A Study of Drivers' Blind Spot in Used of Eye Tracking

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Abstract. This study employed driving simulation and eye tracking to explore the situational perception of drivers under various weather and road conditions.

This study sampled 16 subjects, all of whom were required to hold a valid driver's license. Experimentation was based on factorial design; the independent variables were weather (sunny, foggy) and road conditions (road work, pedestrians crossing the road, and balls appearing suddenly). The dependent variables included Time to First Fixation (TFF)(sec), First Fixation Duration (FFD) (sec), Total Fixation Duration (TFD) (sec), Fixation Count (FC) (frequency). Results showed that under good weather conditions, drivers are more aware of road conditions, resulting in shorter TFF with resulting higher FC and longer TFD. The influence of road conditions on TFF, FFD, TFD and FC varied according to the situation. Overall, our results demonstrated the feasibility of using eye trackers to explore the situational perception of drivers.

Keywords: situational perception, eye tracker, gaze, weather.

1 Introduction

Poor driving is the cause of many types of traffic incident, and as a result, many countries are actively developing electronic alert systems to reduce the risk of accidents. However, few studies have examined how drivers visually track objects in their line of sight. The results of such an investigation could help the developers of road safety systems to enhance the alertness of drivers and overcome the problem of blind spots.

Actual vehicle testing can be difficult and dangerous; therefore, this study used a driving simulator and eye tracker to explore the situational perception of drivers under various weather and road conditions. Our aim was to understand how drivers visually react to road conditions and traffic incidents, and identify the strategies they employ in response, in order to elucidate the relationship between visual response and road safety.

Previous studies on driving simulators have discussed the mental workload (Cantin, Lavallière, Simoneau, & Teasdale, 2009), the function of road signs (Horberry, Anderson, & Regan, 2006), the impact of visual position on driving (Wittmann, Kiss, Gugg, Steffen, Fink, Pöppel, & Kamiya, 2006), collision warning time, driving distractions, and reactions to rear-ending incidents (Lee, McGehee, Brown, & Reyes, 2002).

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Perception is the endless cycle of interaction between people and their surroundings. Endsley (1988) proposed that a pilot's perception can be defined as an inner awareness of his/her surroundings, including control panel signals, the field of vision, and personal factors, such as emotions, personal capacity, training, experience, goals, and workload management. Situational perception is extremely important in environments that require staff to be highly aware of their surroundings, such as aviation, nuclear power plants, medical facilities management, military maneuvers, and driving.

Increasingly sophisticated simulation methods are being developed in many fields, and this is particularly true in the case of driving simulators. These methods eliminate many of the dangers posed by the actual operation of vehicles and helps to reduce experimentation costs. Simulation also enables researchers to carefully set and then repeatedly test the parameters they are examining, such as climate, terrain, and the environment, thereby enhancing the efficiency of experimentation. The movement of the eyes is a direct reflection of human cognitive processes. For the purposes of this study, the key indicators of eye movement were Fixation Duration and Number of fixations.

2 Methodology

2.1 Subjects

The subjects in this study were 16 undergraduate and graduate students, all of whom possessed a driver's license and had corrected visual acuity of at least 1.0. The subjects were required to provide basic information such as age, height, weight, birthdate and driving experience. The average subject was 22 years of age with two years of driving experience over distance of 1,500 km.

2.2 Experimentation

Driving Simulator. This study simulated true-to-life road conditions, based on a simulator comprising a host computer (including control screen), projector (including projection screen) and adjustable seat (as shown in Fig. 1).

Fig. 1. Driving simulator

Eye Tracker. This study used the Tobii X2-60 eye tracking system, which includes a camera and infrared sensor. Infrared light is shone onto the eyes, such that the position of the pupil is determined by differentiating between the low reflectivity of the pupil and the high reflectivity of the iris.

Experimental Environment. The lab was 2.5m long and 2.5m wide, with the temperature set at 26±2 ℃, allowing subjects to complete the exercises in a comfortable environment.

Simulated Scenario. The objective of this experiment was to test the reactions of drivers under various weather and road conditions. The weather in the simulations was sunny or foggy (Fig. 2.4) and road conditions included road work, pedestrians crossing, or a ball bouncing into the street (Fig. 2).

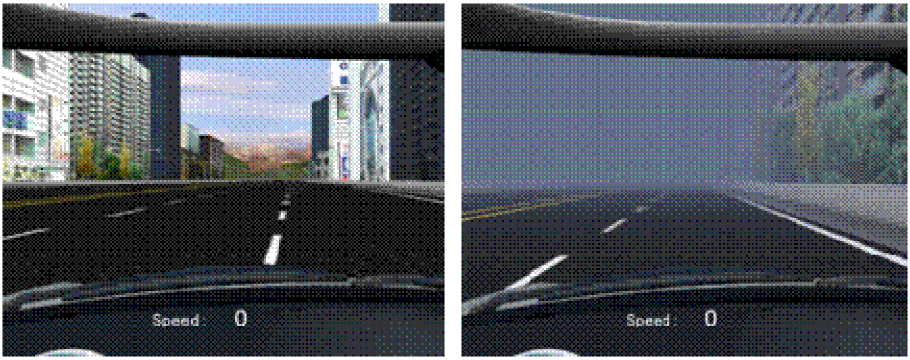

Fig. 2. Weather: Sunny or foggy

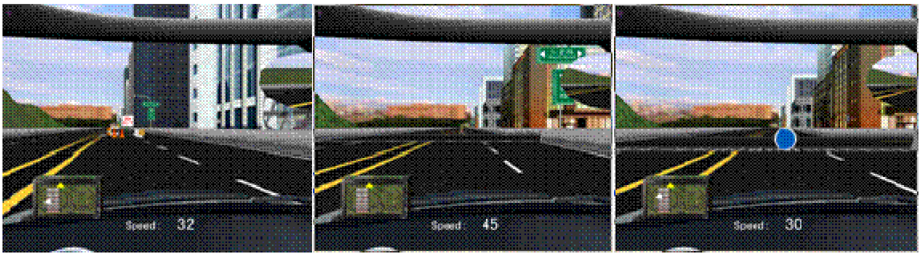

Fig. 3. Road work, pedestrians crossing, and a ball bouncing into the street

2.3 Experiment Design

Our analysis was based on a factorial design, including the independent variables of weather (sunny, foggy) and road conditions (road works, pedestrians, or a ball appearing). To prevent subjects from being influenced by their familiarity with routes, we designed two different routes of similar length and number of turns, to match the weather simulation (sunny, foggy). Each driving scenario occurred twice. To prevent learning effects from influencing experiment parameters, the weather conditions were randomly selected.The dependent variables were Time to First Fixation (TFF)(sec), First Fixation Duration (FFD) (sec), Total Fixation Duration (TFD) (sec), Fixation Count (FC) (frequency).

2.4 Experimental Process

The experiment was divided into two phases: Preparation and Formal Experimentation.

1. Preparation:
   (a) Room temperature was set at 26±2 ℃
   (b) Adjustment and testing of driving simulator
   (c) Calibration of eye tracker
   (d) Explanation of experiment guidelines
   (e) Teaching subjects how to operate the driving simulator
2. Formal Experimentation
   The experiment was meant to test the reactions of drivers to unexpected road conditions in two types of weather. The 16 subjects were randomly categorized into two groups:
   (a) Sunny – Route 1; Foggy – Route 2
   (b) Foggy – Route 1; Sunny – Route 2. Each subject completed two rounds of simulation driving.

3 Results

We first conducted ANOVA of TFF, FFD, TFD and FC, the results of which are presented in Table 1:

Table 1. ANOVA results

Dependent variables / Factor	TFF	FFD	TFD	FC
Climate			*	*
Road conditions	**	**	***	**
Climate*road conditions			*	

*:p<0.05； **p<0.01; ***p<0.001

Different road conditions, as well as the combined effect of weather with road conditions, significantly affected TFF. However, weather conditions alone did not have a significant influence. As illustrated in Fig. 4, TFF increased in foggy weather, particularly when road work was being performed, mainly because road work can be seen from much further than one can see pedestrians or bouncing balls, such that subjects became aware of road work more gradually as they approach. Foggy weather conditions lengthened TFF. Compared to road work, pedestrians and bouncing were more unexpected, attention-grabbing events, and therefore the effects of weather conditions were less pronounced.

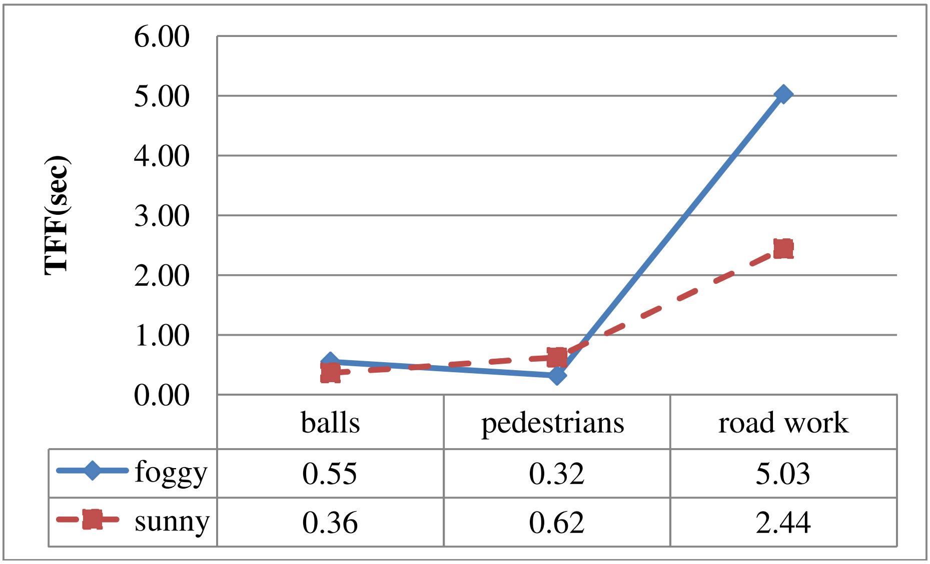

Fig. 4. Influence of weather – road conditions on TFF

Table 1 shows that only road conditions affected FFD. According to Fig. 5, FFD was longest in the case of road works (0.23 sec), with no significant difference in other scenarios (0.09 sec vs 0.11 sec). In addition, FFD was largely unaffected by weather (0.96 sec in sunny conditions and 0.82 sec in foggy conditions).

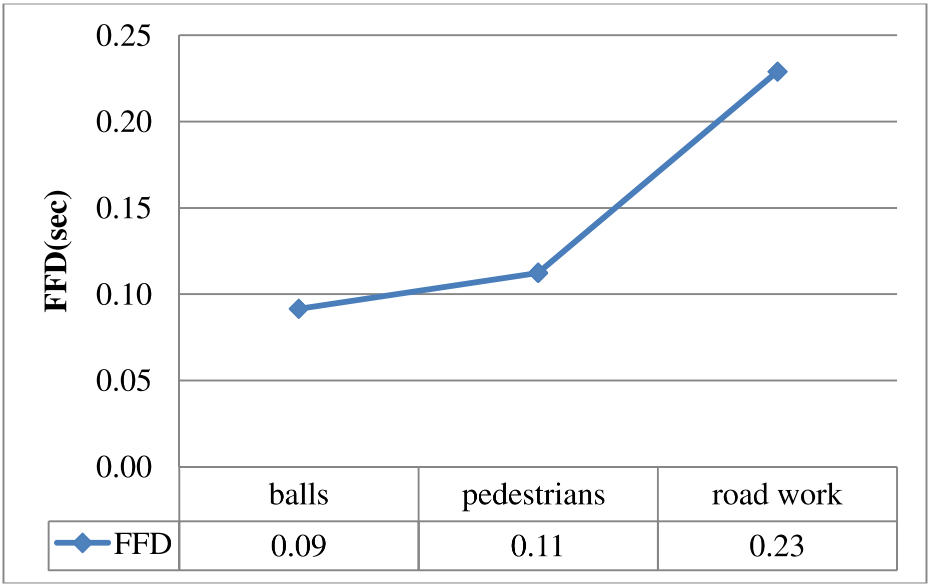

Fig. 5. Influence of road conditions on FFD

As shown in Table 1, weather and road conditions significantly affected FC. From Fig. 6 it is evident that FC was higher in sunny weather than in foggy conditions (2.8 vs. 5.5). FC was similar with regard to pedestrians (2.8) and bouncing balls (2.7), but higher when drivers encountered road works (6.7).

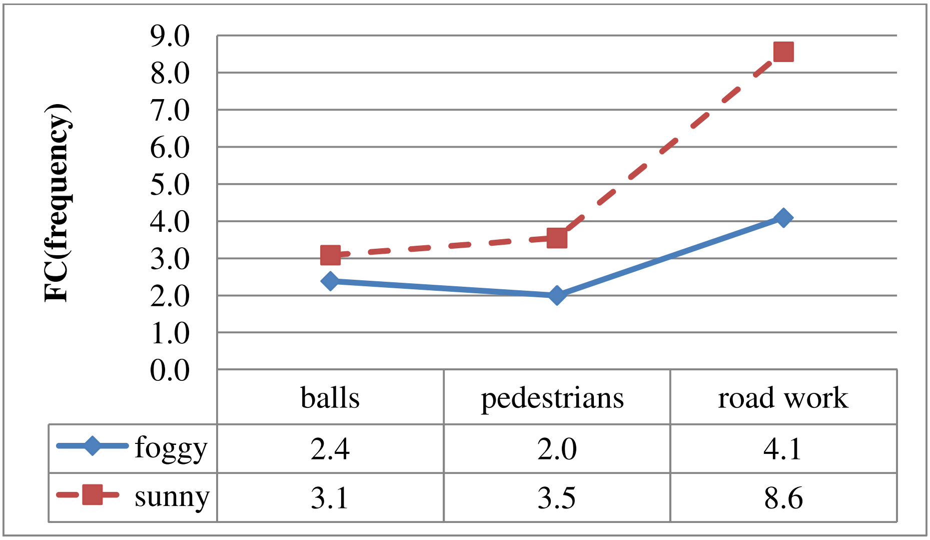

Fig. 6. Influence of weather and road conditions on FC

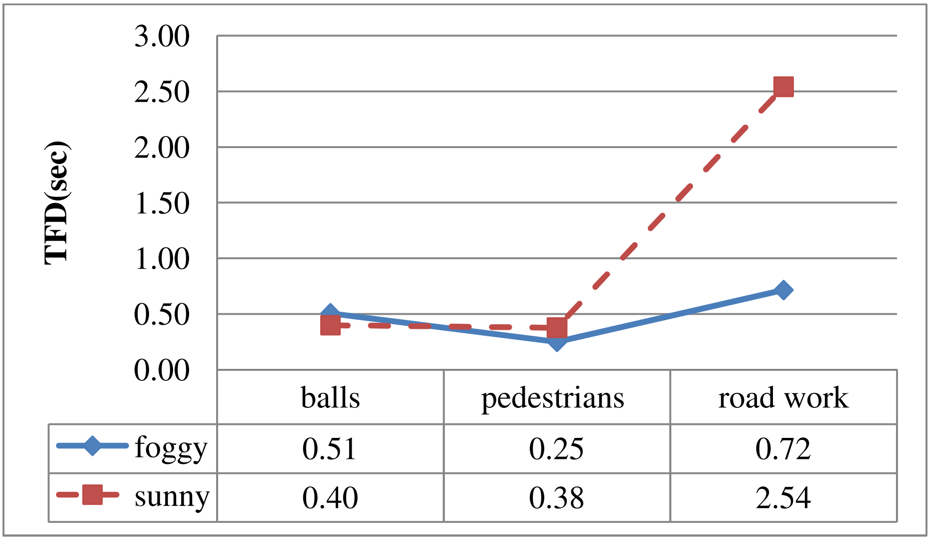

Fig. 7. Influence of weather and road conditions on TFD

Finally, TFD was significantly influenced by all major factors and their combined effects. Figure 7 illustrates the combined influence of weather and road conditions on TFD. Regardless of weather conditions, TFD did not vary considerably when pedestrians or bouncing balls appeared but was extended when road work was encountered. In sunny weather, the TFD for road work was longer.

Time to First Fixation (TFF) was shorter under sunny conditions than under foggy conditions, indicating that in good weather drivers are quicker to spot objects, resulting in higher FC and longer TFD, which in turn reduces the chance of accidents. Weather conditions did not significantly affect FFD. This means that once an object has been spotted by the driver, weather conditions are not a significant factor in FFD (sunny- 0.96 sec; foggy – 0.82 sec).

Road work tends to be static in nature, compared to dynamic subjects such as pedestrians and bouncing balls. Subjects were shown to glance at road work more frequently and for longer periods, perhaps because these distractions were is in the drivers' line of sight for a longer period of time, prompting drivers to pay more attention and thereby avoid collisions.

4 Conclusions and Recommendations

This study employed driving simulation and eye tracking to explore the situational perception of drivers under various weather and road conditions. Our objective was to understand how eye trackers could be applied to improve road safety.

Results show that under good weather conditions, drivers tend to be more aware of road conditions, resulting in shorter TFF, which leads to higher FC and longer TFD, thereby reducing the risk of accident. The influence of road conditions on TFF, FFD, TFD and FC varied according to the situation.

The three scenarios simulated in this study included road work observable from a distance, pedestrians crossing well ahead of the vehicle, and balls suddenly bouncing into the street at a very close range. Drivers took note of construction barriers from a distance and made sure that the width of the road was sufficient to allow them to pass. Drivers noticed pedestrians as they appeared and noted speed limit markers. Balls bouncing into the street meant that drivers concentrated on dodging these objects and were attentive to their driving speed. A schematic trajectory is presented below:

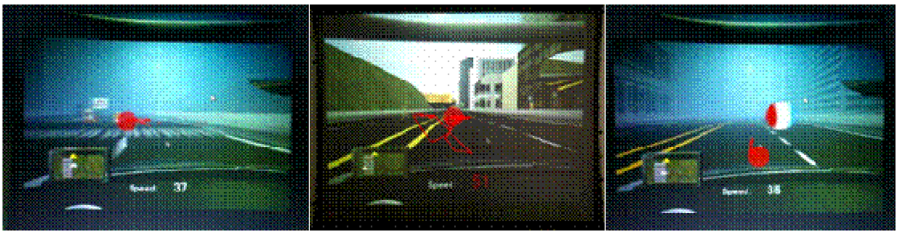

Fig. 8. Eye tracking for different road conditions

This study demonstrated the efficacy of eye trackers in exploring the situational perception of drivers. Our results a valuable reference for the development of systems used to monitor drivers and/or alert them of dangers. Nonetheless, eye trackers must be used carefully because many factors, such as wearing glasses, blinking, or external lighting, can interfere with their use. Simulated driving environments could also be designed to include more diverse scenarios and parameters to facilitate more in-depth study.

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