Simulation Analysis on Driving Behavior during Traffic Sign Recognition

Lishan Sun
Key Laboratory of Traffic Engineering, Beijing University of Technology
Beijing, 100124, P.R.China

Liya Yao*
School of Mechanical and Vehicular Engineering, Beijing Institute of Technology
Beijing, 100081, P.R.China

Jian Rong
Key Laboratory of Traffic Engineering, Beijing University of Technology
Beijing, 100124, P.R.China

Jinyan Lu
Department of Civil and Environmental Engineering, Florida International University
Florida, 33174, USA

Bohua Liu, Shuwei Wang
Key Laboratory of Traffic Engineering, Beijing University of Technology
Beijing, 100124, P.R.China

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Abstract

The traffic signs transfer trip information to drivers through vectors like words, graphs and numbers. Traffic sign with excessive information often makes the drivers have no time to read and understand, leading to risky driving. It is still a problem of how to clarify the relationship between traffic sign recognition and risky driving behavior. This paper presents a study that is reflective of such an effort. Twenty volunteers participated in the dynamic visual recognition experiment in driving simulator, and the data of several key indicators are obtained, including visual cognition time, vehicle acceleration and the offset distance from middle lane, etc. Correlations between each indicator above are discussed in terms of risky driving. Research findings directly show that drivers' behavior changes a lot during their traffic sign recognition.

Keywords: Road safety, Driving behavior, Cognitive task, Traffic sign.

1. Introduction

Traffic accidents kill thousands of people every year. Whenever a driver takes his eyes off the road, even for a few seconds, he put his life and others lives at risk. The traffic signs transfer trip information to drivers through vectors like words, graphs and numbers, which contribute a lot to the distraction of driver during their recognition.

According to Stutts's research, 8.3% drivers who were involved in the official accident in USA (1995-1999) indicated that they were distracted by foreign objects (including signs), 5.4% said that they "looked but did not see" [1]. Stutts's research strengthen the argument that traffic sign with

* Corresponding author: yaoliya@bit.edu.cn

excessive information will affect driving behavior, and leading to risky driving.

The earliest studies in 1960s on traffic signs were related to impact assessment and cost estimation, etc[2]. Since 1980s, researchers started to focus on the driving behavior during traffic sign recognition by measuring their characteristics, reaction time, and sign recall[3-4].

Effect of traffic signs on drivers has been a topic of considerable interest to researchers during the past few years. They covered a wide range of aspect related to recognition, comprehension, distraction, response, and recollection[5-8]. Several studies have been carried out in discussing the relationships between stress, strain, task and driving performance[9-11].

Based on the above-mentioned researches, Bendak assessed the effects of roadside advertising signs on driving performance on a simulator[12]. Five performance indicators, including drifting from lane, recklessly crossing dangerous intersections, number of tailgating times, over-speeding and turning or changing lanes without signaling, drop consistently with the presence of advertising signs in the experiment, which indicate that the advertisement signs create a potential risk factor by distracting drivers off their original task which is driving.

Although effect of traffic signs on drivers has been widely discussed in previously researches, two important questions remain to be answered: What indicators should be selected to quantitatively reflect the correlation between recognition of traffic sign and risky driving? Furthermore, how to determine the threshold on the traffic signs with Chinese character from safety driving aspect?

This dissertation does some in-depth study of risky driving during traffic sign recognition on the driving simulator. The remainder of the paper is structured as follows. Section 2 introduces the basic methods of the experiment. Section 3 presents the indicators relate with the risky driving during traffic sign recognition and the analysis result, followed by the conclusions presented in Section 4.

2. Methods

2.1. *Participants*

Twenty gender-balanced participants, aged between 22 and 32, holders of a valid driving license for more than three years, were recruited in this study. All participants' vision was normal and they were required to drive for more than 30 minutes in the simulator before the test. These conditions above for inclusion in the experiment were put in order to minimize the difference between the simulation and real scene.

2.2. *Simulate scene*

One 7 km long two way lane road with traffic signs was simulated as shown in Figure 1. The lane, marking and traffic sign were all designed according to the Road Traffic Sign and Marking Standard of China (GB 5768-2009)[13]. More than 800 meters were set between each traffic sign to make sure the driver has enough time to adjust themselves before the following recognition. 4 to 8 unfamiliar location names were selected to appear on the traffic signs to ensure the authenticity of simulation test.

Fig.1. Simulated driving environment used in this experiment

2.3. *Driving simulator*

Driving simulator is among the most important applications of virtual reality technology. It is widely considered as valid devices for driving behavior analysis because of its low cost, safe and other significant advantages.

The driving simulator used in this study consists of four large screens and two rearview screens that

provide a 270° virtual driving environment, as shown in Fig 2. Participants were required to recognize the traffic signs at 80km/h, 100km/h and 120km/h speeds separately, during which their fixation duration, visual cognition time, acceleration change, and driving offset, etc were recorded.

Fig.2. Driving simulator system used in this experiment

2.4. *Eye tracker*

Eye tracker was used in this study to obtain the eye movement data during the drivers' driving in the simulator, especially when they undertake the task of identifying signs.

Fig.3. A screenshot from the eye tracker system

2.5. *Experimental procedure*

The whole experimental procedure can be separated into three parts as follow:

- Participants were required to read the purpose and attentions of the experiment, then 30mins were given to participants in getting familiar with the operation skills of the simulator. These steps can ensure that the participants were at their best mental state, and to obtain more accurate data.
- Participants were instructed to seat in the simulator and the eye movement system was adjusted to their heads. They were required to perform their drive task at 80 km/h, 100 km/h and 120km/h, and to identify the target information on the traffic signs appeared in the simulated scene randomly.
- The visual cognition time, distribution of visual fixation, changes of vehicle acceleration, and offset of vehicle track will be recorded by either driving simulator or eye tracker.

3. Data Collection and Analysis

3.1. *Experimental data*

This study investigated how participants responded to traffic signs with different information during the simulated driving session. There are two main issues related to variable selection for driving performance analysis. The first one is the theoretical basis for variable selection. Variable selection for this model is based on other relevant studies related to driving behavior[14-18].

The other issue is the practical basis for variables select. This study is trying to analyze the driving performance during recognition from driver's perceptual and reaction aspects. Changes in driving performance, usually expressed as the driving behavior changes and the vehicle speed and trace changes. Indicators selected in this analysis should be defined to reflect most of the driver's performance during recognition as above.

Based on the two main issues considered above, the driving performance is evaluated by the fixation time, visual cognition time, acceleration, and driving offset.

Specify of these four indicators are as follows.

Fixation time was measured from the time when the driver found the traffic sign to the time when driver identified out the necessary information and took his eye off from the traffic sign.

Visual cognition time refers to the time that driver used on the information indentify, which is usually shorter than the fixation duration.

Acceleration refers to the change of velocity, which mainly measures how fast or slow the vehicle speeds up or down during the traffic sign recognition. Velocity change can be positive, negative or zero. A "0" velocity change means that the driver performed the recognition task at a constant speed.

Driving offset refers to the distance change of the vehicle in the forward direction during the traffic sign recognition. Acceleration and driving offset are both very important in measuring the impact of traffic sign recognition on driving behavior.

In the following sections, the experiment data were discussed to estimate the relationship among the information content on traffic signs, driving speed, velocity change, and other performance indicators. Tables 1 to 4 provide a quick view of the outputs from experiment. All data were coded and analyzed using statistical software called Statistical Package for Social Sciences (SPSS, 1996).

Table 1 Visual cognition time on different information content with changed speeds

Visual cognition time (s)	Information content				
Driving speed (km/h)	4	5	6	7	8
80	1 .490	1.753	2.028	2.104	2.486
100	1.356	1.602	1.796	1.734	1.906
120	1.433	1.233	1.670	1.871	1.688

Table 2 Fixation duration on different information content with changed speeds

Fixation duration (s)	Information content				
Driving speed (km/h)	4	5	6	7	8
80	3.224	3.930	5.236	6.862	7.581
100	3.152	3.787	4.889	5.591	6.543
120	2.245	2.989	4.113	4.467	4.967

Table 3 Acceleration on different information content with changed speeds

Acceleration (m^2/s)	Information content				
Driving speed (km/h)	4	5	6	7	8
80	0.1735	0.2525	0.1740	0.2930	0.3147
100	0.3277	0.3146	0.1881	0.3221	0.3660
120	0.3882	0.3525	0.3227	0.5571	0.4033

Table 4 Driving offset on different information content with changed speeds

Driving offset (m)	Information content				
Driving speed(km/h)	4	5	6	7	8
80	0.120	0.202	0.247	0.266	0.264
100	0.244	0.169	0.286	0.193	0.252
120	0.256	0.277	0.249	0.437	0.292

3.2. *Validation check*

Analysis results obtained for the driving behavior during traffic sign recognition, depending on the six indicators mentioned above. Validity and correlation analysis were carried out in order to check whether the indicators value can be used for subsequent analysis.

P-P test results show that the experiment data of the six indicators follow a normal distribution (Fig.4). In addition, Table 5 shows the good correlation between

each indicator, in which the Pearson correlation factors are all higher than 0.75. These feasibility analyses confirm the validity of the indicators selected in this experiment.

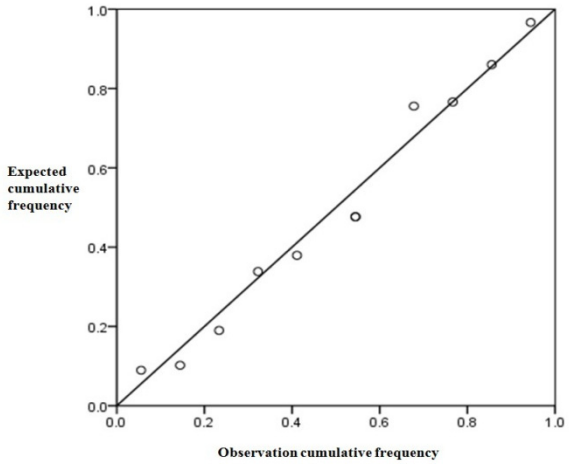

Fig.4. Normal distribution P-P test

Table 5 Pearson correlation between each indicator

Pearson Correlation	Information content	Fixation time (s)	Visual cognition time (s)	Acceleration (m^2/s)	Changes of offset distance (m)
Information content	1	0.991	0.986	0.776	0.906
Fixation time (s)	0.991	1	0.985	0.773	0.882
Visual cognition time (s)	0.986	0.985	1	0.718	0.891
Acceleration(m^2/s)	0.776	0.773	0.718	1	0.641
Changes of offset distance (m)	0.906	0.882	0.891	0.641	1

3.3. *Analysis result*

Based on the validation check of indicator data, safety feature of driving behaviors during traffic sign recognition were discussed according to the changes of performance indicators.

Figure 5 shows, when driving speed increased from 80 km / h to 120 km / h, the visual cognition time of traffic sign with the same amount of information gradually reduced. This is contrary a lot to the common sense that the higher speed the more difficult to perform recognition. In order to find out the reason, a mental status survey on participants was carried out after the simulation test. Result show that driver will be more concentrate on recognition under high driving speeds. This should be the reason why drivers could identify the necessary information on traffic sign in a relatively short time.

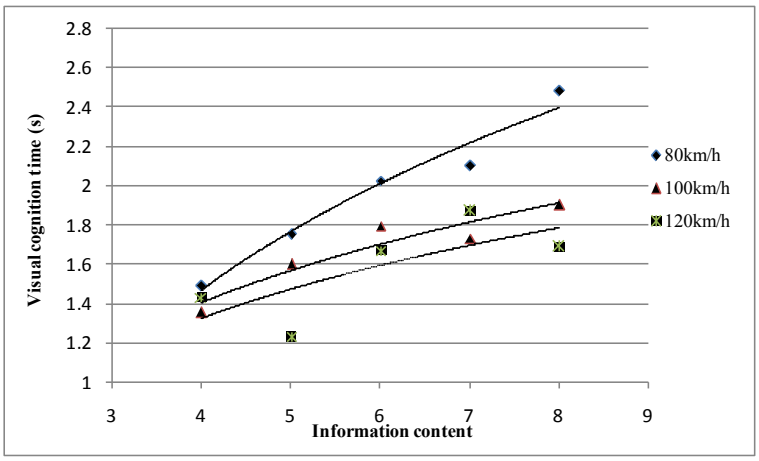

Fig.5. Correlation between visual cognition time and information content under different driving speeds

Figure 6 and 7 describe the changes in vehicle acceleration and driving offset distance in the visual recognition process. The figures show increasing trend of acceleration and driving offset when information content increases under same speed. Similarly, under same information content, with drive speed increasing, the two indicators: acceleration change and track offset distance, also show increasing trends.

There are two points worthy to be mentioned. Firstly, under the speed of 120 km/h, the acceleration change and track offset data show obvious abnormalities during driver's recognition process on traffic signs with 7 information contents. For example, the acceleration change under 7 information contents increases by about 50% compared with other amount of information. Unexpectedly, the acceleration change and track offset data of an even greater amount of information eight maintained consistency with that of four, five and six. Combined with a questionnaire on participants, traffic sign with seven information contents was considered to be overloaded. Most drivers have to take aggressive driving behavior such as deceleration in order to obtain the necessary information they want, which leading to a higher vehicle offset. For information content more than seven, the driver will be perceived that all the information can't be identified within a limited time. They have to give up some of the information, and usually do not take aggressive driving behavior. This also shows that seven should be the upper limit of information content in a separate traffic sign.

Secondly, according to figure 7, when the speed increases from 80km/h to 100km/h, tracking offset of the vehicle show reduction in average. The main reason is driver will be more focused in order to complete the identification process when their speed increased to 100km/h. Differently, the increasing trend at 120km/h should be a true reflection of the exceed recognize burden on driving behavior.

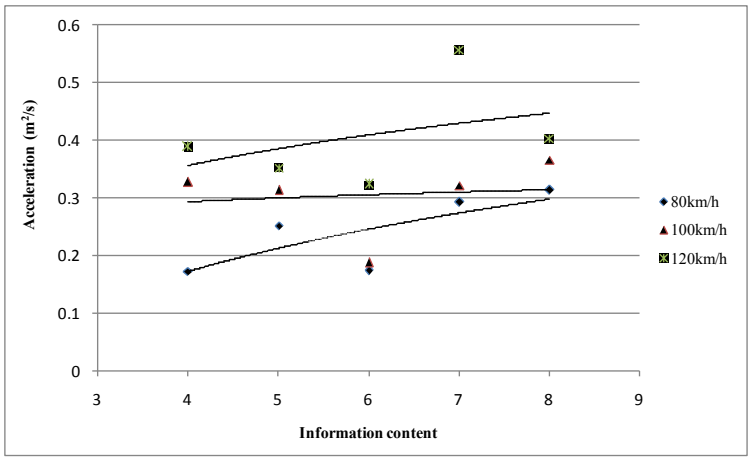

Fig.6. Correlation between Acceleration and information content under different driving speeds

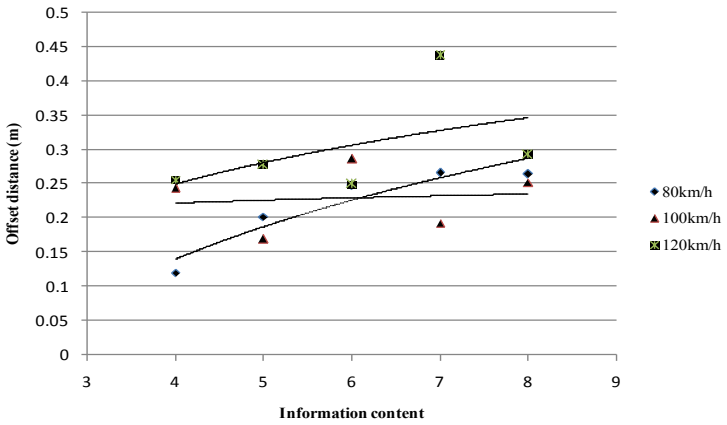

Fig.7. Correlation between driving offset and information content under different driving speeds

Figure 8 shows, with the increase of the information content on traffic sign, driver's fixation time increased more significantly than the visual cognition time. The visual cognition time remains approximately constant even the information content is eight. This result confirmed that the amount of information on traffic sign should be strictly limited, in order to make sure the driver can identify the necessary information in a very short time.

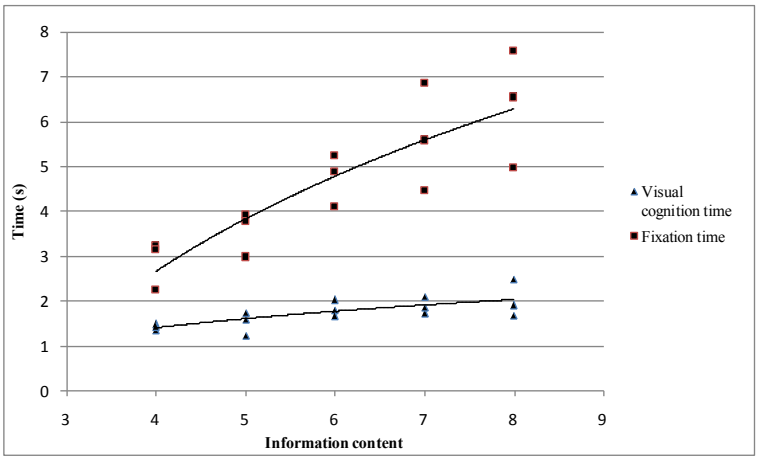

Fig.8. Correlation between cognition time and fixation time under different information content

4. Conclusions

Driving behavior has become an extremely important issue in enhancing the overall performance of traffic safety. In response to the absence of safety analysis on risky driving during driver's traffic sign recognition, this paper presented a factor analysis based on a dynamic simulation test

According to the data analysis of the driving simulation experiment, correlations between the acceleration, driving offset, visual cognition time, fixation time, etc, were discussed from the driving safety aspect. The main conclusions are as follows:

- Driving behavior indicators, such as cognition time, acceleration changes, track offset distance, show strong correlation with the traffic sign recognition process.
- With the increase of information content on traffic sign, the fixation time, acceleration and offset distance, etc, also show increasing trend in average accordingly. The more information contents on the traffic sign, the higher risky in driving. Seven should be the upper limit of information content in a separate traffic sign.
- Driving speed show significant effect on fixation time, acceleration and track offset while driver has to perform their recognition. Therefore, it is necessary to remind the drivers to slow down before the traffic signs with excessive information.

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