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The relationship between attentional bias toward safety and driving behavior

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ABSTRACT

As implicit cognitive processes garner more and more importance, studies in the fields of healthy psychology and organizational safety research have focused on attentional bias, a kind of selective allocation of attentional resources in the early stage of cognitive processing. However, few studies have explored the role of attentional bias on driving behavior. This study assessed drivers' attentional bias towards safety-related words (ABS) using the dot-probe paradigm and self-reported daily driving behaviors. The results revealed significant negative correlations between attentional bias scores and several indicators of dangerous driving. Drivers with fewer dangerous driving behaviors showed greater ABS. We also built a significant linear regression model between ABS and the total DDDI score, as well as ABS and the number of accidents. Finally, we discussed the possible mechanism underlying these associations and several limitations of our study. This study opens up a new topic for the exploration of implicit processes in driving safety research.

1. Introduction

The exploration of cognitive factors related to driving safety has been the subject of several recent research studies, and may help to reduce traffic accidents and improve road safety. Information is typically processed via two types of processes: "explicit processes," which require consciousness and "implicit processes," which do not. Like most studies on human cognitive resources, those concerning driving safety have primarily focused on explicit cognitive processes, exploring how these processes can affect and predict driving behavior. These studies have explored the relationships of driving behavior with speed perception (e.g., Milošević and Milić, 1990), working memory (e.g., Ross et al., 2014), executive control function (e.g., Almahasneh et al., 2014), and so on. During these explicit processes of cognition, subjects are generally consciously aware of and able to monitor their performance, which is usually measured using self-reports. However, researchers have gradually realized the significant influence of information processing that occurs outside of consciousness (i.e., the implicit processes) on our attitudes, emotions, thoughts, and behavior (Olson and Fazio, 2003; Evans, 2008; Dijksterhuis, 2010). Related work in the field of driving safety is still scarce. Through analyzing early research, we began to realize that some possible bias and selectivity of attention during the early stages of information processing may have important effects on individuals' safety-related behaviors, which have long been neglected in traffic-safety research. One factor that deserves further investigation is the concept of "attentional bias," meaning the selective allocation of attentional resources toward specific aspects of stimuli (Williams et al., 1988). This is important because we need to process a lot of information most of the time, and it is necessary to apply some strategies for noting those cues that are fatal for life (e.g., natural enemies). This is especially true during driving, because this task continually requires attentional resources and involves a certain risk. Fortunately, researchers in a domain closely connected to driving, the safety research domain, which primarily explores employees' safety behaviors in the workplace, have recently focused on the role of implicit processes in safety behavior (e.g., Barsade et al., 2009; Harms and Luthans, 2012). They have found that several implicit processes can indeed predict employees' safety behaviors in the workplace, including automatic association (reflecting individuals' implicit attitudes) (Marquardt et al., 2012) and attentional bias toward safety-related stimuli (Xu et al., 2014). This implies that attentional bias may also affect people's safety behavior when they are driving cars, considering the interconnection between organizational safety behavior in the workplace and safety behavior while driving.

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1.1. Implicit processes and safety behavior

Typical underlying implicit processes include (a) automatic association, (b) attentional bias, and (c) automatic approach–avoidance tendencies (Wiers and Stacy, 2006). Automatic association reflects people's attitudes toward specific stimuli stored in long-term memory, and is usually measured through the implicit association test (IAT), while automatic approach–avoidance tendencies are a behavioral mode of approach or avoidance that is automatically activated by environmental stimuli (Hofmann et al., 2009).

In our work, we focus on attentional bias, which refers to the selective allocation of attentional resources toward specific aspects of stimuli (Williams et al., 1988). This process, which is automatic and occurs outside of consciousness, reflects individuals' selective addressing of stimuli relevant to their particular goals and concerns in order to save their limited cognitive resources in the early stage of environmental information processing (Williams et al., 1988). Numerous studies were conducted on attentional bias toward emotional information, especially the negative affect (MacLeod et al., 1986; Williams et al., 1996; Fox et al., 2001; Yiend, 2010), which are generally linked to emotional disorders (Van et al., 2014). It was then observed that attentional bias also occurs in the case of some other categories of stimuli. Evidence shows that individuals with particular psychological characteristics (Teachman et al., 2007) or behaviors (Cohen et al., 1998; Brevers et al., 2011; Veenstra et al., 2010) display attentional bias toward specific stimuli or cues. For example, heavy drinkers exhibit greater attentional bias toward alcohol-related cues than do social drinkers (Fadardi and Cox, 2009). An individual's further suicide attempts can be significantly predicted by attentional bias toward suicide-related cues (Cha et al., 2010). Optimism is associated with a greater attentional bias toward positive stimuli relative to negative stimuli (Segerstrom, 2001). Attentional bias reflects a relatively stable characteristic of one's cognitive processes in the early stage. When something becomes a major goal in a person's life, the corresponding motivational state called *current concern* (Cox and Klinger, 1990, 2004), will activate, direct, and maintain goal-related cognitive processes in implicit, automatic ways (Cox and Klinger, 2004). Having a current concern will energize and direct the person's thoughts and behavior toward goal-related stimuli, then develop attentional bias toward these stimuli. More importantly, attentional bias is not simply a by-product of behavior but plays a vital role in behavioral causation and maintenance (Williams et al., 1996). For example, the causal and maintenance effect of attentional bias on emotional disorders have been generally studied and discussed (see Van et al., 2014).

Among these implicit processes, automatic association has been relatively well investigated in safety research. Marquardt et al. (2012) used the IAT and found that an automatic association between "I" and "safety" could significantly predict safety performance. With regard to driving behavior, it was recently discovered that an automatic association between "positive/negative" and "safe/risky driving" predicted participants' real driving behavior (Martinussen et al., 2015), suggesting that implicit processes indeed have some effect on driving behavior. Recently, an early attempt began to explore attentional bias (Xu et al., 2014), in which researchers reported that in high-risk industries in which safety is a priority, employees who value safety highly may pay more attention to and be more sensitive to stimuli and cues relevant to safety (i.e., show attentional bias toward safety, ABS) compared to employees who value safety poorly. Thus, ABS may be an indicator for safety performance. The authors explored the relationship between the ABS of workers in a nuclear power plant and a coal company and their safety performances; the results showed a significant positive correlation between ABS and two types of safety behavior: safety compliance and safety participation. They also examined the possible underlying mechanism, and concluded that ABS may lead to greater perceived safety climate and safety motivation, and thereby influence behavior. That is to say, people with higher ABS may find it easier to perceive cues relevant to safety in a given context (e.g., safety posters, feedback of experience from events) and thus perceive a more positive safety climate; they would also be more highly motivated to adopt safety measures. Mounting evidence from safety research studies shows that implicit processes do indeed influence safety behavior (e.g., Marquardt et al., 2012; Xu et al., 2014). Researchers also have attempted to investigate the effects of implicit processes on driving behavior, but the related work remains scarce.

1.2. Driving behavior and organizational safety behavior

Thus far, we have focused on findings pertaining to implicit processes from safety research, since direct evidence from driving research is absent. Safety research, unlike driving research, which focuses on a more specific behavior (i.e., driving), is aimed at organizational safety behavior in a work organization, and primarily concerns the effects of situation- and person-related factors on employees' safety behavior (i.e., safety compliance and safety participation) and subsequent injuries and accidents in the workplace (Christian et al., 2009). Strictly speaking, the road traffic system cannot be regarded as completely equivalent to a work organization, considering that typical hazardous industries, such as nuclear power plants and coal companies, differ in many ways from the road traffic context (Nævestad and Bjørnskau, 2012). Even so, some researchers think that it is possible to apply some concepts and factors from safety research to the domain of road traffic and driving safety research, for example, safety culture and safety climate, which have recently attracted widespread attention. Nævestad and Bjørnskau (2012) discussed the possibility of the safety culture perspective being applied to road traffic (i.e., traffic safety culture), and concluded that the key is to find an analytical unit equivalent to organizations in the road traffic system. They thought that the peer group alternative seemed to be a proper one. There are studies designed to explore organizational safety culture and safety climate among professional (or work-related) drivers in road transport (e.g., Davey et al., 2006). In fact, many ideas of safety research have provided new insights into traffic safety problems.

1.3. ABS and driving behavior

As discussed earlier, implicit processes, including automatic association and attentional bias toward surrounding environmental cues, affect our safety behavior without us being aware of it, when we are working or more specifically, driving. This raises the question of whether ABS influences driving safety performance in the way it affects organizational safety behavior as reported in previous studies (e.g., Xu et al., 2014). We think the mechanism via which ABS influences safety behavior (i.e., through safety climate and safety motivation) is also applicable to driving behavior. Drivers with higher ABS may allocate more attentional resources toward safety-related cues and perceive a greater safety climate, and may also be more willing to adopt safety measures (i.e., have a greater safety motivation) and thus drive more safely. Considering that previous studies have primarily focused on explicit processes rather than implicit processes, which may also influence drivers' behavior, our aim in this study is to determine whether ABS can predict the safety of drivers' daily driving behavior.

Based on our analysis above, we made the following hypotheses: (a) drivers' ABS is negatively correlated with the scores of self-reported dangerous-driving indicators, and drivers with fewer self-reported dangerous-driving behaviors show greater ABS than those with more dangerous-driving behaviors, and (b) drivers' ABS is negatively correlated with the number of accidents during the last 3 years, and drivers with fewer accidents show greater ABS than those with more accidents.

2. Methods

2.1. Participants

The experiment involved a sample of 68 adult drivers (45 men), who were recruited by posting announcements about the experiment on the bulletin board systems of local universities and information websites. The participants consisted of urban residents in Beijing and students from colleges and universities in Beijing, including undergraduates and graduate students. The participants' ages ranged from 20 to 39 years (M = 28.68 years, SD = 5.30 years). All participants were licensed drivers with more than 1 year of driving experience. The average participant had been driving for 5.37 years (SD = 4.12 years) since obtaining a driver's license.

2.2. Measures

2.2.1. ABS

ABS was measured using a visual dot-probe task (MacLeod et al., 1986; Xu et al., 2014). The participants needed to complete the practice and formal trials on a computer. In a single trial, one word each was initially presented on the left side and right side of the screen. Then, the words disappeared, and a dot appeared at the one of the locations of the two words. Participants were asked to respond on which side (left or right) the dot appeared. This allowed us to assess the extent to which participants initially oriented themselves towards a particular stimulus. For formal trials, one of the two words was safety-related, while the other was neutral. If one has high ABS, which means that attention was automatically directed towards the safety word, he/she is assumed to respond faster to the dot appearing at the location of the safety word than to the dot appearing at the location of the neutral word. The difference between the reaction latency in these two conditions represents the extent of ABS. We presumed that participants with more dangerous driving performance would show a smaller degree of ABS in the dot-probe task.

The six safety-related words used in this experiment were "safety," "cautiousness," "caution," "carefulness," "concentration," and "calmness," and the six neutral words were "orientation," "speed," "space," "road," "efficiency," and "target." These words were selected on the basis of previous studies (Marquardt et al., 2012; Xu et al., 2014) as well as by considering the specific context of driving. All these words are common two-character, Chinese, driving-related words. The participants completed 96 formal trials during which every word would be presented 16 times. In half of the trials, safety-related words appeared on the left side, while in the other half, they appeared on the right. Also, in half of the trials, the dot appeared at the location of the safety-related word (i.e., the congruent condition), and in the other half, it appeared at the location of the neutral word (i.e., the incongruent condition). The sequence of the locations of the words and dots was randomized. Before the 96 formal trials, the participants needed to finish 20 practice trials using another group of ten neutral words that were unrelated to driving: "table," "pencil," "floor," "air," "window," "clothes," "tree," "stone," "people," and "tool."

Participants were seated 60 cm away from a 19-inch CRT display. Each trial began with a fixed "+" presented at the center of a black screen for 500 ms. Then, one word each was presented on the left and right sides of the screen for 500 ms. The font was Times New Roman in size 16. Harkness et al. (2009) used size 12 font, but we made an adjustment according to the size of our display and the distance between the participants' eyes and the screen to ensure that the participants could see the words clearly. The viewing angle of the distance between the center of the two words was 3°. After the word pair had disappeared, a round dot, the viewing angle of the diameter of which was 0.2°, was presented at the location of one of the two words. The participants were instructed to press the "up" key if the dot appeared on the left side and the "down" key if it appeared on the right (we did not choose the "left" and "right" keys to avoid the potential influence of consistency of location). The dot disappeared after the response or after 3 s in case no response had been made. Following this, a blank screen was presented for 500 ms, and then, the next trial began. In addition, during the practice period, every response was given an immediate feedback with the word "right" or "wrong" presented in the center of the screen for 1000 ms. That was for the purpose of helping the participants to learn and ensure the match of the keys and the responses. In the formal trials, this feedback was not included to avoid the potential influence of the feedback of a trial on one's response in the next trial.

The ABS index was calculated by subtracting the latencies under the congruent condition from the latencies under the incongruent condition. Thus, a greater ABS index indicated a greater degree of attentional bias toward safety.

2.2.2. Driving behavior

2.2.2.1. Dula dangerous driving index. The Dula Dangerous Driving Index (DDDI) is a self-reported questionnaire developed by Dula and Ballard (2003) to assess individual propensities for dangerous driving. All 28 items of this index describe a series of dangerous behaviors related to driving, like "I still drive when I am mad or frustrated." The participants rated how often they do these behaviors in their daily lives on a 5-point Likert scale ranging from 1 ("never") to 5 ("always"). The DDDI has four dimensions: negative cognitive/emotional driving (NCE; 9 items), aggressive driving (AD; 7 items), risky driving (RD; 10 items), and drunk driving (DD; 2 items) (Willemsen et al., 2008), which was included under the RD dimension in the initial edition. The total DDDI score was determined by adding the scores of all items, and the four subscale scores were determined by adding the scores of items belonging to each subscale.

The DDDI was proved to have good reliability, with a Cronbach's alpha coefficient of 0.94; the subscales NCE (α = 0.85), AD (α = 0.84), and RD (α = 0.83) were also highly reliable (Dula and Ballard, 2003), but the DD subscale was not (α = 0.62) (Qu et al., 2014). In this study, we adopted the Chinese version of the DDDI compiled by Qu et al. (2014), which supports the four-factor model, and has good convergent validity and criterion validity. The Cronbach's alpha coefficient was 0.90 for the total DDDI, 0.80 for NCE, 0.78 for AD, 0.78 for RD and 0.63 for DD.

2.2.2.2. Driver behavior questionnaire. The Driver Behavior Questionnaire (DBQ) is another scale measuring dangerous-driving behaviors, and was developed by Reason et al. (1990). This self-administered questionnaire includes 28 items describing several illegal or wrong behaviors likely to happen when driving, such as "hit something when reversing that you had not previously seen." A 5-point Likert scale ranging from 1 ("never") to 5 ("nearly always") is used to measure the frequency at which people usually engage in these behaviors. Initially, the DBQ as described by Reason et al. (1990) contained three dimensions: violations (12 items), errors (8 items), and lapses (8 items). Lawton et al. (1997) further divided the dimension violations into aggressive violations (3 items) and ordinary violations (9 items). This four-factor model was supported by some researchers (Gras et al., 2006; Mesken et al., 2002). We used the four-factor model in our study, and calculated the subscale scores by adding the scores of items belonging to each subscale.

In this study, we adopted the Chinese version of the DBQ (Yang et al., 2013). The reliability of this version was moderately good, with Cronbach's alpha coefficients for the four subscales being 0.75 (for the aggressive violations subscale), 0.74 (for the ordinary violations subscale), 0.70 (for the errors subscale), and 0.81 (for the lapses subscale).

2.2.2.3. Accident involvement. Participants self-reported the number of accidents they had been involved in during last 3 years, including less serious accidents in which nobody needed to go to hospital or in which the property loss was no more than 2000 yuan RMB, and relatively serious accidents in which someone needed to go to hospital or in which the property loss was over 2000 yuan RMB. Penalty points and fines during the last year were also asked. The number of accidents is a common indicator of driving behavior (e.g., Gehlert et al., 2014), while penalty points and fines, which are not always related to dangerous driving and may be related to situations such as being fined because of parking, were used as a reference when screening participants. Only the number of accidents has been reported in the results.

2.2.3. Sociodemographics

Several sociodemographic variables were measured, including gender, age, education, background, and marital status, as well as some basic information about daily driving, including number of years driving, type of license, driving mileage, and vehicle type.

2.3. Procedure

All participants were informed that their information would be strictly confidential, and would be used only for scientific research. After they filled in the consent form, the participants took part in the experiment. First, the participants were led to a 3.5 m × 2.3 m single room and given an overview of this study. The first step was to finish the dot-probe task, prior to which instructions were displayed on the computer screen. After that, driving behaviors were tested using the DDDI and DBQ, assisted with self-reports of accident involvement. At last, demographic variables were measured. The whole procedure took about 50 min, and every participant was paid 50 yuan RMB (approximately USD 8). The study was approved by the Institutional Review Board of the Institute of Psychology, Chinese Academy of Sciences.

3. Results

3.1. Descriptive statistics

The percentage of incorrect responses in the dot-probe task ranged from 0 to 6.25% (M = 1.19%, SD = 1.39%). These trials were not analyzed any further (Keogh et al., 2001; Xu et al., 2014). The response data of subject no. 42, whose error rate was more than 3 SD from the mean, were excluded as outliers; thus, we had 67 valid subjects.

The mean reaction times in the congruent condition (i.e., the dot and safety-related words were in the same locations) and incongruent condition (i.e., the dot and safety-related words were in different locations) were 467.02 ms (SD = 55.89 ms) and 468.81 ms (SD = 58.55 ms), respectively. The paired-samples t-test revealed no significant difference between the RTs under the two conditions (t (66) = −0.83, p = 0.41), which implied that the participants as a whole did not show any holistic tendency of ABS.

Table 1 shows the descriptive statistics for each indicator of driving behavior, including the total score and four subscale scores of the DDDI, the four subscale scores of the DBQ, and the number of accidents during last 3 years.

Table 1
Descriptive statistics for indicators of driving behavior.

	Mean (ms)	SD
Total DDDI	66.12	16.34
NCE	25.07	6.16
AD	15.28	4.52
RD	22.79	6.81
DD	2.97	1.30
Aggressive violations	7.60	2.54
Ordinary violations	18.25	4.87
Errors	14.10	4.22
Lapses	16.70	4.29
Number of accidents	2.21	2.13

3.2. Correlation analysis of ABS and driving behavior

The ABS index of each participant was calculated by subtracting latencies under the congruent condition from latencies under the incongruent condition. The mean of all people's ABS scores was 1.79 ms (SD = 17.76 ms). The correlations between ABS and all indicators of driving behavior are shown in Table 2. ABS showed significant negative correlations with the total DDDI score (r = −0.24, p < 0.05), RD score (r = −0.26, p < 0.05), aggressive violations score (r = −0.25, p < 0.05), and number of accidents (r = −0.25, p < 0.05), and marginally significant negative correlations with NCE score (r = −0.22, p = 0.074), ordinary violations (r = −0.22, p = 0.070), and lapses (r = −0.24, p = 0.055).

3.3. Do drivers with fewer dangerous behaviors exhibit greater ABS?

To answer this question, we selected participants whose driving behavior scores were higher and lower than the median value to form a high-dangerous group and a low-dangerous group respectively. Based on the 10 indicators of driving behavior listed in Table 1, we made 10 pairs of groups (20 groups in total), of which the number of participants and descriptive statistics of ABS scores are shown in Table 3. The independent-samples t-tests revealed that ABS scores in the low RD group (t (48.10) = 2.08, p < 0.05), low aggressive violations group (t (54) = 2.53, p < 0.05), low ordinary violations group (t (61) = 2.17, p < 0.05), and small number of accidents group (t (51) = 2.77, p < 0.01) were significantly greater than those in the corresponding high-dangerous groups. Moreover, the same discrepancy in ABS scores was observed between the low and high total DDDI score groups (t (62) = 1.95, p = 0.055) as well as between the low and high errors groups (t (59) = 1.82, p = 0.074), with the differences reaching marginal significance.

3.4. Can ABS predict driving behavior?

To answer this question, we used ABS as the independent variable and the indicators of driving behavior as dependent variables (one at a time) to try to build linear regression equations. We chose two driving-behavior indicators to build equations: the total DDDI score and the number of accidents, which represented self-reported driving behaviors and the consequences of these behaviors, respectively. In addition, the participants' age and number of years driving were generally revealed to be related with driving behavior and needed to be controlled. Therefore, before building the regression equations, we conducted linear correlation analyses between the above two sociodemographic parameters and the two driving-behavior indicators. For the total DDDI score, the correlations with age and number of years driving were not significant, so we only

Table 2
Correlations of ABS with indicators of driving behavior.

	1	2	3	4	5	6	7	8	9	10
1. ABS	–									
2. Total DDDI	−0.24*	–								
3. NCE	−0.22^{+}	0.90**	–							
4. AD	−0.17	0.88**	0.72**	–						
5. RD	−0.26*	0.92**	0.71**	0.73**	–					
6. DD	−0.06	0.45**	0.33**	0.31**	0.37**	–				
7. Aggressive violations	−0.25*	0.81**	0.77**	0.75**	0.69**	0.29*	–			
8. Ordinary violations	−0.22^{+}	0.78**	0.66**	0.61**	0.80**	0.30*	0.66**	–		
9. Errors	−0.20	0.51**	0.51**	0.28**	0.53**	0.28*	0.53**	0.57**	–	
10. Lapses	−0.24^{+}	0.40**	0.41**	0.21**	0.39**	0.27*	0.45**	0.39**	0.73**	–
11. Number of accidents	−0.25*	0.17	0.23	0.04	0.18	−0.03	0.39**	0.31*	0.36**	0.35**

$^{+}p < 0.1$ (two-tailed).
$^{*}p < 0.05$ (two-tailed).
$^{**}p < 0.01$ (two-tailed).

Table 3
Mean, SD, and results from the independent-samples *t*-test for ABS scores for each pair of high- and low-dangerous groups.

Group	*n*	Mean (ms)	SD	*t*	*df*	*p*
Low total DDDI	31	6.08	19.64	1.95	62	0.055^{+}
High total DDDI	33	−2.51	15.42			
Low NCE	32	4.46	18.60	1.53	63	0.132
High NCE	33	−2.05	15.74			
Low AD	31	3.93	18.44	0.19	57	0.85
High AD	28	3.07	16.70			
Low RD	30	6.21	21.46	2.08	48.10	0.043*
High RD	32	−3.30	13.42			
Low DD	30	5.44	18.05	1.39	45	0.17
High DD	17	−1.50	12.86			
Low aggressive violations	33	5.60	16.54	2.53	54	0.014*
High aggressive violations	23	−6.03	17.47			
Low ordinary violations	33	6.81	15.47	2.17	61	0.034*
High ordinary violations	30	−2.21	17.52			
Low errors	32	4.60	16.40	1.82	59	0.074^{+}
High errors	29	−3.49	18.34			
Low lapses	27	2.98	17.15	1.16	58	0.251
High lapses	33	−2.17	17.10			
Small number of accidents	30	9.76	16.29	2.77	51	0.008**
Large number of accidents	23	−3.11	17.43			

Note: *p* is the significance level of the independent-samples *t*-test for ABS for each pair of driving-behavior groups.
$^{+}p < 0.1$ (two-tailed).
$^{*}p < 0.05$ (two-tailed).

entered ABS into the regression model. The results showed that we could build linear regression equations between ABS and the total DDDI score. The multiple correlation coefficient (R) was 0.24, and the coefficient of determination (R^2) was 0.058, which implied that ABS could account for 5.8% of the variation in the dependent variable "the total DDDI." The results of analysis of variance were $F = 4.03$ and $p < 0.05$, which indicated that the linear correlation between ABS and the total DDDI score was significant. In the linear model, the regression coefficient of ABS was −222.28 ($p < 0.05$), and the constant was 66.52 ($p < 0.001$).

For the number of accidents, there was only a marginal correlation with age ($r = 0.21$, $p = 0.082$) and no significant correlation with the number of years driving. Thus, we chose ABS as an independent variable and controlled age using the stepwise method to build the model. The results showed that the model was significant ($R = 0.36$, $R^2 = 0.13$, $F = 4.64$, $p < 0.05$). The regression coefficient of ABS was −34.47 ($p < 0.05$), while that of age was 0.10 ($p < 0.05$), and the constant was −0.68 ($p = 0.622$).

4. Discussion

This study explored the relationship between drivers' ABS and their daily driving behavior. This is the first attempt concerning the role of attentional bias, an important implicit cognitive process, on driving behavior and traffic safety. The results demonstrated a significant negative correlation between ABS and dangerous driving behavior, including the self-reported total DDDI, risky driving, aggressive violations and number of accidents (ordinary violations and lapses also reached marginal significance). Moreover, drivers with fewer dangerous driving behaviors, mainly reflected by risky driving, aggressive violations, ordinary violations, and number of accidents, exhibited greater ABS. We further conducted a linear regression analysis and found that a linear regression model could be built between the total DDDI score and ABS as well as between the number of accidents and ABS and age. The results supported that like explicit processes, implicit processes such as attentional bias played an important role in determining final driving performance. Thus, we concluded that ABS may be an indicator to predict the safety of drivers' daily driving behavior and its potential bad consequences, and may therefore be useful in selecting professional or long-distance drivers.

As to the mechanism via which ABS affects driving behavior, we think that a possible explanation is that ABS affects driving behavior through changing drivers' perceived safety climate and safety motivation. We are inspired by the conclusion of the mechanism through which ABS affects safety performance in the workplace as described by Xu et al. (2014). Although different from the high-risk context of the workplace in hazardous industries in some aspects, the road traffic system is still an organization in which emphasis is laid on safety. There exist numerous specialized driving safety-related cues, including various traffic lights, traffic signs, traffic lines, and police command. It is reasonable to speculate that drivers with higher ABS may allocate more attentional resources toward these cues and perceive a more positive safety climate, and then drive more safely. In fact, the safety climate has been already applied to predict driving behavior; the concept is termed "traffic safety climate" and is defined as road users' (e.g., car drivers') attitudes toward and perception of current traffic conditions at a particular point in time, in a specific environment (Ozkan and Lajunen, 2011). Evidence has proved that different compositions of traffic safety climate are correlated with driving-related attitudes and behaviors such as risk perception, driving style, and second task performance (Gehlert et al., 2014). More specifically, we can divide dangerous driving behaviors into two forms: one form are slips and lapses (i.e., unintentional errors like switching on the windscreen wipers instead of the indicators), and the other are intentional violations (i.e., speeding to get to an appointment because you are late). On the one hand, a positive traffic safety climate perception has been revealed to be related to a higher risk perception of unsafe traffic behavior (e.g., distraction) (Gadd and Collins, 2002), thus may lead to more cautious attitudes and fewer errors and lapses. On the other hand, the links between perceived safety climate and safety rule violations has also been analyzed (Carr et al., 2003; Fogarty and Shaw, 2010). Fogarty and Shaw (2010) found that safety climate indirectly shaped intentions to violate and self-reported violations through individual attitudes, subjective norms and perceived behavioral control. Thus ABS may affect both unintentional driving errors and intentional violations via affecting perceived traffic safety climate. Meanwhile, higher ABS may also improve drivers' safety motivation, making them more willing to drive safely and avoid dangerous behaviors like distraction, speeding, running red lights, and abusing other drivers. It may also affect both unintentional behaviors (e.g., less distraction may lead to fewer lapses) and intentional behaviors (e.g., less motivations to avoid risks may lead to more violations). Confirming this hypothesis about the mechanism of the role of ABS in driving safety is the aim of our future research.

It is noteworthy that the linear correlations between ABS and indicators of driving behavior are generally weak (<0.04). We think it may due to several reasons. First, the sample size is small, especially since our participants are drawn from the adult driver group (large population). Second, the participants' driving experience, vehicle types and socio-demographic variables were various, thus may enlarge the standard deviations of the measures of driving behavior. It seems better for us to focus on a smaller and more homogeneous group (e.g., long-distance truck drivers). Moreover, the measurement of ABS was so precise that any possible disturbance may lead to large random errors. Those variances coming from individual differences and the random errors of measure may impair the effect of ABS.

Our discovery has certain theoretical meaning. Our current work has expanded the research on implicit processes in driving behavior and traffic safety. With our current understanding of dual-processing models, it is recognized that purely focusing on several traditional explicit cognitive processes, like cognitive distraction, working memory, and executive control function, is not enough in the driving behavior and traffic safety domain. Combining these processes with implicit processes that occur out of consciousness can help us to more deeply and fully understand driving, a type of sophisticated behavior that requires complicated cognitive processing. Martinussen et al. (2015) investigated drivers' implicit attitudes toward safety/risky driving, and the influence of these attitudes on practical driving behavior (thereby bringing in implicit processes in driving research for the first time). However, the transition from attitude to practical action is an indirect process. In contrast, attentional bias reflects the characteristic of information processing itself, and thus, may play a more direct and important role in the whole process from perceiving visual cues (e.g., road, signs, and pedestrians) to enacting a series of tasks (e.g., pressing the clutch, turning the steering wheel, and honking). The concept of attentional bias was initially mentioned in the driving field in a simulated driving task (Benedetto et al., 2013), aimed at confirming a feature of spatial attention: the asymmetry in spatial attention orienting (also known as pseudoneglect). Our study further considered the difference in different types of stimuli in a specific context. In the road traffic context, where safety-related stimuli may be more peculiar than others, more allocation of attention to such stimuli would help drivers perform better, and this fact also reflects the flexibility of our information-processing system. Even the very basic early stage of cognition is able to automatically convert into the most proper and efficient mode according to the specific environment.

Our work also has practical meaning. In general, it supplies a potential predictive indicator for selecting safer drivers. More importantly, the RT-based implicit measures have some advantages over self-reported explicit measures, since individuals are unable to manipulate the outcomes, and impression management and social desirability can be avoided to a large extent. Furthermore, it may be feasible to improve the safety of driving behavior by improving drivers' ABS through attentional bias training (Fadardi and Cox, 2009). For example, in the training version of the dot-probe task, the probe (almost) consistently appears behind the safety-related stimulus, such that attention has to be directed to the safety cues in order to indicate the location of the probe (e.g., Field and Eastwood, 2005; Friese et al., 2011).

There are several limitations of our study. First, since the experiment was performed on a campus, in which experienced drivers are relatively scarce, our number of subjects is not large, especially, considering that this was a correlation research study, and the objects of our investigation were an adult driver group. After the participants were divided into subgroups, the number of participants in some subgroups was smaller than 20. Second, we measured drivers' behavior mainly using self-report questionnaires. Although supplemented by reports of number of accidents as a subject indicator, we cannot completely exclude the possibility that ABS affect the way in which participants evaluate their behavior rather than their actual behavior. People who pay more attention to safety-related cues may selectively neglect or forget their unsafe behavior. However, it still needs to be demonstrated. Another limitation is that the safety-related words we used in our study were selected based on previous studies (Marquardt et al., 2012; Xu et al., 2014). However, these studies were aimed at work organizations, in which the safety-related cues may be different from those in traffic systems. Considering the specificity of driving, we can attempt to select words that are more alike to safety-related cues in the road traffic context in future research. These words may better distinguish safe drivers from dangerous drivers. Finally, we only used the dot-probe task to measure ABS because we think that the way that stimuli are presented in this paradigm is most similar to that in real scenes, and the task has been used before in safety-related research (e.g., Xu et al., 2014). However, there are incongruent results about the reliability of the paradigm (Schmukle, 2005; Bar-Haim et al., 2010), and its convergent validity with the Stroop task does not seem to be good enough (Van et al., 2014). Furthermore, the reliability and validity when stimuli are replaced with driving-related words and viewing angles are finely adjusted (as in our study) remain unknown. Finally, the overall reliabilities and validities of several other measures of attentional bias, like the spatial cuing paradigm, the visual search task, and the attentional blink task, are still unknown and deserve to be examined further in driving research. If their reliabilities and validities are satisfactory, further studies on ABS and driving behavior using various paradigms may supply stronger evidence for our conclusion.

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