

## *Original Paper*

# Effects of In-vehicle Information on Driver Blink Characteristics and Workload

Ling WU<sup>1\*</sup>, Weihua ZHAO<sup>1</sup>, Tong ZHU<sup>2</sup> & Haoxue LIU<sup>2</sup>

<sup>1</sup> School of Vehicle Engineering, Xi'an Aeronautical University, Xi'an, 710077, Shaanxi, China

<sup>2</sup> Key Laboratory for Automotive Transportation Safety Enhancement Technology of the Ministry of Communication, Chang'an University, Xi'an, 710064, Shaanxi, China

\* LING Wu, School of Vehicle Engineering, Xi'an Aeronautical University, Xi'an, 710077, Shaanxi, China

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### **Abstract**

*A real-vehicle experiment was carried out to study the effects of in-vehicle information on driver workload, during which data of the driver blink duration and frequency were collected to check for discrepancies among drivers with and without vehicle navigation usage. In the meanwhile, the blink characteristics of drivers with vehicle navigation device mounted at three different positions were explored through image prompt or image & sound multi-channel simultaneous prompt. Experimental results showed that when the data of blink with a duration of 0-200ms was distributed at a 10ms interval, the driver blink count distribution curve shows obvious bimodal characteristics. The peak of blink with 50-60ms duration was lower than that with 10-20ms duration when vehicle navigation was not used, and higher when vehicle navigation was used. The difference between medium and long blinks was not significant when the navigation device was mounted at different positions, yet the short blinks showed a significant difference. The peaks of blink count without voice navigation were all greater than those with voice navigation. In particular, without voice navigation, the short blinks increased obviously, and the medium blinks increased relatively, but the long blinks remained almost unchanged. The above results indicate that the driver workload was greater when using vehicle navigation. When the navigation device is installed in position B, the driver workload reaches the minimum. Using voice navigation could reduce driver workload.*

### **Keywords**

*Traffic psychology, Driver, In-vehicle information, Blink, Workload*

## 1. Introduction

Driving workload is an important factor affecting driving performance. As intelligent transportation systems have been developing rapidly in recent years, in-vehicle information system (IVIS) (Benedetto et al., 2011) has been widely used to provide drivers with entertainment, route guidance, and real-time road conditions, even taxi order and payment information (Gonçalves, Rossetti, & Olaverri-Monreal, 2012). Convenient as it is, IVIS backfires by leading to an unbalanced distribution of driver's psychological resources (Jin et al., 2014) and increased workload, which makes it one of the major reasons causing traffic accidents (Yang et al., 2012). Therefore, it is necessary to measure and analyze the driver workload when using IVIS.

To this end, scholars have begun in recent years to study the measurement methods. Jin et al. (2014) summarized relative methods. O'Donnell et al. (1986) outlined four categories, namely main task performance method, dual-task method, subjective evaluation method, and physiological parameter method. The subjective evaluation method cannot evaluate driver performance in real time (He et al., 2012). The main task performance method and the dual-task method are difficult to deploy in a real driving environment (Chen, 2009). The previous drive workload evaluation is constrained to indoor experiments (Ma et al., 2014) or virtual environment (Bedziouk, Golikov, & Kostin, 2004). By contrast, in the case of real driving, acquiring driver's physiological indicators and analyze the change of them is closer to reflect the real driver situations.

In-vehicle information exerts an influence on driver instantly and subtly. Therefore, it is necessary to select highly sensitive physiological indicators to reflect the change of driving workload. Mostly focused on indicators such as gaze duration and gaze count, previous studies probed in matters such as the time a driver looked away from the front view (Ma et al., 2013), or the impact of sub-task interference on a driver (Li et al., 2010). The problem lied in that these indicators were used to characterize the scope and amount of information acquisition, rather than the driving workload. Attention was scarce on the impact of in-vehicle information on driving workload. In view of that status quo, the study selected the indicators of blink duration and blink frequency for in-depth analysis on driving workload, but more accurately and comprehensively. Blink has been proven as an important indicator of a driver's psychological status. High blink frequency usually indicates high tension and anxiety level (Lu, 2009; Tang, Cheng, & Fang, 2013; Hancock, Lesch, & Simmons, 2003). Benedetto et al. (2011) found that blink duration was a sensitive indicator for driving workload evaluation. Furthermore, the number of short blinks can better reflect the consumption of a driver's attention resources.

In summary, only a few studies have been conducted on the relationship between in-vehicle information and driver workload, even fewer based on a real driving experiment. Thus, a real-vehicle experiment was carried out on urban driveways and with common in-vehicle navigation system applied as an information server, so as to address the problem. Data on the drivers' blink duration and frequency were collected. The differences in the blink characteristics of the driver in various situations

were drawn out. The variation law of the driving workload, reflected by the blink indicators, was discussed. This study is of critical theoretical and application significance for further revelation of the driver information process model and for optimization of the human-machine-environment system.

## **2. Real-vehicle Road Experiment**

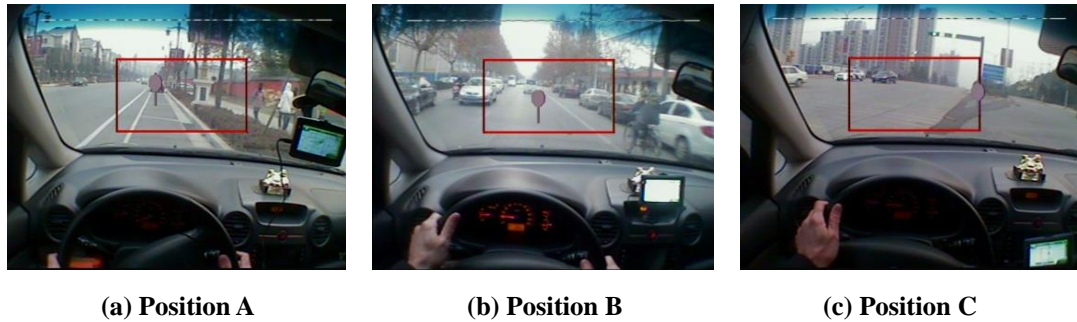
### *2.1 Experimental Scheme*

Twelve drivers (8 males, 4 females, average age of 31.5 years old, average driving experience of 3.8 years) of different occupations, ages, genders, and driving ages were included. All of the 12 participants had obtained a driving license, and their visual acuity or corrected visual acuity was in line with relevant requirements. EyeLink II eye tracker manufactured by SR Research, Canada, was used to measure the driver's eye movement parameters. The 2007 KIA Carens, equipped with Newman S480 portable touch-screen car navigator, was the experimental vehicle. The experiment was carried out on four urban expressway sections in sunny weather. The participants were tested in the same period from 15 o'clock to 16:30 (which is a non-traffic peak period) on different days.

### *2.2 Experimental Design*

Variables in the experiment included: with or without in-vehicle information service, equipment mounting position, and information prompt methods. Other factors were considered as interference. The experiment consisted of 9 stages, as shown in Table 1. The experiment applied intra-group comparison. Each participant was asked to complete all the 9 stages. The purpose of stage 1 was to familiarize the drivers with the vehicle and the experimental environment. The following 7 stages were the main parts of the experiment. Stage 9 was a recovery stage aimed to compare with stage 1 to check for any significant differences in blink data of drivers before and after the experiment, thus eventually verifying the experiment validity.

In stage 2, none-in-vehicle information data was collected. In stage 3-8, data under different mounting positions and information prompt modes were collected, respectively. There was no standard for the mounting position of the navigation device by the time of the experiment. Based on common driving habits and expert opinions, three popular mounting positions were set as experimental variables. The mounting positions included: the middle of the front windshield, above the center stack, and below the center stack (i.e., positions A, B, and C). The three positions were vertically aligned, as shown in Fig.1. The drivers were informed of the departure and destination only. The route from departure to the destination was determined by the car navigation. There were two ways of navigation information prompt: by image only, and by image plus voice. Respectively the two ways represented the two workload modes, i.e., workload generated by visual subtask, and workload generated by auditory subtask.



**Figure 1. Three Mounting Positions of the Portable Navigation Device**

**Table 1. Experimentation Scheme and Design**

Stage	With or without IVIS	Mounting position	Prompt method	Record (N/Y)
1	N	—	—	N
2	N	—	—	Y
3	Y	Position A	Image	Y
4	Y	Position B	Image	Y
5	Y	Position C	Image	Y
6	Y	Position A	Voice + image	Y
7	Y	Position B	Voice + image	Y
8	Y	Position C	Voice + image	Y
9	N	—	—	Y

### 2.3 Experimental Process

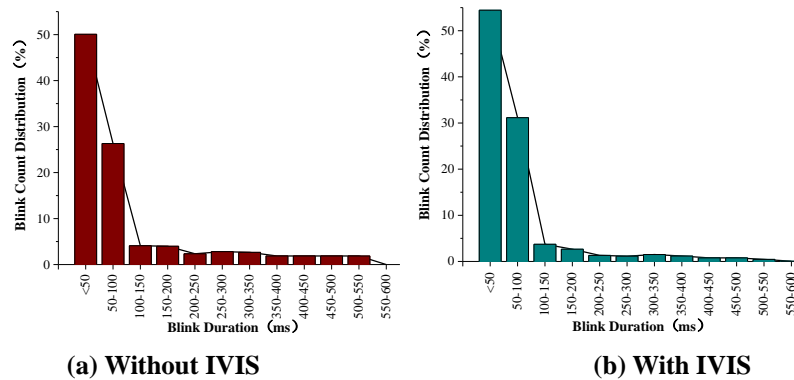
The drivers tested the cars and the IVIS before the experiment started, and wore the eye trackers. After being confirmed unfamiliar with the experimental route, the drivers were informed to fully follow the image or voice information provided by the navigator. Sitting on the front seats of each experimental vehicle were the driver and a staff, and installed on the rear seats were the eye tracker and related electrical equipment. Upon fully understood how to use the device and confirmed the task, the participants started the experiment at the designated departure.

The 9 experimental stages were carried out in sequence to minimize the singularity of the route and the interference of long-time eye tracker wearing on the experimental results. The drivers' eye movements were calibrated, and a 5-10 minute break was given, at the start and end points of each route sector. Each stage lasted approximately 8-10 minutes.

### 3. Blink Duration Characteristics

The distributions of blink counts, with and without navigator usage, were compared in 50ms intervals, as shown in Figure 2(a) and Figure 2(b). When IVIS was not used, drivers' blink durations were mainly

concentrated in 0-200ms, in which about 50% was less than 50ms, and about 25% was 50-100ms. When IVIS was used, the number of blinks less than 50ms increased significantly and exceeded 50%. Meanwhile, the 50-100ms blinks accounted more than 30%, and the blinks over 100ms were significantly reduced.



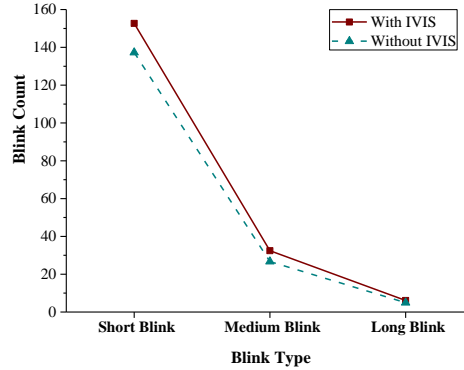
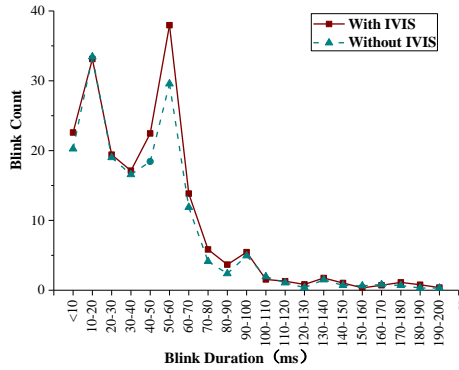
**Figure 2. The Distribution of Blink Counts**

Arraying the data of 0-200ms blinks at a 10ms interval, the blink count distribution over different blink durations was obtained. The distribution curve displayed a distinct bimodal characteristic, as shown in Figure 3. The proportion of blinks with a duration of 10-20ms and 50-60ms was significantly higher than others, a feature that was not observed at 50ms intervals. When IVIS was not used, the peak of 50-60ms blink duration was lower than the peak of 10-20ms blink duration, which could be simply expressed as the value of left peak higher than the value of right peak. When IVIS was used, on the contrary, the value of left peak was lower than the value of right peak. The difference among other duration sections was not obvious.

Given the above observations and inspired by the classification method of reference 1, the K-means cluster analysis was applied to divide the ranges of the three types of blinks into three categories, to further explore the problems behind the phenomenon. The results showed statistical significance (Sig. = 0.000). The three types of blinks were called short blink (0-60ms), medium blink (61-130ms) and long blink (131-200ms), as shown in Figure 4. On the basis of which, again, driver's blinks with or without IVIS were compared. The result showed that short blink and medium blink increased significantly, and long blink did not change much.

Independent sample T-test was used to quantitatively determine the impact of IVIS on the three types of blinks. Taking into consideration that the overall variance was not equal under the Levene test, the t-test method with unequal variance was applied. The results were shown in Table 2. Again, short blink and medium blink changed significantly before and after IVIS usage, while long blink did not change much. According to the reference 1, increase in the short blink and the medium blink indicated a rise of driving workload, which proved that the driving workload went up when IVIS was used to assist driving on an unknown path. Also, it showed that acquiring information from inside of the brain was

more efficient than from the outside.



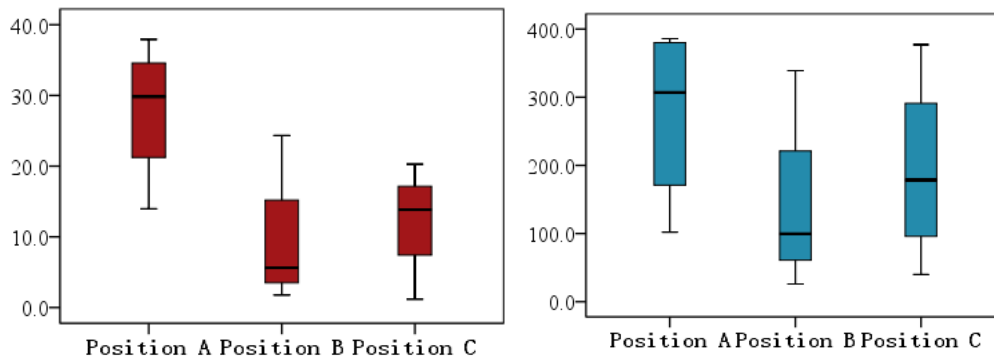
**Figure 3. Distribution of Blinks on a Scale of 0-200ms** **Figure 4. Comparison of Blink Type**

**Table 2. T-test Table of Blink Classification**

Grouping variable	Blink type	Sig. (two-sided test, $\alpha=0.05$ )	Conclusion
With/Without IVIS	Short blink	0.000	Mean difference significant
	Medium blink	0.003	Mean difference significant
	Long blink	0.055	Mean difference not significant

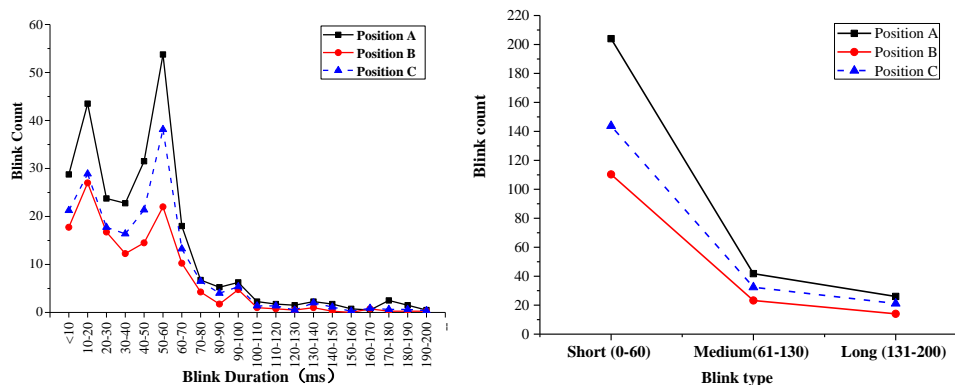
**4. Impact of Mounting Positions**

Drivers’ blink duration and frequency when the IVIS was mounted at different positions were observed, as shown in Figure 5. When the IVIS was installed at position A, the average blink duration reached the peak, so did the average blink frequency. The data was distributed in the higher part. When set at position C, the above two indicators were second to those at position A. When setting at position B, the above two values reached the smallest, the data was distributed at the lowest part, and the lower quartile was close to the mean value.



**Figure 5. The Box Plot of Blink Duration (ms) and Frequency (times/minute) in Different Positions**

Drivers' blink durations were compared when IVIS was mounted at different positions. In the meantime, the blink count fluctuation patterns were similar but with differences, as shown in Figure 6. At position A, the two peaks of blink count were higher than that at position C. At position B, the two peaks were the lowest. Classification comparison revealed that the distribution of blink types was different under different mounting positions. One-way analysis of variance showed that the mounting position had no significant effect on medium and long blinks (Sig. = 0.162; Sig. = 0.213), while to short blinks it had a significant effect (Position A, Sig. = 0.000; Position B, Sig. = 0.013; Position C, Sig. = 0.002).

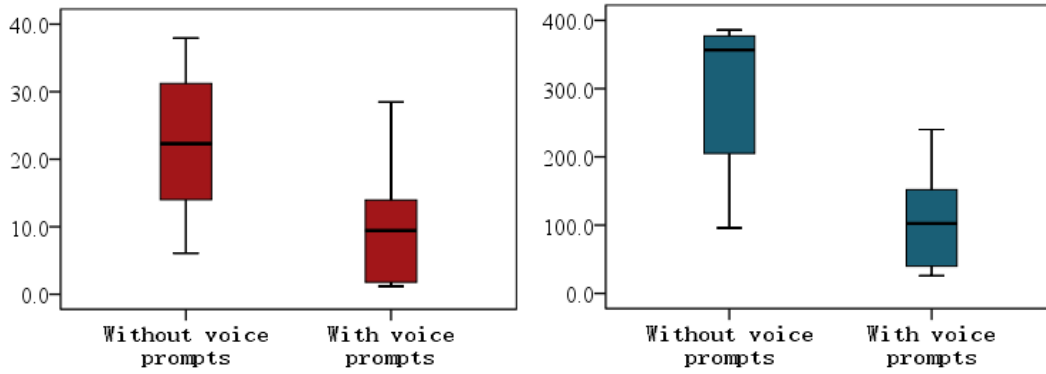


**Figure 6. The Influence of Positions on the Distribution of Blink Counts and Types**

As an “involuntary movement”, blink is an important psychological indicator. Chen (2009) found that blink duration was a sensitive indicator for driving workload evaluation. Furthermore, the number of short blinks could better reflect the consumption of a driver's attention resources. From the ergonomics perspective, an improved design could reduce the driving workload while raising efficiency. The difference of short blink in the experiment indicated that drivers had a smaller workload when the navigation device was mounted at the position B.

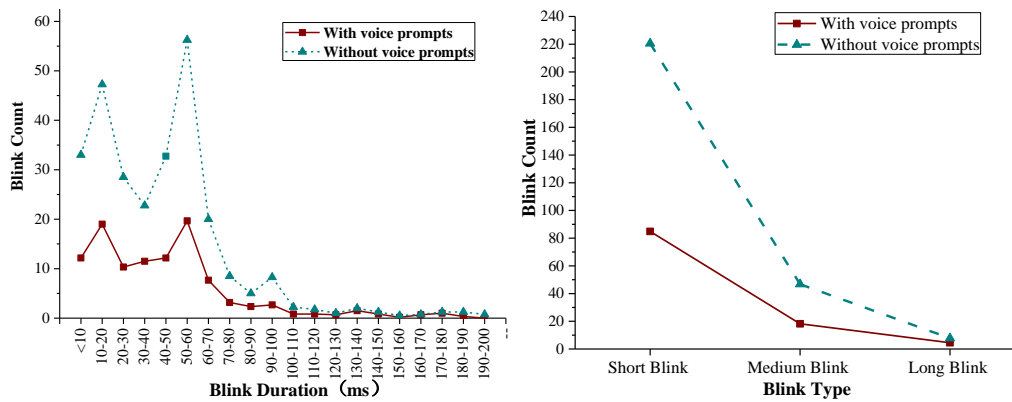
### 5. Impact of Voice Navigation

The experimental results indicated a significant impact of voice prompts on blink duration and frequency. Blink duration and frequency means were significantly lower with voice prompts, so were the maximum value and quartile values, as shown in Figure 7.



**Figure 7. The Box Plot of Blink Duration (ms) and Frequency (times/minute) in Voice Prompts**

Distributions of blink duration and blink type with and without voice prompts were shown in Figure 8. The peaks of blink count without voice navigation were all greater than those with voice navigation. In particular, without voice navigation, the short blinks increased significantly and the medium blinks increased relatively, but the long blinks remained almost unchanged. Therefore, it was proven that voice prompts could bring down the driving workload. It is quite clear that the multi-channel information prompt has advantages over the single-channel—it allows drivers to select information receiving mode and reduces the occupation of mental resources.



**Figure 8. The Distribution of Blink Counts and Types in Voice Prompts**

**6. Conclusions**

This study collected the driver blink duration and frequency data through a controlled real-vehicle road experiment, and realized three different comparisons, namely, comparing the blink characteristics, with and without navigator, with navigator mounted in three different positions, and with image prompts only and image-voice multi-channel prompts. The above endeavor mainly led to the following conclusions:

When the data of blink with a duration of 0-200ms was distributed at a 10ms interval, the driver blink count distribution curve showed obvious bimodal characteristics. The proportion of blinks with a



duration of 10-20ms and 50-60ms was significantly higher than others, a feature that was not observed at 50ms intervals.

The peak of 50-60ms blink duration was lower than that of 10-20ms duration when the vehicle navigation was not used, and higher when used. Difference between other duration sections was not obvious.

Blinks were clustered into three types—short blink (0-60ms), medium blink (61-130ms) and long blink (131-200ms). Then driver's blinks with or without navigator were compared. Compared to not using, when using navigator, short blink and medium blink increased significantly, while long blink did not change much. Increase in short and medium blinks indicated that the driving workload was greater when using navigator.

The difference between medium and long blinks was not significant when the navigation device was mounted at different positions, yet of the short blinks there was a significant difference under this condition. The driving workload reached the minimum when at mounting position B.

The peaks of blink count without voice prompt were all greater than those with voice prompt. In particular, without voice prompt, the short blinks increased obviously, the medium blinks increased relatively, but the long blinks remained almost unchanged. Apparently using voice prompts could reduce driving workload.

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