and expressway courses. As shown in the figure, in both the urban road and expressway courses the total distances of the eye movements were longer for the event situations than for the straight road situations, although there were individual differences (indicated by error bars). The total distance of the eye movements did not depend on the differences of the driving course (i.e., the urban road and expressway courses).

### *Fixation Duration*

Figure 5 shows mean fixation durations for the event and the straight road situations in the urban road and expressway courses. As shown in the figure, in both the urban road and expressway courses the mean fixation durations tended to be longer for the straight road situations than for the event situations, although there were relatively large individual differences.

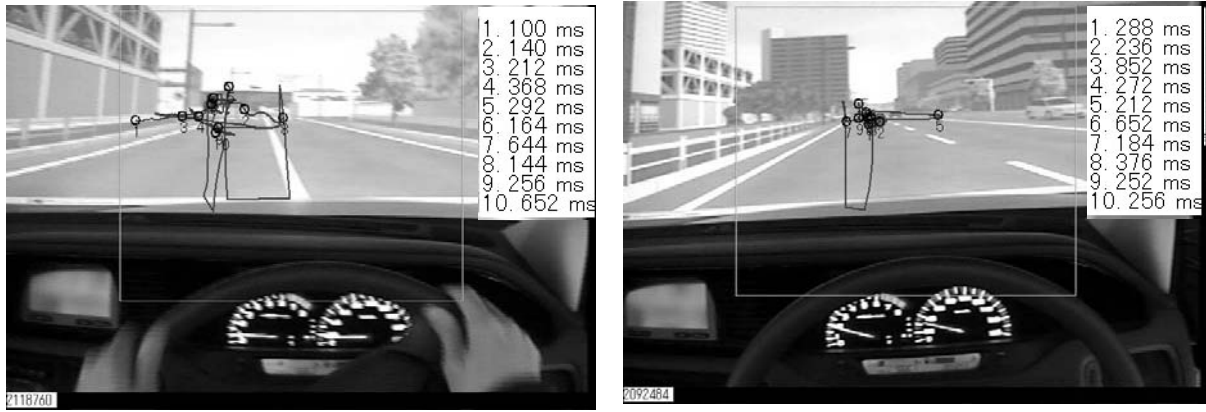


Figure 2. Representative scan paths of the eye movements of one participant (N.Y.) at the crosswalk (left panel) and at the straight road (right panel) in the urban road course. Values in the figures indicate the fixation durations for each fixation.

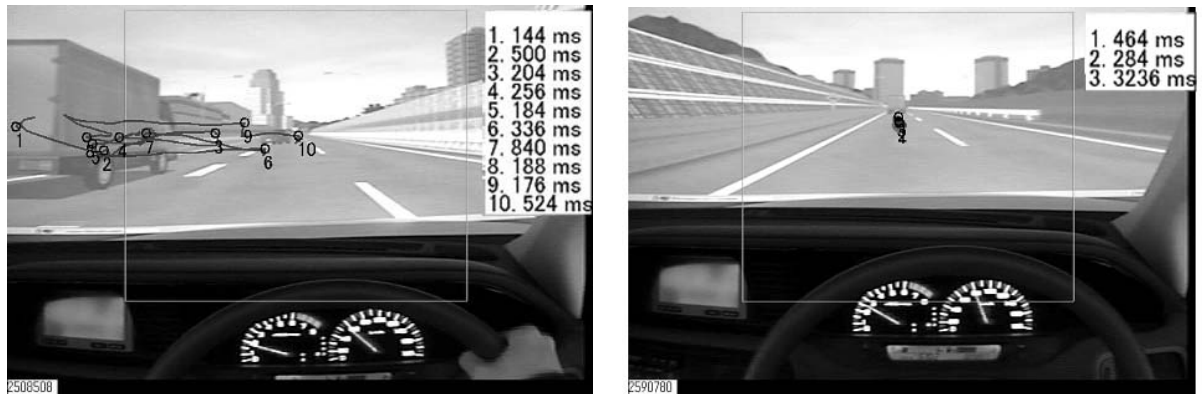


Figure 3. Representative scan paths of the eye movements of one participant (N.Y.) at the merging section situation (left panel) and at the straight road situation (right panel) in the expressway course. Values in the figures indicate the fixation durations for each fixation.

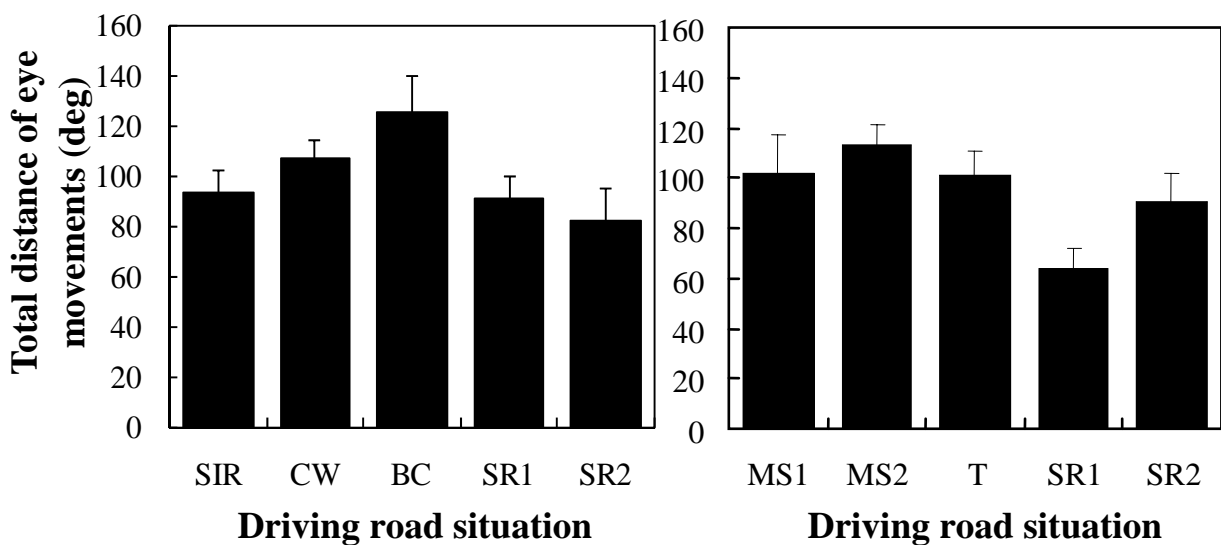


Figure 4. Mean length of the eye movements for different driving situations in the urban road (left panel) and expressway (right panel). Abbreviations of the horizontal axis correspond to those in Figure 1. Error bars indicate standard errors of the mean.

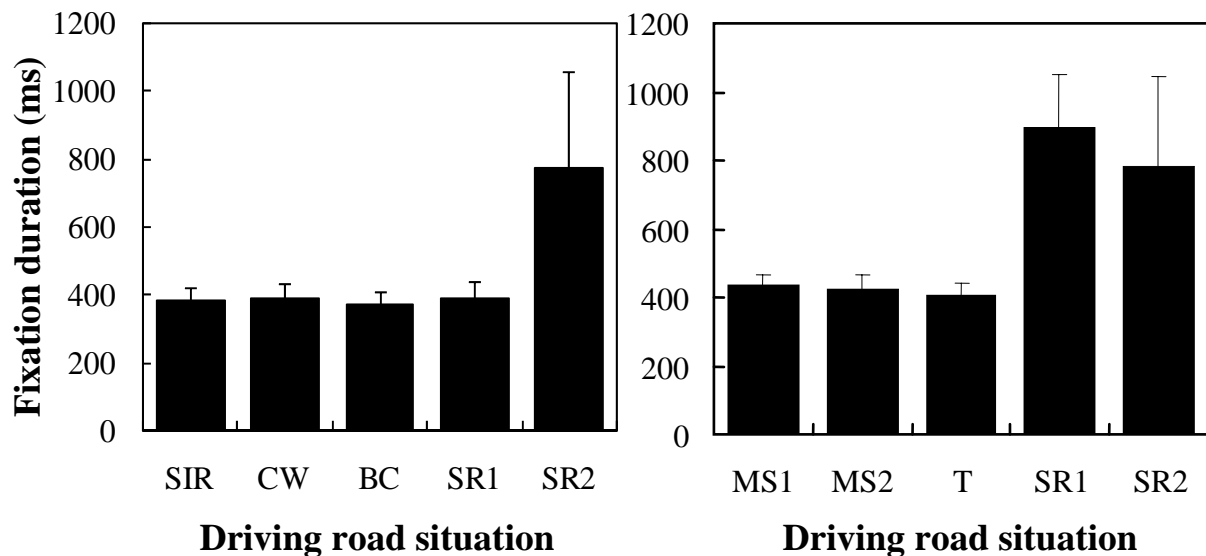


Figure 5. Mean length of the eye movements for different driving situations in the urban road (left panel) and expressway (right panel). Abbreviations of the horizontal axis correspond to those in Figure 1. Error bars indicate standard errors of the mean.

## DISCUSSION

In this study, eye movements during automobile driving were measured and analyzed in the context of selected driving road situations in order to examine visual search strategies during driving. The results of the scan paths showed that the changes of the fixation point were more frequent at the event situations, where there were many objects to be attended to (e.g., at the crosswalk situation), than at the straight road situations where there were few objects. The total distances of the eye movements and the fixation durations at the event situations were longer than those at the straight road situations in both driving courses. These results were consistent with previous studies (e.g., Miura, 1992) showing that, with increasing the number of the objects, the saccadic frequencies were higher and fixation durations were shorter, and suggest that the drivers change their visual search strategies, depending on the driving road situations.

The reason for the dependence of the visual search strategies on the driving road situations is not clear in this study. One possibility is due to anticipation skill for a potential risk. When the automobile approached at the event situations (e.g., the crosswalk), the participants may have anticipated potential dangerous events and varied their visual search strategies in order to obtain relevant information quickly and accurately. Indeed, research suggests that the visual search of drivers depends on expectancy or anticipation skills based on their experiences (Hills, 1980). Another possibility is due to the changes in a useful field of view defined as the visual field in which an observer is able to perceive visual stimuli quickly and accurately during complicated perceptual-motor tasks, such as reading and driving. When there are many objects, more resources will be needed for visual information processing and, as a result, the range of the useful field of view will be narrower. In other word, the range of the useful field of view may be traded off with the depth of the information processing of the visual objects (Miura 1992). We are now investigating possible effects of the anticipation skill of the drivers and the range of the useful field of view on the eye movements.

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