Influence of Different Types of Auxiliary Sensors on the Behaviors of Right Turn and Right Changes of Lane

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Abstract. There is a visual blind spot when a driver tries to change his direction to right. If the driver ignores the blind spot, the vehicle accident may be occurred. Therefore, many drivers install sensor devices which can help them to know the blind spots on the right of the road. The paper conducted the online questionnaire to acquire the degree of driver's subjective acceptance of for different external tips. And later a simulation experiment was conducted to compare the performances of three different modes of human-computer interaction for the auxiliary devices during the turning right and changes of lane process, including the sound tips, flash tips and vibration tips. Nine non-professional drivers aged between 21 and 24 with one to five years of driving age conducted the experiments. The times of action and response time were recorded and analyzed. The result shows that in the three kinds of tips in the sound tips is more effective.

Keywords: Auxiliary sensors turn right · Sound tips · Flash tips
Vibration tips

1 Introduction

There are more and more cars on the road and the traffic become more and more worse. The more the traffic volume is, the more obvious of the conflict between pedestrians and vehicles [1].

There is a visual blind spot when a driver try to change his direction to right or change his lane to right. Visual blind spots make drivers not see pedestrians clearly. Many auxiliary sensors have been sold on the market. Sensors can give the drivers the tips if there is any obstacle in the blind spot. The sensors as the tips can improve the efficiency of converting information, but when the driver catch the traffic tips, he will lose about 30% of the attention. And nearly 36.4% of all traffic accidents caused by distracted [2]. So the different ways of tip will affect driving safety. It is necessary to discuss the effect of different tips on drivers' behaviors.

At present, a lot of researches have been conducted on the vehicle driving. Pei [3] proposed the relationship between reaction time and interactive security. By sending tips to the driver can effectively reduce the possibility of accidents. It is possible to

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improve driving safety by improving the way of tips. When a driver made a decision on the road, he will only make decision relied on the information currently available to him, not the information provider. [4] Young drivers are more likely to drive at risk than older one [5]. Therefore, for the male drivers, the similar period of driving as the main aspects would be considered in the choice of subjects.

Most of the researches adopt the method of constructing the models. Bao [6] proposed the movement model of right-turn vehicle and pedestrian crossing at signalized intersection. Zhang [7] studied on the conflict characteristics of right-turn vehicles and pedestrians ahead of time. He established the time distribution model of right-turn ahead vehicles with right-right mixed mode and right-turn dedicated right-turn mode. Yang [8] putted forward the factors that may influence the merging decision-making and established a decision-making model of right-turning vehicles merging. Through these models, it can be considered that in the process of driving motor vehicles, drivers mainly derive information from visual, auditory and tactile. Among them, sub-tasks of vision and hearing will make the driver's mental workload increase significantly [9], affecting the driver's normal driving. So we choose flash, sound, and vibration as independent variables.

It can be seen from the above research results that most researches on the performance of right-turn vehicles are from the perspectives of signalized intersection, traffic delay and other aspects. There are not many researches focus on the connection between the way of tips and driver behavior in driving process. Therefore, based on the driver's response to different tips, the different behavior of drivers in response to different tips and the time for response are analyzed.

2 Experimental Design

In order to clearly understand the subjects' acceptance of external tips during driving, an online questionnaire was designed to acquire the degree of driver's subjective acceptance of for different external tips. And later a simulation experiment was conducted, and the objective data was analyzed to acquire which tip was optimal.

2.1 Questionnaire Survey

By consulting the literature, we summarize three main types of tips for the right turn and right changes of lane. They are sound, flash and vibration.

The online survey was used to explore drivers' perception of right-turn behavior. The questionnaire includes three questions: the factors that could cause accidents when turning right or changing to the right lane, the most acceptable way of prompting and the reasons.

The questionnaire surveyed 41 Chinese drivers with more than a year of driving experience. The Table 1 shows the proportion for the factors that could cause accidents when drivers turn right or change to the right lane.

As we can see from Table 1, most pilots think the speed and blind spots are the main causes of driving accidents. Among them, about 65.80% pilots regard the blind spots are the main factors. The Table 2 gives the degree of acceptance of the three tips

Table 1. The proportion of the factors that could cause driving accidents

The factors	Proportion
Speed	75.60%
Blind spots	65.80%
Driving habit	53.70%
The number of cars	46.30%
Reasons of other vehicles	34.20%
Other	17.00%

for the blind spots when turning right or changing to the right lane, and Table 3 gives the reasons for the degree of acceptance of the three tips.

Table 2. Driver's acceptance of different tips

Tip ways	Proportion
Sound	58.50%
Flash	2.50%
Vibration	2.40%
Sound+flash	36.60%

From Table 2, we can see that most drivers think that sound tip is more effective. The reason is the sound has less distraction during driving than the flash and vibration. About 44% persons think it is a distraction during driving, the proportion is lower than the flash and vibration tips, which are 61% and 51% respectively. So from the online subjective questionnaire, we can see that the sound tips has the highest acceptance when drivers turn right or change to the right lane.

2.2 Simulation Experiment

2.2.1 Research Goal

Later, we conducted a quantitative study by means of simulated driving. The experiment compares the performance of the drivers under the three different modes.

The experiment takes three different interaction modes as independent variables, and the response time of the driver as the dependent variable. In addition, for the sake of comparison, the behavior of the subject is also recorded.

2.2.2 Test Subject

The subjects were nine non-professional drivers aged between 21 and 24 with one to five years of driving age, all of whom were college students.

2.2.3 Experiment Preparation

This experiment was carried out in the vehicle laboratory of Beijing University of Architecture and the experiment environment was quiet. There is a car parked in the middle of the laboratory, and at the top of the car there's the projector. The projector's

Table 3. The reasons for the degree of acceptance of the three tips.

Reasons	Proportion
The sound is a distraction during driving	44%
The flash is a distraction during driving	61%
The vibration is a distraction during driving	51%

screen is adjusted to the white wall in front of the car. The Torcs driving system is used as the simulated software. A LED light connected with a thin wire is placed on the right side of the car's glass to achieve flash tips. A small motor is placed on the steering wheel to achieve the vibration prompt mode. The LED light and small motor are both connected with the battery box to ensure they are under control (Fig. 1).

Fig. 1. Experiment scene

Three driving scenarios with different speeds and different speed limits were modeled, which are the highway, the city road and the mountain road. All of three scenes are two lanes with no speed requirements. The driving scenarios are shown in Fig. 2 and the detailed settings for the three experimental scenes are shown in Table 4.

2.2.4 Experimental Process

First, the contents of the experiment and experimental tasks were introduced to the subjects to ensure they can successfully complete the experiment. In order to avoid the error caused by the subjects' incompatibility with the experimental environment, they are required to make a practice for 5 min before the formal experiment.

The formal experiment process lasts about 20 min. The subjects are required to overtake the vehicle right in front of their own vehicle and reduce the speed, then observe the right rearview mirror to change the lanes. Once the subject attempts to turn

Fig. 2. Three driving scenarios

Table 4. Experimental scene

Simulated road	Number of lanes	Speed limit	Traffic	Terrain
Highway	3	120	Smooth	Straight
City road	3	/	Complex	Curved
Mountain road	2	/	Smooth	Uphill and curved

right, a warning is given. At this time, subjects may face four different situations: no prompt, sound tips, flash tips and vibration tips. Two speeds of 60 km/h and 100 km/h are set during the experiment. The subjects were observed whether they were taking the experiment seriously by setting experimental scene, such as setting pedestrians and obstacles on the roadside. Once the participant was found that they had a random driving behavior, the experiment was stopped immediately and the experimental data of the subject was considered invalid. The response of subject will be recorded by a video camera.

3 Experimental Results and Analysis

3.1 Basic Data

Two data were recorded during the experiment. The response time, that is the time from the instruction to the response of the subject. The shorter the time, the better the effect. The times of action of the subjects, that is what is the behavior of the subject after they receiving the prompt instructions, such as turning back, and the length of time. The time of turning right, that is the numbers for the subjects to conduct the behaviors.

The response time and the times of action in Speed of 60 kg/h are given in Table 5. From the data in Table 5 we can see that the sound tip has less response time than the other two tip ways (Table 7).

The response time and the times of action in Speed of 100 kg/h are given in Table 6. From the data in Table 6 we can see that the sound tip has less response time than the other two tip ways.

Similar with the Table 6. The data in Table 8 also indicate that the flash will cause fewer respond, while the sound tip will cause a faster react.

Table 5. Action and response time in speed of 60 kg/h

Subjects	Sound tip		Flash tip		Vibration tip	
	Times of action	Response time	Times of action	Response time	Times of action	Response time
1	2	2	2	1.5	2	2
2	4	1.5	2	2	2	2
3	2	2	2	1.5	2	2
4	4	1.5	2	2	2	2
5	2	2	2	2	2	2
6	2	2	2	2	4	2.5
7	2	1.5	2	2	2	2
8	2	2	2	1.5	4	2.5
9	2	1	2	2	2	2

Table 6. Action and response time in speed of 60

Tip method	Mean value	
	Times of action	Response time
Sound	2.44	1.72
Flash	2.22	1.83
Vibration	2.56	2.11
Total	2.41	1.89

Table 7. Action and response time in speed of 100 kg/h

Subjects	Sound tip		Flash tip		Vibration tip	
	Times of actions	Response time	Times of action	Response time	Times of action	Response time
1	4	1	2	1.5	2	2
2	2	1	2	2	2	2
3	3	1.5	3	2	3	2.5
4	6	1.5	2	3	4	1.5
5	3	1.5	3	2.5	2	1.5
6	2	2	2	2	3	2
7	2	2.5	3	1.5	3	2.5
8	2	2	2	1.5	4	2
9	2	1.5	2	2	2	2

By comparing Tables 6 and 8, we can see that they have a similar trend. With the increase of speed, both the number of actions and reaction time have increased. A correlation analysis is performed to determine which one is more effective.

Table 8. Mean value in speed of 100

Tip method	Mean value	
	Times of action	Response time
Sound	2.89	1.61
Flash	2.33	2
Vibration	2.78	2
Total	2.67	1.87

3.2 Statistical Data

Single factors of ANOVA

If the α value is more than 0.05, there is no significant difference. If it is less than 0.05, there is a significant difference. As can be seen from Table 9, only the α value of response time in 60 km/h was less than 0.05, and the other three α value are more than 0.05. The times of action for the three tip ways in 60 km/h and 100 km/h have no significant difference. It shows that the total times of action has no significant influence on the ways of tip, and it can not be judged more effective.

Table 9. Comparison of significance level

	α value of times of action	α value of response time
60 km/h	0.646	0.023
100 km/h	0.447	0.13

At the same level of risk, the amount and manner of behavior mainly depend on individual experience, including the different ways of getting current information And how to deal with the results of the information. The research on risk perceptions has found that driver's emotions can influence their perception of risk and lead to different behaviors [10]. And the driver's own factors, such as age, driving experience, education, safety consciousness are also the direct factors to effect the driving behaviors [11].

4 Conclusion

According to the result of questionnaire survey, there are 58% of drivers who can accept the sound tip. The results of the quantitative simulation experiment are consistent with the results of the questionnaire. The sound tip interaction has less response time and it is more effective.

However, it can be seen from the analysis data of the significant difference that there is no difference in the number of actions for the three tip ways, indicating that the actions during the driving can not be used as a measure criterion of the validity of tips and the relative response time can be used as a measure criterion. The average response time of the sound tip is superior to the other two tips at both 60 km/h and 100 km/h. It is concluded that sound as a reminder is better than vibrations and flashes and it is more

acceptable to the driver because the sound tips are more direct to make the driver aware of the current road and to make response.

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