

Research
Report

Assessment of Drivers' Risk Perception Using a Simulator

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シミュレータによるドライバのリスク知覚評価

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Abstract

Drivers' "prejudice" is the major cause of road traffic accidents in Japan. Here, "prejudice" refers to a driver's cognitive status being such that he or she perceives an accidental risk as being smaller than an objective risk. In this study, a simple method named SUPREME is proposed to estimate a driver's perception of risk, both in real-time and quantitatively, using driving behavior data. In addition, a simple driving simulator named TEDDY was developed to easily assess a driver's prejudice. Sixty subjects participated in a prejudice assessment trial. The validity of the

assessment technique was confirmed by analyzing the driver's selection of vehicle velocity when the degree of prejudice was assessed as being high. The relationship between the assessed prejudice and a conventional aptitude test was investigated. As a result, the assessed prejudice was judged to be related to the driver's tendency to be accident-prone. This study aims to establish a basis for new types of driver assistance and training programs that prevent prejudice in the ITS epoch.

Keywords

Active safety, Risk perception, Prejudice, Driving simulator, ITS, Driver assistance,
Human interface design, Driver training

要 旨

日本における交通事故の主な原因はドライバの「思い込み」である。「思い込み」とは、交通状況に対する客観的な危険度よりも、ドライバが主観的に知覚した危険感が過小な状態を示す。本研究では、運転操作データをもとにドライバのリスク知覚の程度を簡便に推定する方法SUPREMEを提案する。また、ドライバの思い込みを評価するための簡易なドライビングシミュレータTEDDYを開発する。60名の被験者により、TEDDYによる

思い込み評価を試行した。思い込みが高いと評価された場面での車速変化の分析から、本評価方法の妥当性が確認された。次に、評価された思い込みの程度と伝統的な運転適性検査との関係を調べた。その結果、思い込みの程度が高い者ほど事故親和性が高いことが確認された。これらの取り組みにより、ITS時代における、思い込みを低減させる新しいタイプの運転支援や運転教育方法開発の基礎とすることを狙う。

キーワード

予防安全, リスク知覚, 思い込み, ドライビングシミュレータ, ITS, 運転支援,
ヒューマンインタフェース設計, 運転教育

1. Introduction

Although the number of road traffic accident fatalities has been falling in Japan, the actual number of accidents and that of resulting injuries have been increasing each year. Most road traffic accidents are caused by human errors. An accident survey by the Japanese Institute for Traffic Accident Research and Data Analysis (ITARDA) showed that judgment errors, called "prejudices," are the major cause of accidents.¹⁾ A "prejudice" refers to a driver's cognitive status being such that he or she perceives the accidental risk as being less than the objective risk²⁾ (**Fig. 1(a)**).

Around the world, research into Intelligent Transport Systems (ITS) is aiming to reduce the number of accidents. Trial calculations³⁾ have shown that a vehicle's advanced safety devices (e.g. rear-end collision alarm, lane-keeping system, night-view system, etc.) can effectively prevent or reduce the resulting damage in about 50% of the accidents that occur. The other 50%, in which such devices would be ineffective, are mainly caused by the driver's prejudice. Therefore, there is a definite need to develop driver assistance and training methods to prevent driver prejudice and thereby reduce accidents.

Before we can attempt to reduce driver prejudice, we need a means of assessing that prejudice. We have been investigating a method of estimating the degree of a driver's risk perception using driving behavior data. The assessment of the driver's

prejudice was attempted using a driving simulator. To validate our assessment, the index that we obtained was compared with a traditional driving aptitude test. Ultimately, we intend to apply these techniques to the development of new driver assistance systems that will prevent prejudice, as well as driver training programs that will improve the driver's risk perception ability (**Fig. 1(b)**).

2. Assessment method and system

2.1 Perceived risk estimation

We can safely assume that drivers would avoid or attempt to avoid risky situations if they could perceive them as being so. Deceleration can reduce the risk of accidents and mitigate damage by maintaining a temporal and spatial distance between the driver's vehicle and the hazard. Similarly, a driver's steering patterns reduce the possibility of accidents occurring by maintaining a lateral displacement from hazardous objects. Therefore, we proposed a simple method for estimating the degree of a driver's risk perception that is based on the driver's manipulation of the pedals and steering wheel. We dubbed this method the Simple and Useful Perceived Risk Estimation Method, or SUPREME.

First, the driver's pedal and steering wheel operations, and the surrounding traffic situation, are classified using the standards listed in **Table 1**. Next, the driver's intention to decelerate at time t (D_t), intention to steer (S_t), and the modification coefficient (M_t) are determined. Finally, Eq. (1) is

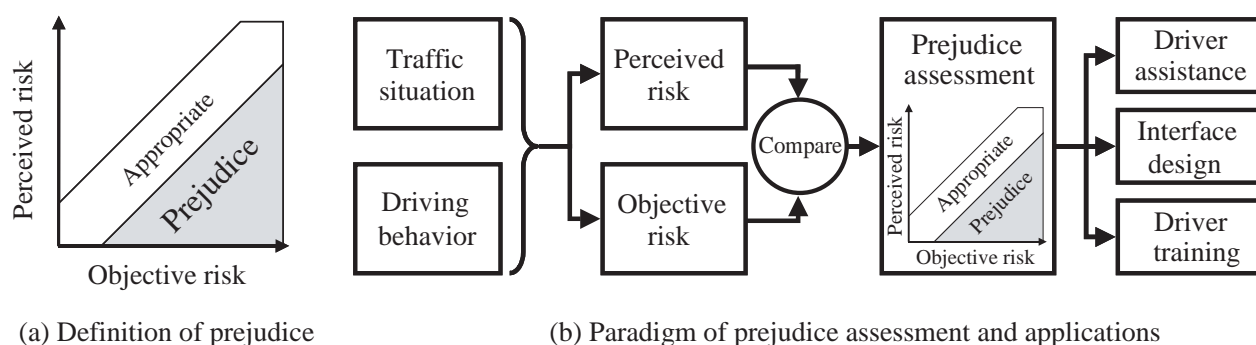


Fig. 1 Prejudice assessment and its applications.

used to calculate the degree of risk perception (R_i) from these three parameters:

$$R_i = (D_i + S_i) M_i \dots\dots\dots(1)$$

where, M_i is configured in such a way as to mitigate the effect of D_i and S_i , both of which have only a slight relationship with risk perception. For example, drivers usually decelerate if they see a red signal or a stop sign. Similarly, drivers usually decelerate and steer when faced with an intersection. These operations are performed not for the purpose of avoiding risk but to obey the traffic rules governing the situation.

We evaluated the performance of SUPREME using four driver subjects, and applied the method to an actual driving situation. The correlation coefficients between the risk, as estimated by SUPREME, and the subjectively rated risk were calculated, assuming the rated risk to be the correct degree of risk perception. The maximum and average correlation coefficients obtained were $r = 0.85$ and $r = 0.53$, respectively (**Fig. 2**). We regard SUPREME as being a simple and convenient means of estimating the degree of a driver's risk

perception.

2.2 Simulator and prejudice assessment

A driving simulator known as the Toyota Educational Driver-Diagnosis System (TEDDY) was developed to allow us to easily assess a driver's prejudice (**Fig. 3**). TEDDY is equipped with a video-based visual display that allows us to simulate driving by controlling the playback speed of the video according to the vehicle velocity that would be attained by the driver's pedal operations. Although TEDDY is a simple simulator, drivers can perceive risks visually from video stimuli.

SUPREME was implemented with TEDDY, and the degree of risk perception was estimated in real time. Furthermore, risk perception data that had been obtained previously from driving school instructors was stored in TEDDY. The instructors' data was used as the "objective risk" for each course, assuming the instructors to be experts who are capable of perceiving normative risks in a range of traffic situations. Therefore, the average risk perception for 13 male instructors (age: 28 to 58 [avg. 39.0], years as instructor: 5 to 30 [avg. 15.2])

Table 1 Classifications of driving behaviors and traffic situations.

(a) Intention to decelerate		(b) Intention to steer	
Pedal actions	D	Steering actions	S
Stepping on gas pedal strongly	0	No steering	0
Stepping on gas pedal lightly	1	Light, slow steering	1
Foot placed on gas pedal	2	Moderate steering	2
Foot placed on brake pedal	3	Wide, fast steering	3
Stepping on brake pedal lightly	4	Extremely wide, fast steering	4
Stepping on brake pedal strongly	5		
Stepping on brake pedal very strongly	6		
(c) Modification coefficient			
Traffic situations	M		
Avoidance is required without reference to risk perception	0.5		
- Stop sign exists			
- Signal is red or yellow			
- On-street parked car exists			
- Obstacle lies in path of car			
- Vehicle turning in intersection			
Other	1.0		

was used as the objective risk.

By using TEDDY, the degree of a driver's prejudice (P_t) was calculated using Eq. (2):

$$P_t = (RI_t - R_t) / SI_t \quad \dots\dots\dots (2)$$

where, RI_t is the averaged instructors' risk (objective risk) at time t , and SI_t is the standard deviation. Assuming that RI_t conforms to a normal probability distribution, 68% of the instructors' data is included within $|P_t| \leq 1$, 95% within $|P_t| \leq 2$, and almost 100% within $|P_t| \leq 3$. Therefore, we defined the assessment standards for prejudice as follows: if $P_t \leq 1$ then the prejudice level is "low", if $1 < P_t \leq 2$ then it is "rather high", if $2 < P_t \leq 3$ then

it is "high", and if $P_t > 3$ then it is "very high". In this report, we deal only with positive P_t values; negative P_t values are omitted from the figures.

3. Experiment

3.1 Detection of prejudiced traffic situation

The validity of the prejudice assessment was investigated by analyzing whether the accidental risk was higher in situations in which the degree of prejudice was assessed as being higher using TEDDY. Sixty driver subjects (53 males and 7 females, age: 24 to 79 [avg. 54.5], years driving: 3 to 55 [avg. 29.3], driving frequency: 1 to 30 h/week

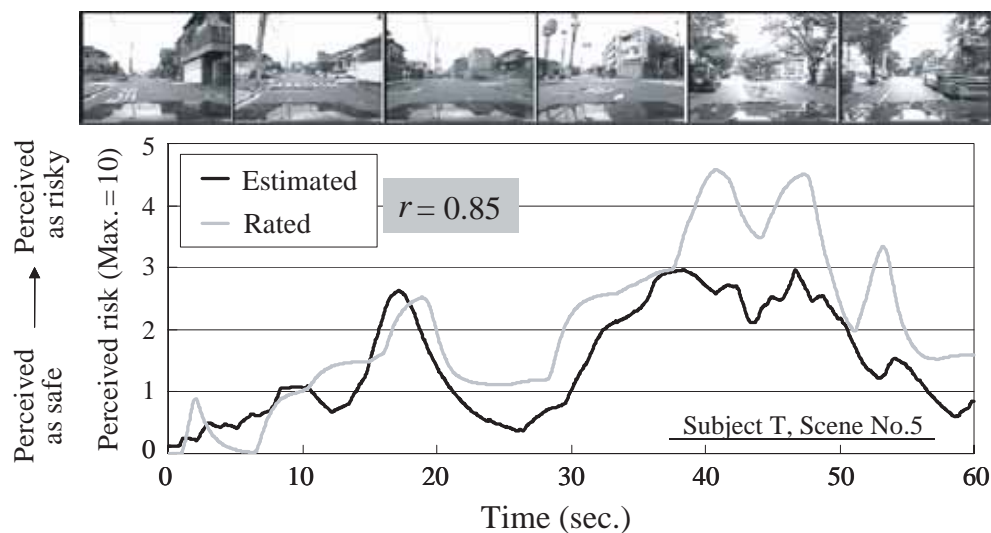


Fig. 2 Sample of perceived risk estimation by SUPREME.

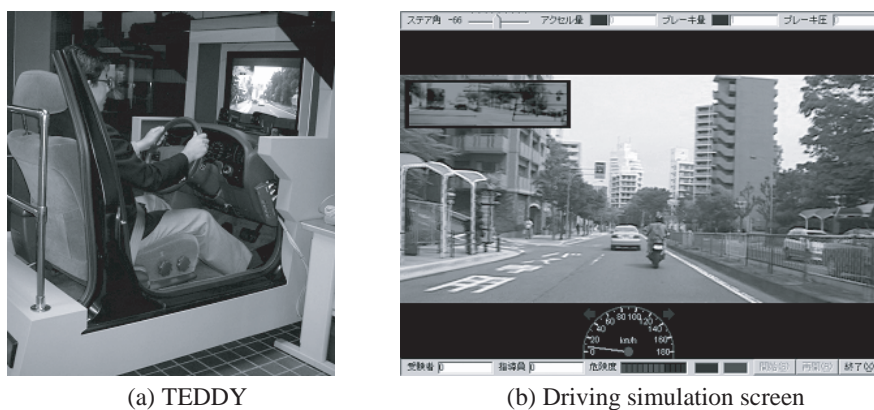


Fig. 3 TEDDY: Driving simulator for prejudice assessment.

[avg. 6.6 h/week]) participated in the experiment. They drove two course series, named course 1 (about four minutes in duration) and course 2 (about 2.5 minutes). The videos for both courses had been recorded by us while driving along a public road in Nagoya, Japan.

The average degree of prejudice (P_t) for the 60 subjects was a maximum ($P_t=3.53$) at a given instant (frame No. 4584) on course 1 (Fig. 4(a)). At this point, the vehicle approached a bicycle on the left and had to follow it for a while. There would have been a danger of this bicycle possibly wobbling into the vehicle's path because of the rider not being alert and not noticing the approaching vehicle. In such a situation, there would be a danger of the vehicle colliding with the bicycle.

Figure 4(b) shows a time series of the average vehicle velocity for the 60 subjects and 13 instructors for the previous 150 frames (about 5 s) to the next 60 frames (about 2 s) of this scene. The instructors started decelerating about 2.5 seconds before this scene. Their velocity at the actual scene was about 13 km/h. The instructors all aimed to maintain a significant distance from the bicycle. In contrast, the subjects failed to decelerate and maintained a velocity of about 20 km/h while

following the bicycle. Considering the usual velocity of bicycles, it would be difficult to avoid the bicycle if it crossed into the path of the vehicle. We could infer that the subjects had assumed that the bicycle would not cross into their path; that is, they had attained the state of prejudice.

3.2 Prejudice and accident proneness

It is well known that some drivers are prone to causing accidents (the so-called "accident-prone" drivers). Maruyama and Kitamura⁴⁾ invented the Speed Anticipation Reaction Test (SART) for detecting accident-prone drivers. In SART, a target object moves from the right of the screen to the left at a constant speed. It then moves behind a masking object and stops moving. The test subjects were instructed to react by pushing a key at the same time as the target object reemerged from behind the masking object, assuming that the target continues to move at the same speed. The latency from the masking of the target until the subjects' reaction were recorded as their speed anticipation performance (anticipation time; AT). In fact, previous studies revealed that drivers who react significantly earlier or later than the correct AT (2.08 s) experience several accidents.

Fifty-four subjects (47 males and 7 females, age:

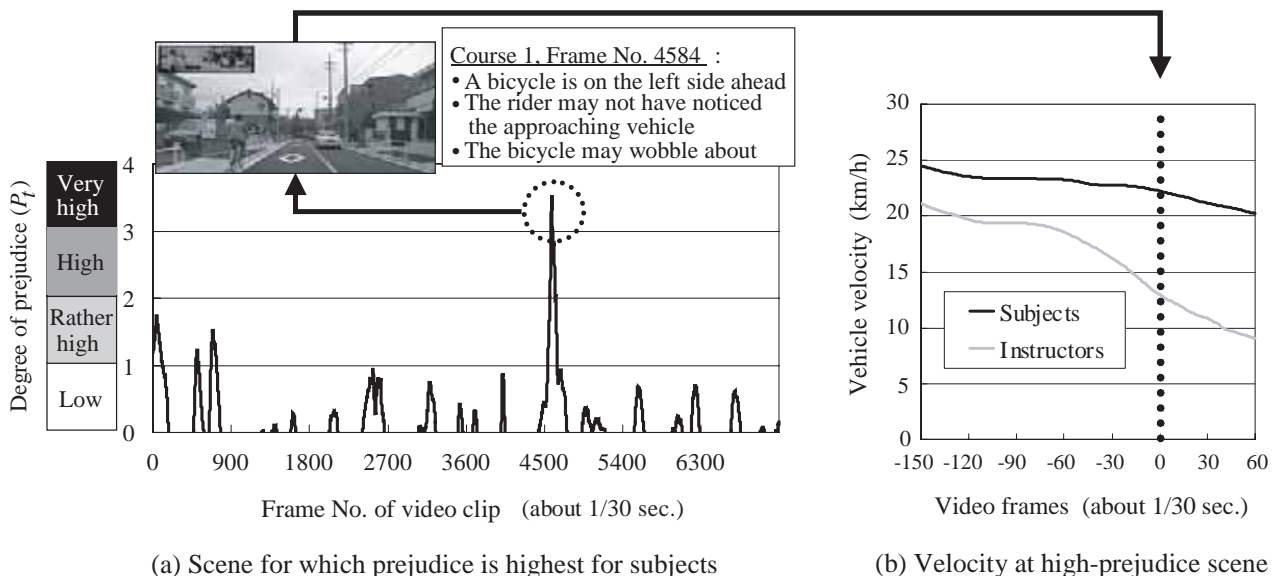


Fig. 4 Vehicle velocity at high-prejudice scene.

24 to 77 [avg. 52.1]) out of above 60 subjects, obliged us by taking the SART. They were then divided into three groups according to their AT ; namely, the early group ($AT < 1.5$, $N = 20$), the proper group ($1.5 \leq AT \leq 2.5$, $N = 26$), and the late group ($AT > 2.5$, $N = 8$).

Meanwhile, the Prejudice Quotient (Q), as defined by Eq. (3), was calculated for each subject and for each course:

$$Q = \frac{1}{T} \sum_{t=1}^T P'_t \quad \dots\dots\dots (3)$$

where, T is the total number of frames for each course, and for which Eq. (4) is used to calculate P'_t :

$$P'_t = \frac{1}{2} \{ \text{sign}(P_t - 1) + 1 \} P_t \quad \dots\dots\dots (4)$$

In short, Q is the averaged P_t that is assessed over the "rather high" range through a course. A driver who has a higher Q is assumed to have a tendency to be prejudiced in a greater number of traffic situations.

The mean Q s of the two courses were compared between groups (Fig. 5). The result of ANOVA showed the significant effect of the groupings [$F(2, 51)=4.32, p<0.05$]. Multiple comparisons by LSD indicated that Q of the early group was significantly higher than that of the proper group ($p<0.01$), and that Q of the late group tended to be higher than that of the proper group ($p<0.10$). These

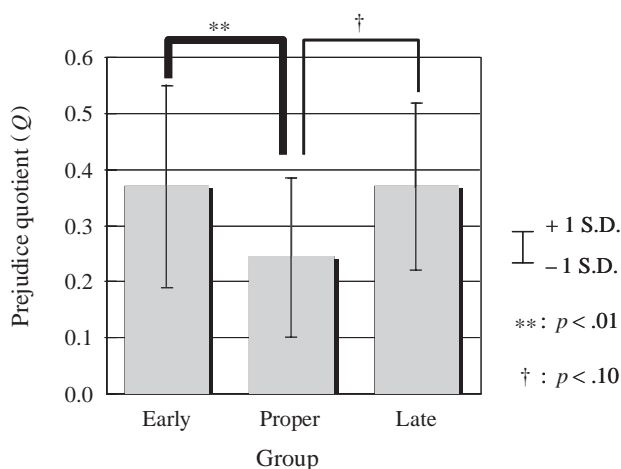


Fig. 5 Relationship between prejudice quotient and SART (accident proneness).

results suggest that those drivers with a higher degree of prejudice are more prone to causing accidents. Therefore, the estimation of risk perception by SUPREME and the assessment of prejudice by TEDDY can be considered valid.

4. Conclusion

It has been empirically stated that a driver's lack of risk perception is mainly associated with traffic accidents. In the past, however, a driver's risk perception ability could only be measured qualitatively and offline by using a desk-checked Q&A type Risk Perception Test.⁵⁾ Such qualitative data is difficult to apply to some driver assistance systems because the systems usually need real-time quantitative data.

The proposed SUPREME method enables us to quantitatively estimate the degree of a driver's risk perception in real-time by using driving behavior data. SUPREME can be readily applied to driver assistance systems that modify assistance strategies based on the driver's level of risk perception. It can also be applied to human-machine interface designs for driver assistance systems that prevent a driver's risk perception from falling too low.

Additionally, a driver's prejudice as assessed by TEDDY reflected the degree to which a driver is accident-prone. Thus, TEDDY is suitable for application to driver training. Instructors can give adequate advice to each student based on the results of their using TEDDY. The advice based on the objective data obtained from the driving behaviors is considered to be highly persuasive and more accurate than conventional aptitude tests. Currently, a trial of TEDDY is being carried out at a driving school. Thanks to this, we will soon have access to substantial amounts of basic data for analysis.

We aim to develop new methods to reduce a driver's prejudice and subsequently develop new driver assistance systems. Future studies will propose an ideal mode of interaction between drivers and vehicles in the ITS epoch.

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