Study on Correlation between Driving Emotion and Intention in Car-following State

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***Abstract*— Driving emotion is a relatively intense psychological reaction of drivers to external stimuli. Driving intention is a self-inner state formed by the driver during the driving process, which is related to the driving environment and the state of vehicle and can determine the driving behavior of the next moment. Emotion regulates people's cognition and behavior, and intention is the indicator of real behavior. The research on correlation of automobile drivers' emotions and intentions is an important precondition to realize the accurate identification of driving intention and the active vehicle safety warning. In this paper, the car-following state is taken as an example, and the human-vehicle-environment multi-source dynamic data of the drivers in different emotional state is obtained with the virtual driving experiment. Then one-way analysis of variance is used to analyze the correlation between driving emotion and intention. Results show that the influence factors of driving intention (driver's speed estimation ability, operation reaction time and attention etc.) are significantly different in the four emotional states of happiness, anger, sadness and fear, which indicates that emotion has significant influence on driving intention.**

***Index Terms*— Emotion, Intention, One-way analysis of variance, Active vehicle safety warning**

I. INTRODUCTION

With the rapid development of modern transportation industry, the problem of traffic safety is becoming more and more prominent. Driver is the core factor in the traffic system composed of human-vehicle-environment, and their driving behaviors affect the safety level of road traffic system to a great extent. Therefore controlling driver's behavior is an active factor to reduce the occurrence of traffic accidents and improve vehicle driving safety [1]. Emotion regulates people's cognition and behavior, and intention is the indicator of real behavior. All purposeful behavior is carried out under the influence of emotion [2]. The research on correlation of automobile drivers' emotion and intention is an important precondition to realize the accurate identification of driving intention and the active vehicle safety warning. At present, domestic and foreign scholars have carried out a lot of research on driving emotion and intention [3]. In the aspect of driving emotion, an emotion recognition system were established by Paschero M. et al. [4] with classical neural network model and fuzzy neural network classifier, which can detect the user's emotion by monitoring facial expression in real time. Martin Schmidt-daffy [5] pointed out that fear emotion would appear when current task requires were more beyond driver's perception ability, and the intensity of anxiety emotion would increase when there is a conflict between driver's safety and speed target. Reducing the speed would weaken the fear of the drivers significantly, but wouldn't weaken the driver's anxiety feelings. The effects of different types of front-car on the driver's anger of following-car were studied by Amanda N. Stephens et al. [6] when the front-car ran at low speed. The results showed that compared with the van, driver's anger is relatively weak when the front car was an ambulance vehicle. Moreover, driver's behavior of following-car would vary depending on the front vehicle's state. Mark J. M. Sullman [7] used confirmatory factor analysis method to study the way of expression of the driver's anger emotion in the course of road driving. Results showed that venting anger through offensive language and driving behavior can easily lead to traffic accidents, such as vehicle time zone control and security incidents caused by lack of concentration. The study also showed that men and young drivers tended to vent their anger emotion through aggressive behavior. In terms of driving intention, S. Helman et al. [8] pointed out that the attitude and intention of the driver before learning to drive and during learning to drive largely determined the behavior of driving independently. Louise P. Waddell et al. [9] studied revealed that attitudes, subjective norms, perceived behavioral control, and descriptive norms have a significant impact on both the driver's initiative and the passive use of mobile phone intentions by using hierarchical multiple-source regression analysis method. Laurent Auzoult et al. [10] considered that the road safety intervention measures have a significant impact on the driver's cognition and intention when it is effectively perceived by the driver; and the cognitive effect of the driver on road safety depends on their own self-consciousness. Xiaoyuan Wang et al. [11] studied the driver's tendency identification and prediction from the aspect of cognitive mechanism. Based on the analysis of the dynamic multi-source data of human-vehicle-environment, dynamic Bayesian network was used to construct the dynamic identification model of driving tendency in multi-lane complex environment, and the validity of the model was verified with the methods of actual driving, virtual driving and computer simulation and so on.

Through the analysis of the literature, it can be seen that domestic and foreign scholars have done a lot of work on

driving emotion and intention, but it is very rare in the correlation between driving emotion and intention. In view of this, the correlation between driving emotion and intention is studied by analyzing drivers' physiological, psychological and physical characteristics. Then one-way analysis of variance is used to study the correlation between driving emotion and intention. And the validity of the model is verified finally.

II. Influence Factor Analysis of Driving Intention

Driving intention is a kind of self-inner state, which is related to the driving environment and the state of the vehicle during driving. And it can decide the action of the next moment driving behavior, which reflects the psychological emotional state of the driver in the process of vehicle operation and movement. In the course of driving, the external behavior of drivers with different intention has certain difference, and the reason of the difference is the driver's own factors, such as the physiological and psychological difference, and the state of driving environment. Through the analysis of a lot of experimental data, the driving intention in the car-following state is divided into three types, that is, speeding up, keeping speed and slowing down. According to the method in the reference [11], the main factors in the characteristics of the driver's physical, psychological and physical are selected to anticipate the driving intention. The impact factor for driving intention anticipation with visual reaction time, operation reaction time, discrimination reaction time, choice reaction time and other physiological characteristics, and temperament, attention, willpower, emotional and other psychological characteristics, and the target vehicle speed and acceleration, the loudness velocity of target vehicle and the ahead vehicle, relative distance and other physical characteristics. Among them, driving emotion is intense psychological reaction of the driver to outside stimulation in the running process. The driver's emotional state is different, the performance of the physiological and psychological characteristics is also different, and then they have a certain effect on the determination of driving intention. The emotion is the organism in the life evolution process gradually differentiation. In order to adapt the survival environment, four basic emotions of happy, anger, sadness and fear are divided. Therefore, the four basic emotions are selected in this experiment.

III. Study on Correlation Between Driving Emotion and Intention

A. Experimental Design

1) Experimental materials and equipment

Chinese Affective Picture Systems (CAPS), interactive virtual driving system, high-definition camera, notebook computer, pedal force sensor etc. Some of the experimental equipment is showed in Fig. 1.

Fig.1 Virtual Driving Experiment Equipment

2) Experimental Conditions and Subjects

The subjects are general drivers in the Zibo Zhangdian, whose occupations include the teacher, staff, worker and freelancer. The sample capacity is 50. There are 30 male drivers and 20 female drivers. Age distribute between 18 to 58 years old, driving age distribute between 0.5 to 22 years. 92% of the subjects have different types of illegal driving phenomenon, and the average number of violations is 5.12 times, the average frequency of violation is 0.63 times per year. 44% of the subjects have different types of traffic accidents, and the average number of accidents is 2.54 times, the average frequency of accidents is 0.31 times per year.

3) Experiment Contents

Before the start of the experiment, let the subjects be familiar with the experimental vehicle environment. According to the method of reference [12], visual reaction time, speed estimation ability, selection reaction time, operation reaction time and attention of the driver were obtained. Before emotional stimulation, the experimenter played soothing music for the subjects to keep them in a peace state. Then the experimenter showed the pictures, videos, audios and other emotional stimuli from IAPS and CAPS to subjects. According to the driver's facial expression and the results of their inquiries to determine whether the corresponding emotion is produced. Start to drive after corresponding emotion was stimulated. During driving process, a variety of instruments were used to synchronize the human-vehicle-environment dynamic data in different vehicle grouping situations, and the driver's facial expressions and actions were videoed.

B. Experimental Data

Through above experiments, the physiological, psychological and physical characteristics data of the driver under different emotions were obtained. And the corresponding driving intention was prejudged. Part of the experimental data was showed in Tab. 1, 2, 3, 4.

Tab.1 Values of physiological, psychological and physical indexes of drivers in happy emotional state

Number	Visual reaction time /s	Speed anticipation ability/（km·h^{-1}）	Selected reaction time/s	Operation reaction time/s	Attention	Relative speed between target vehicle and front vehicle /（km·h^{-1}）	Relative distance between target vehicle and front vehicle /（m）
1	0.440	1.921	0.559	1.182	0.11	6.59	20.25
2	0.430	1.859	0.555	1.188	0.26	8.62	23.10
3	0.427	1.931	0.562	1.185	0.25	5.93	19.87
4	0.434	1.914	0.553	1.186	0.07	2.30	18.26
5	0.419	1.775	0.568	1.133	0.25	4.29	20.63
…	…	…	…	…	…	…	…
50	0.436	1.723	0.546	0.839	0.21	5.21	20.12

Tab. 2 Values of physiological, psychological and physical indexes of drivers in anger emotional state

Number	Visual reaction time /s	Speed anticipation ability/（km·h^{-1}）	Selected reaction time/s	Operation reaction time/s	Attention	Relative speed between target vehicle and front vehicle /（km·h^{-1}）	Relative distance between target vehicle and front vehicle /（m）
1	0.424	1.879	0.549	1.191	0.11	6.46	15.37
2	0.429	1.848	0.557	1.185	0.16	5.38	10.32
3	0.430	1.839	0.552	1.187	0.11	6.39	16.64
4	0.424	1.838	0.561	1.188	0.19	8.26	13.32
5	0.419	1.859	0.556	1.143	0.26	10.37	15.63
…	…	…	…	…	…	…	…
50	0.431	1.750	0.540	0.843	0.21	4.29	17.13

Tab.3 Values of physiological, psychological and physical indexes of drivers in sadness emotion state

Number	Visual reaction time /s	Speed anticipation ability/（km·h^{-1}）	Selected reaction time/s	Operation reaction time/s	Attention	Relative speed between target vehicle and front vehicle /（km·h^{-1}）	Relative distance between target vehicle and front vehicle /（m）
1	0.435	1.925	0.561	1.188	0.35	6.33	18.37
2	0.421	1.870	0.560	1.109	0.15	5.62	20.32
3	0.426	1.936	0.566	1.183	0.30	7.53	17.64
4	0.422	1.897	0.556	1.184	0.20	8.24	19.32
5	0.428	1.793	0.562	1.129	0.25	6.33	18.63
…	…	…	…	…	…	…	…
50	0.428	1.718	0.545	0.846	0.55	5.26	20.13

Tab.4 Values of physiological, psychological and physical indexes of drivers in fear emotional state

Number	Visual reaction time /s	Speed anticipation ability/（km·h^{-1}）	Selected reaction time/s	Operation reaction time/s	Attention	Relative speed between target vehicle and front vehicle /（km·h^{-1}）	Relative distance between target vehicle and front vehicle /（m）
1	0.358	1.793	0.562	1.129	0.25	4.12	19.63
2	0.429	1.890	0.558	1.132	0.10	3.69	20.53
3	0.430	1.810	0.554	1.142	0.25	5.21	22.11
4	0.432	1.835	0.551	1.122	0.10	5.39	23.62
5	0.436	1.780	0.552	1.189	0.3	6.43	25.32
…	…	…	…	…	…	…	…
50	0.423	1.721	0.525	0.835	0.56	4.59	22.61

C. Analysis of Correlation Between Driving Emotion and Intention Based on One-way Analysis of Variance

Assuming that the whole is a normal variable, one-way analysis of variance method [13-15] is used to study whether there are significant changes in driver's physiological and psychological indexes in different driving emotional states, which have a significant impact on the driving intention. In this paper, the single factor variable is driving emotion.

One-way analysis of variance is carried out by using SPSS19.0 statistical analysis software [16-17]. Data processing is as follows:

Data entry. The visual response time is represented by a variable X1, the variable X2 represents the speed estimate ability, the variable X3 indicates the choice reaction time, the

variable X4 indicates the operation reaction time, the variable X5 expresses the attention, the variable X6 indicates the relative speed between the target vehicle and the front vehicle , the variable X7 indicates the relative distance between the target vehicle and the front vehicle; variable G indicates driving emotion (happy, anger, sadness, fear), 1 is happy emotion, 2 is anger, 3 is the sadness emotion, 4 is the fear emotion; the variable ID indicates that the subjects (with the number representing the different subjects), if the subject's with the number 1 visual response time is 0.440, the input data is X1 to 0. 440, G is 1, and ID is 1.

Statistical analysis. Select in turn: "Analysis", "compare means", "single factor ANOVA". The X1, X2, X3, X4, X5, X6 and X7 of the drivers were chosen as the dependent variables for analysis, and the emotion G was chosen as the fixed factor.

Options setting and selection. Self-setting model was set as the main effect type, the square and type is selected as the third class, The emotion G is selected to do multiple comparison factor box, select the SNK namely q test, the significance level is set to 0.05, and choose to carry out homogeneity test for variance, then submitted to the execution.

Output the result. The homogeneity test for variance is shown in Tab. 5, and the results of single factor analysis of variance are shown in Tab. 6.

Tab.5 Homogeneity test of variance

	Levene statistics	Freedom df1	Freedom df2	Significant Sig.
*X*1	1.049	2	147	0.362
*X*2	1.275	2	147	0.279
*X*3	1.146	2	147	0.318
*X*4	2.801	2	147	0.071
*X*5	0.666	2	147	0.521
*X*6	1.133	2	147	0.332
*X*7	0.923	2	147	0.389

As can be seen from the Tab.4, the significant probability is greater than 0.05, which indicates that the variance of each group has no significant difference on the significant level of 0.05. Therefore, the variance is homogeneous, and the one-way analysis of variance is feasible for the test index.

Tab.6 One-way analysis of variance

		Sum of squares	df	Mean square	F	$F_{0.05}(2,147)$
*X*1	Between groups	0.0000482	2	0.0000241	0.482	3.000
	In group	0.007	147	0.0000476		
	Total	0.007	149			
*X*2	Between groups	0.094	2	0.047	3.568	3.000
	In group	1.961	147	0.013		
	Total	2.056	149			
*X*3	Between groups	0.000	2	0.0000395	0.447	3.000
	In group	0.013	147	0.0000884		
	Total	0.013	149			
*X*4	Between groups	0.013	2	0.007	2.196	3.000
	In group	0.445	147	0.003		
	Total	0.459	149			
*X*5	Between groups	0.079	2	0.040	3.613	3.000
	In group	1.627	147	0.011		
	Total	1.706	149			
*X*6	Between groups	0.134	2	0.067	4.459	3.000
	In group	2.221	147	0.015		
	Total	2.265	149			
*X*7	Between groups	0.363	2	0.181	8.054	3.000
	In group	3.311	147	0.023		
	Total	3.674	149			

As can be seen from the Tab.6, values of $F(X2)$, $F(X5)$, $F(X6)$ and $F(X7)$ are all greater than value of F0.05（2,147), indicating that driving emotion has significant influence on the physiological and psychological indexes, such as driver's speed estimation ability, operation response time, attention, the relative distance between target vehicle and the front vehicle etc.

IV. Model Validation

Driving intentions of 50 subjects in different emotional states is calculated by the driving intention prediction model. Next, driving intention of the driver under a certain traffic situation is dynamically identified in four kinds of affective states with the driving intention identification method in reference [31]. Then the statistical analysis of the identification results can be obtained by the driver in a time-varying environment, by the different intention to predict the type of identification of the probability of other intentions, as shown in Tab. 7. Among them, in the column of

driving emotions, 1 is happy emotion, 2 is anger emotion, 3 is sad emotion, 4 is fear emotion.

Tab.7 Dynamic identification result of driving intention

Number	Driving emotions	Identify results		
		Speeding up	Keeping speed	Slowing down
Speeding up	1	0.72652	0.11563	0.15785
	2	0.85362	0.11635	0.03003
	3	0.65212	0.24962	0.09826
	4	0.79532	0.18365	0.02103
Keeping speed	1	0.13976	0.70485	0.15539
	2	0.10801	0.85847	0.03352
	3	0.00713	0.51096	0.48191
	4	0.15131	0.79212	0.05657
Slowing down	1	0.08965	0.10725	0.8031
	2	0.08581	0.06532	0.84887
	3	0.1776	0.09898	0.72342
	4	0.10325	0.11011	0.78664

As can be seen from the Tab.7, driving intention of the subject is significantly changed in four different emotional states, that is, the driver's emotion has a significant effect on the intention.

According to the verification method of reference [12], the accuracy of different driving intention is compared, and the comparison results are shown in Fig. 2. The recognition accuracy rate A indicates the result of the dynamic identification of the driving intention considering the emotion; the recognition accuracy rate B indicates the result of the dynamic identification of the driving intention without considering the emotion.

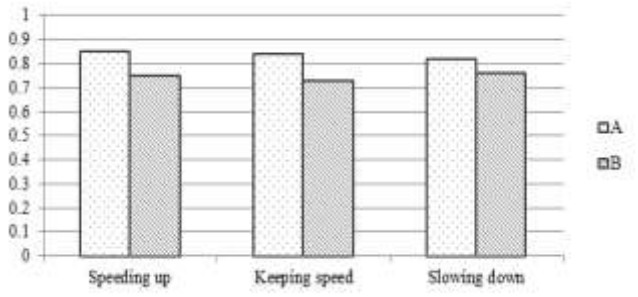

Fig. 3 Identification accuracy rate of different driving intentions

The results show that the accuracy of driving intention is higher when considering the influence of emotion on the physiological and psychological characteristics of drivers.

V. Conclusion

The accuracy of driving intention evaluation is not only affected by the driver's internal factors, but also by some external factors. Emotion is a strong psychological reaction of drivers to external stimuli. It usually affects the result of judgment by affecting the physiological, psychological and physical characteristics of drivers. In this paper, a number of experiments are carried out to obtain the physiological and psychological factors of drivers under different emotional states. Then the one-way analysis of variance method is used to analyze the effects on the physiological, psychological and physical characteristics with SPSS19.0 statistical analysis software. Results show that the influence of the emotion on the driver's speed estimation ability, the operation reaction time, the attention, the relative distance between the target vehicle and front vehicle is significant, namely, driving intention is different in different emotional states.

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