

Investigation of a Driver-to-Driver Communication Method Through Rear Window Display for Chinese

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Abstract. There exists major information asymmetry of traditional driver-to-driver communication method that may result in misunderstandings among drivers. In this study, a driver-to-driver communication method through rear window display was designed and evaluated. Drivers can express their feelings when they drive or explain their intentions before performing specific actions. Their feelings or intentions were presented by text signs or emoticon signs on the rear window. The study investigated the effect of driver-to-driver communication on people's perception and preference for two information presentation types. The experiment used three typical driving scenarios, i.e. normal driving, cutting in line and overtaking. The results indicated that information communication had a significant effect on people's perception. Their preference for the information presentation types depended on driving scenarios. Suggestions about the design of information display through rear window were provided to increase the communication effectiveness among drivers and thus improve driving safety.

Keywords: information display, emoticon, text, driver-to-driver communication

1 Introduction

Daily vehicle driving is a common activity in modern society. The number of private vehicles was about 88.39 million and the number of drivers was about 0.25 billion in China until 2012 [1]. More frequent driving increased the opportunities for driver interaction.

In road transportation, communication can be seen as the interaction between the drivers, the vehicles and the environment (road, signage, signals and other road users) [2]. As car drivers are sitting behind the wheel, the traditional driver-to-driver communication is realized through a limited set of channels, including signals, lights, horn, and behavior. It can be direct using hand and electronic signals, or indirect, like the sound of squealing of tires, change in vehicle trajectory etc. Both direct and indirect communication methods use visual and auditory channels, with visual providing the

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majority of information [3]. Interactions through these channels are not as effective as common communication ways in daily life, such as speech, facial expression, gestures, etc. It is difficult for drivers to clearly understand what the intentions of the other drivers are [4]. If a driver is not aware of other road users' real intentions, it can lead to misunderstandings, which can potentially cause stress and extreme emotional responses [4]. Research related to driver-to-driver communication device suggests that the driver-to-driver communication plays a very important role in ensuring safety in road transportation [2]. It was found that drivers would be willing to use a hypothetical device to send messages to other drivers [5].

During the tasks of driving, drivers perceive other traffic participants and the environment mainly through visual channels. Visual display mounted on vehicles is a compatible way of information presentation while driving. Observers would instantly understand the source of the information. A series of patents related to digital message display for vehicles have been claimed. The digital message display for vehicles is a device to be mounted on the rear window of an automobile, capable of displaying a number of pre-defined messages [6]. U.S. Pat. No. 5500638, issued on Mar. 19, 1996 to I. George, disclosed a vehicular goodwill message system that was intended to issue a message on command from the operator of a vehicle. The system allows for the display of four pre-defined messages including courtesies such as "SORRY" or "THANK YOU!", and distress messages such as "PLEASE HELP" or "PLEASE CALL 911", which may be signaled to a trailing driver. U.S. Pat. No. 5,905,434, issued on May 18, 1999 to P. Steffan, showed a vehicle communication device that was another example of a message display that allows the driver of a vehicle to select from a number of preset and pre-programmed messages to be presented on a display device mounted on the exterior of the vehicle. We are concerning about whether presenting information through rear window display is a proper way for driver-to-driver communication.

Information presented by displays can be categorized as dynamic and static. Dynamic information continually changes, such as traffic lights, and temperature gauges. Static information remains fixed over time, such as printed alphanumeric data, graphs and labels [7]. Typical display types include verbal signs, symbolic signs and so forth [7]. Previous studies compared the effectiveness of some information presentation types [8, 9, 10]. The utilization of various information presentation types depends on specific scenarios. It needs to investigate people's preference for information presentation types for driver-to-driver communication through rear window display.

The purposes of the study are to investigate the effect of driver-to-driver communication on people's perception and to evaluate people's preference for two kinds of information presentation types, text and emoticon, for rear window display on three driving scenarios. The study is expected to provide design suggestions for the information presentation types on the rear window when drivers communicate with other drivers.

2 Method

2.1 Participants

Twenty participants (10 male and 10 female, mean age = 32.2, standard deviation of age = 4.5) were recruited to participate in the experiment. They were licensed drivers and had driving experiences for more than three years. All participants had normal or corrected normal visual acuities and healthy physical conditions.

2.2 Design and Variables

The study identified three scenarios, i.e. normal driving, cutting in line and overtaking. In cutting in line and overtaking scenarios, driver-to-driver communication was vital for eliminating misunderstandings. The driver of the front car performed a seemingly aggressive driving maneuver which might cause anger on the driver of the following car. However, the driver of the front car did not intend to cause any harm to others. In such cases, it was expected that an additional channel of communication was provided so that the driver of the front car could effectively inform the driver of the following car about the intentions of his or her behavior. The scenarios were reviewed by experienced drivers so that they were representative. In all scenarios, there were two vehicles, denoted by vehicle *A* (observer vehicle) and vehicle *B*, each having a driver, driver *A* and driver *B*, respectively.

In normal driving scenario, driver *A* approached driver *B* from behind and seeing the rear window display which indicated the feeling of driver *B*. The first independent variable was information content, and it had two levels, positive information and negative information. The second variable was information presentation types, and it also had two levels, emoticon and text. The dependent variables were participants' perception of these four settings (2 information content \times 2 information presentation types) and their preference for presentation types.

In cutting in line scenario, driver *A* was waiting in line to go through an intersection. Driver *B* overtook from an adjacent lane and cut in the line in front of driver *A*. Driver *B* would like to let driver *A* know his situation and to express his gratitude. In this scenario, information communication existed or not. When there was information displayed, it either presented by text or by emoticon. The information presented the driver's motivation and explanation of his behavior. The dependent variables were participants' perception and preference.

In overtaking scenario, driver *A* ran normally on urban expressway. Driver *B* changed the lane and went in front of vehicle *A* with very close distance. Driver *B* wanted to express his apology to driver *A*. In this scenario, the information communication existed or not. It only used text displaying driver *A*'s explanation. Participants were required to give their perception and cognition after seeing the information presentation.

During the experiment, participants were set as drivers in vehicle *A* who saw the driving behavior of vehicle *B* and received the information displayed on the rear window in vehicle *B*. Participants reported their perception to the behavior and preference

for the display by filling in a questionnaire. The test settings in each scenario were as follows,

- In normal driving, the information content was the feelings of drivers in the front. When the feeling was positive, text “I am happy (presented in Chinese)” or emoticon “☺” was shown. When the feeling was negative, text “I am upset (presented in Chinese)” or emoticon “☹” was shown (Fig.1).
- In cutting in line scenario, information was either displayed or not. When communication existed, the information was either text “Sorry, in a hurry (presented in Chinese)” or emoticon “☺” (Fig.2).
- In overtaking, information was either displayed or not. When communication existed, the display used text type, “Sorry, in a hurry (presented in Chinese)” (Fig.3).



Fig. 1. Information display in normal driving scenario. Happy emoticon; Upset emoticon; “I’m happy” (presented in Chinese); d. “I’m upset” (presented in Chinese).



Fig. 2. Information display in cutting in line scenario. Happy emoticon; “Sorry, in a hurry (presented in Chinese).



Fig. 3. Information display in overtaking scenario. “Sorry, in a hurry” (presented in Chinese).

2.3 Measurements

Participants reported their perception and evaluations by filling in a questionnaire. All the questions in the questionnaire were measured by a five-point Likert scale from strongly disagreement to strongly agreement (1 = “strongly disagreement” and 5 = “strongly agreement”). The questionnaire composed of two parts, the perception part,

measuring participants' feelings of the information communication, and the evaluation part, measuring participants' preference for the information presentation types.

In normal driving scenario, participants' perception of the information communication was measured in five dimensions: the extent of being eased or worried on following the vehicle, being pleased or upset with the display, being annoyed by the display, and the extent to which it is interesting to me and it is silly to me. The ergonomics features of the display, concerning clearness, distraction degree, and willingness to use were measured as well. When the content was positive, participants were asked to give their ratings on the item "at ease and pleased by the information communication". When the content was negative, participants needed to rate the worrying and upsetting level.

Participants' perception about the behavior of cutting in line and overtaking was measured in three main dimensions: the extent of being annoyed by the cutting in line behavior or overtaking behavior; the extent in which I think the driver was malicious and I think the driver may have a reason. Participants' willingness to use the information communication display was measured as well.

2.4 Apparatus

The experiment was conducted in a full-cabin Daewoo Nubira driving simulator. It was installed in the laboratory in the Institute of Human Factors and Ergonomics in Tsinghua University. The experiment scenarios were presented to the participants through video clips and projected to a curved screen in front of the car cabin. The car cabin simulated the real in-vehicle driving environment. Participants were seated in the car cabin and watched the scenarios on the screen.

The videos were recorded beforehand on the real road. A digital camera mounted on an observer vehicle (vehicle *A*) recorded the scenes where another vehicle (vehicle *B*) performed the actions and displayed information on the rear window just as the design of the experiment scenarios. A tablet (iPad, 9.7", with a pixel resolution of 2048 × 1536) fixed on the back of the headrest of rear right seat on the vehicle *B* was used as the display media. In the lab experiment, participants received the information through videos and their vision angle was the same as the observer vehicle.

2.5 Procedures

After arriving at the laboratory, participants signed the informed consent and completed a general survey about their demographic information. The participants were asked to sit into the simulator to get ready for the test. Then the participants were asked to watch a five-minute video clip of general driving to get familiar with the system and get immersed in the virtual driving environment. After that, the videos of three experiment scenarios were played for the participants. In each video clip, about two minutes in the beginning was for warm-up. The video lasted 15 minutes in each scenario. When information communication existed, information was displayed three times in each presentation setting. After seeing each video clip, they filled in the questionnaire to give their

perception of the information communication method and their preference for the information presentation types. Each participant spent about one hour finishing the experiment.

3 Results

3.1 Normal driving

160 ordinal scale data (20 participants \times 8 questions) was collected. The one-sample Wilcoxon sign rank test was used to measure the effect of positive and negative information display on drivers' perception. Results indicated that positive emoticon information display had significant effect on participants' feelings (Table 1). Participants tended to feel pleased, eased, less annoyed with the information display and thought that the communication was interesting and not silly (p 's $< .05$). After seeing the positive text display on the rear window, participants felt eased following the vehicle, felt pleased, less annoyed with the information communication and thought it interesting significantly (p 's $< .01$) (Table 2). The negative information display (both text and emoticon) had significant effect on drivers' feelings (Table 3, Table 4). When the participants saw the negative display mounted on the front car, they felt worried about the information content (p 's $< .05$).

Nonparametric Mann-Whitney test was conducted to compare the effect of the two types of information presentation on participants' preference from three aspects, clearness, distraction degree and intention to use the device. The results showed that participants preferred the emoticon display because it showed information more clearly than text display ($p < .05$) (Table 5).

Table 1. Results of positive emoticon display in normal driving scenario

Item	Estimation of a median	Wilcoxon statistics	p value
at ease on following the vehicle	4.00	100.5	0.023
pleased with the display	4.00	136.0	<.001
annoyed by the display	1.50	<0.1	<.001
it is interesting to me	4.00	122.0	0.033
it is silly	2.50	13.0	0.025

Table 2. Results of positive text display in normal driving scenario

Item	Estimation of a median	Wilcoxon statistics	p value
at ease on following it	4.00	121.0	0.007

pleased with the display	4.00	99.0	0.004
annoyed by the display	2.00	4.0	0.004
it is interesting to me	3.50	98.5	0.004
it is silly	2.50	35.0	0.164

Table 3. Results of negative emoticon display in normal driving scenario

Item	Estimation of a median	Wilcoxon statistics	<i>p</i> value
worried on following it	4.00	91.0	0.002
upset with the display	3.50	57.0	0.170
annoyed by the display	3.00	50.0	0.410
it is interesting to me	2.50	25.0	0.090
it is silly	3.00	29.0	0.756

Table 4. Results of negative text display in normal driving scenario

Item	Estimation of a median	Wilcoxon statistics	<i>p</i> value
worried on following it	4.00	120.0	0.001
upset with the display	3.00	30.0	0.407
annoyed by the display	3.50	74.0	0.187
it is interesting to me	3.00	57.0	0.887
it is silly	3.00	44.5	0.972

Table 5. Comparison of two display methods

Item	Estimation of a median difference	<i>p</i> value
I could see it clearly	1.00	0.017
It is distractive for me	-0.50	0.285
I am willing to use this device	0.50	0.579

3.2 Cutting in line

Participants' perception about the behavior of cutting in line was measured by three items, "I felt annoyed by this behavior", "The driver may have a reason" and "The driver is malicious". 120 ordinal scale data (20 participants \times 6 questions) was collected. Nonparametric Mann-Whitney test was used to measure the effect of information communication on participants' perception (Table 6). The results showed that text display made participants significantly believe that the drivers cutting in line had some reasons for doing that ($p < .05$) and they were not malicious ($p < .05$), and participant felt less annoyed after seeing the text display than without information communication significantly ($p < .01$). On the other hand, the emoticon display did not show significant influence on participants' feelings (p 's $> .05$) (Table 7).

Three items with respect to clearness, distraction degree and willingness to use were utilized to measure participants' preference for two display types. Nonparametric Mann-Whitney test results showed that participants were more willing to use text display than emoticon display significantly ($p < .01$). It did not show significant difference on clearness, distraction degree between two information presentation types (p 's $> .05$).

Table 6. With text display and without information display comparison

Item	Estimation of a median difference	p value
annoyed by cutting in line behavior	1.00	<.001
the driver may have a reason	-1.00	0.031
the driver is malicious	1.00	0.034

Table 7. With emoticon display and without information display comparison

Item	Estimation of a median difference	p value
annoyed by cutting in line behavior	0.00	0.152
the driver may have a reason	0.00	0.190
the driver is malicious	0.00	0.190

3.3 Overtaking

80 ordinal scale data (20 participants \times 4 questions) was collected. Nonparametric Mann-Whitney test was used to compare the ratings of the two settings, i.e. with information displayed by text and without information displayed (Table 8). Although people still thought that the behavior was dangerous (no significant difference between the two groups, $p > .05$), and they felt less annoyed ($p < .05$) and were more inclined to think the driver had reasons for this behavior ($p < .01$). Nearly half of the participants reported

the text in the display could not be seen clearly and distracted their attention. Despite this legibility problem, more than half of them had the intention to use this display.

Table 8. Comparison of text display and without information display

Item	Estimation of a median difference	<i>p</i> value
it is dangerous	0.00	0.989
annoyed by this behavior	1.00	0.022
the driver may have a reason	-1.00	0.002
the driver is malicious	1.00	0.120

4 Discussion

A typical scenario that may induce anger on drivers is traffic jam accompanied by unlawful or immoral driving behaviors. As the driver drives through an intersection, driver *A* lined up along with the traffic. Driver *B* overtook through an adjacent lane and drove up in front of driver *A*. Such a cutting-in-line behavior may easily arouse the anger on driver *A*. In the given context, misunderstandings between drivers would induce or exacerbate road rage. It has been proven that road rage is a causal factor to traffic accidents [11]. Aggressive driving is a common cause for road rage in drivers [12]. As a driver is impatient or in emergency, he may perform driving actions that cause physical or mental harm to others. In some cases, drivers only wish to bring some benefits to themselves, without any intention to produce any harm to others. Such actions are still perceived as aggressive by other drivers and arouse discomfort and anger on them. In this situation, it is necessary to provide an additional channel to enhance driver-to-driver communication and therefore to promote driving safety and efficiency. It was found that participants' perception was influenced significantly by the information display on the rear window of other drivers. People's stress relived after seeing the information display. The information communication through rear window between drivers would reduce extreme stress and improve traffic safety to some extent.

The study tested participants' preference for two typical information presentation types, verbal signs (text) and symbolic signs (emoticon). It was found that people's preference depended on driving scenarios. In normal driving scenario, driver *A* saw the status information of drivers in the front vehicle and did not need to fully comprehend the meanings of the information. Symbolic signs would deliver the information effectively and efficiently. Previous studies have indicated that signs with symbolic messages can be understood more quickly than those with verbal messages. Visually degrading the signs resulted in a greater decrement in performance for verbal than for symbolic signs [13]. Text, icon and modified icon have been compared in higher-velocity condition. It was found that the two iconic versions were superior to the text version [14]. Icon signs were visible at much greater distances than were text signs for people of different age [15]. In this study, participants preferred to use emoticon in normal driving scenario because they considered that emoticon showed information more clearly than text.

The main purpose of the information communication in cutting in line and overtaking scenarios was to explain to the driver of the following car about the behavior performed by the front car. In this situation, the information and messages should be clear to see and quick to comprehend. In addition, the information should help explain the intentions of performing such behavior. Symbolic signs were assumed to be improper as it could not present the reasons for taking such actions. In the experiment, we presented “Sorry, in a hurry (presented in Chinese)” on the experiment display. The results indicated that emoticon signs were not proper. Participants were more willing to use text type than emoticon type in cutting in line scenario.

Visual workload affects driving performance in various ways [16]. It may reduce the speed and increase lane keeping variation. When visual attention is diverted from the road, the driver cannot give any tracking response, which results in periods with fixed steering wheel angle. In normal driving scenario, as both vehicles are travelling at high speed, visual workload of the driver behind is relatively high. It is required that the information in the scenario is simple and highly readable. Emoticon presentation type is recommended in this situation. In cutting in line scenario, as the both vehicles are nearly stationary, the visual workload of the driver behind is relatively low, more detailed information can be displayed. Thus, text presentation type is a proper design in this situation.

5 Conclusion

The study investigated the effect of driver-to-driver information communication on people’s perception. It compared the two information presentation types, text type and emoticon type, to figure out which was better in information communication on rear window display. A driver-to-driver communication interface was designed and an experiment was conducted to fulfill the study goals. The experiment used three typical driving scenarios, normal driving, cutting in line and overtaking. The results indicated the information display through rear window had significant effect on people’s perception. It was necessary to provide additional channel for information communication among drivers. People were willing to receive information of other drivers through rear window and their stress relieved when information communication existed. The design of information presentation should take driving scenarios into consideration. In normal driving, emoticon type was better than text type because emoticon was easy and quick to comprehend. In cutting in line scenario, text type could deliver more detailed information and explain drivers’ intentions, which was better than emoticon type. Information communication through rear window could increase the communication effectiveness among drivers and thus improve driving safety.

Acknowledgement. The authors would like to acknowledge the support from the Natural Science Foundation of China (71071085), Natural Science Foundation of China (71471098), National Key Technology R&D Program of the Ministry of Science and Technology (2014BAK01B03) and China National Institute of Standardization through the “special funds for the basic R&D undertakings by welfare research institutions” (552013Y-3078).

References

1. National Bureau of Statistics of China, <http://www.stats.gov.cn/tjsj/ndsj/2013/indexeh.htm>
2. Pillai S S, Ray G G.: Ergonomics Intervention in Automobile Driver Communication in a Developing Country. In: the 2014 European Conference on Cognitive Ergonomics, pp.8, ACM (2014)
3. Macadam, C. C.: Understanding and modeling the human driver. *Vehicle System Dynamics* 40, 101-134 (2003)
4. Renner, L., Johansson, B.: Driver coordination in complex traffic environments. In: the 13th European conference on Cognitive ergonomics: trust and control in complex socio-technical systems. pp. 35-40. ACM (2006)
5. Lamas, R., Burnett, G., Cobb, S., Harvey, C.: Driver Link-up: Exploring User Requirements for a Driver-to-Driver Communication Device. In: the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications. pp. 1-5. ACM (2014)
6. Somuah, E.: Digital message display for vehicles: Google Patents (2004)
7. Sanders, M. S., McCormick, E. J.: Human factors in engineering and design. McGraw-Hill (1987)
8. Benbasat, I., Dexter, A. S.: An investigation of the effectiveness of color and graphical information presentation under varying time constraints. *MIS quarterly* 10, 59-83 (1986)
9. Speier, C., Vessey, I., Valacich, J. S.: The Effects of Interruptions, Task Complexity, and Information Presentation on Computer-Supported Decision-Making Performance. *Decision Sciences* 34, 771-797 (2003)
10. Tractinsky, N., Meyer, J.: Chartjunk or goldgraph? Effects of presentation objectives and content desirability on information presentation. *MIS Quarterly* 23, 397-420 (1999)
11. Galovski, T. E., Malta, L. S., Blanchard, E. B.: Road rage: Assessment and treatment of the angry, aggressive driver. American Psychological Association (2006)
12. Dukes, R. L., Clayton, S. L., Jenkins, L. T., Miller, T. L., Rodgers, S. E.: Effects of aggressive driving and driver characteristics on road rage. *The Social Science Journal* 38, 323-331 (2001)
13. Ells, J. G., Dewar, R. E.: Rapid comprehension of verbal and symbolic traffic sign messages. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 21, 161-168 (1979)
14. Long, G. M., Kearns, D. F.: Visibility of text and icon highway signs under dynamic viewing conditions. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 38, 690-701 (1996)
15. Kline, T. J. B., Ghali, L. M., Kline, D. W., Brown, S.: Visibility distance of highway signs among young, middle-aged, and older observers: Icons are better than text. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 32, 609-619 (1990)
16. Lansdown, T. C.: Causes, measures and effects of driver visual workload. *Stress, Workload and Fatigue* 351-369 (2001)