Hindawi
Journal of Advanced Transportation
Volume 2024, Article ID 8474050, 19 pages
https://doi.org/10.1155/2024/8474050

Research Article

Correcting the Cognitive Bias for Commuting Time to Relieve the Driving Stress Level in Snow Weather Condition: A Naturalistic Driving Study in Harbin, China

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Received 4 March 2023; Revised 23 October 2023; Accepted 17 February 2024; Published 5 March 2024

Academic Editor: Laura Garach

As a negative emotion, professional drivers' stress levels significantly affected driving behavior and thus were related to driving safety issues. Nevertheless, current evidence fell considerably short of explaining whether and why private drivers' stress levels might be influenced while commuting driving in a specific scenario and how to relieve their stress levels. This study aimed to identify and analyze the contributing factors of the drivers' stress levels while commuting driving in various scenarios (clear or snow weather conditions). On weekdays between 1st October 2020 and 31st January 2022, the questionnaire data from a sample of 985 private drivers were collected from six different locations of business districts in Harbin, China. Based on the naturalistic driving study (NDS) database, a 7-item questionnaire was designed for participants to self-report their driving stress levels in various scenarios, which was generated from the shortened and adapted version of the Perceived Stress Scale (PSS). The results showed that participants' stress levels had significantly increased in snow weather conditions, especially nervous and stressed feeling, and unable to control the arrival time, which indicated that participants' highly increased cognitive bias for commuting time could be the critical reason. The results of hierarchical linear regression models indicated that overall stress scores could be predicted through participants' sociodemographic characteristics, driving experience, commuting driving, and cognitive bias for commuting time. Such an association was significantly strongest with commuting time gaps, especially in snow weather conditions. In addition, a recommendation was derived from these results that correcting the cognitive bias for commuting time could relieve participants' stress levels. The implication of the reminder message supported this recommendation. The participants' stress levels were reduced significantly after providing a reminder message every 10 mins while commuting driving in clear weather conditions and every 5 mins in snow weather conditions.

1. Introduction

As one of the traditional adverse weather conditions, the snow weather condition is a significant cause of increased traffic accidents and compromised traffic flow in northern Europe and northern America [1]. Also, the Traffic Administration Bureau of the Ministry of Public Security of the People's Republic of China (2021) proposed that between 2015 and 2020, snow weather conditions in northern China contributed to an average of 1085 fatalities, 3800 injuries, and 25% of total traffic accidents annually. Primarily during morning peak hours, snow weather conditions have long been known to contribute to the higher frequency of severe traffic accidents, due to the reduced visibility, the slick surface conditions, and the increased interaction between vehicles and pedestrians [2].

Moreover, the surge in traffic accidents reduced the transportation network's safety, mobility, and reliability, a significant priority of state departments of transportation and other transportation agencies in China and around the world [3, 4]. In practical terms, meta-analytical evidence suggests that most traffic accidents are preventable and caused by driving errors and traffic violations [5, 6]. Therefore, driving behavior as the most prevalent factor contributing to traffic accidents is needed to understand how the snow weather condition contributes to this driving behavior during the morning peak hour, why this driving behavior occurs, and how to reduce this driving behavior, which further reduces the snow weather-related traffic accidents during morning peak hours [7–9].

Some previous studies have concentrated on the links between negative emotions and unsafe/risky driving behavior. For example, anger and pleasure affected risky driving behaviors positively by enhancing the relationship between self-reported driving style (SDBS) and actual risky driving (ARD) behaviors, while surprise and fear weakened this relationship to affect risky driving behaviors negatively [10]. Contempt affected risky driving behaviors positively by enhancing the relationship between self-reported sensation seeking (SSS) and ARD, while helplessness and relief weakened this relationship to affect risky driving behaviors negatively [11–13]. Anxiety positively affected risky driving behaviors by synchronously enhancing the relationship between SDBS and ARD and the relationship between SSS and ARD [14]. Furthermore, anger, anxiety, depression, contempt, fatigue, and other harmful and robust emotions led to stronger acceleration and higher speeds [15, 16], breaking driving rules [17, 18], crossing yellow traffic lights (e.g., [18]), and harder braking (e.g., [16]). Other previous studies have further emphasized the differentiating roles of some specific negative emotions on particular unsafe/risky driving behavior. For example, anger and hostility were related to aggressive driving [19], which may have been more sensitive to anger-based violations [20], including higher driving speed [15, 21] and aberrant lane position [22]. Anxiety and fear could negatively affect a driver's adjustment to changes in the driving environment, which can lead to a deterioration in driving behavior [23, 24], including an increased risk of collision [25], more driving errors [23, 26], increased reaction times in braking tasks [27], and greater likelihood of speeding [28]. Moreover, fatigue decreases the driving behaviors of commercial motor vehicle drivers, resulting in the increased risk of crashes. Restricting the driving hours could mediate the causal path from fatigue to performance shortfalls to crashes [29]. On the other hand, several studies have provided evidence that anxiety and fear due to experiencing near-misses or crashes can result in various problematic driving behaviors, such as slowing for green lights, driving far below the speed limit [30], increased speed compliance [31], avoiding nonessential journeys, and even avoidance typical of phobia [32]. An alternative perspective that linked negative emotions and unsafe/risky driving behavior by considering and comparing the changing driving context, such as adverse weather conditions (e.g., rain, fog, and snow), driving time (e.g., daylight and nighttime, morning/evening peak hour or leisure time, and workdays or weekends), and driving purpose (e.g., work, shopping, and school), has received very little attention in the empirical literature [5]. These specific changing driving contexts represented the situational factors ignored by the drivers in planning behavior, which induced negative emotions and further affected the driving behavior [4].

In the changing driving context, experimental studies have shown that driving under stressful conditions led to adverse changes in physiological parameters, including increased arterial blood pressure [33], reduced heart rate variability (HRV) [34], and increased salivary stress hormones' concentrations (i.e., salivary cortisol levels) [35], which could be a predictor of unsafe/risky driving behavior [22]. Moreover, several recent studies have documented stress as one of the traditional negative emotions, which could be a symptom of potential accident risk [6, 36, 37]. Based on the transactional framework for driver's stress, these studies linked stress with unsafe/risky driving behavior through psychophysiological mechanisms (stress reactions) [6, 38]. This theoretical approach defined unsafe/risky driving behavior as transactional outcomes generated by interactions between drivers and the changing driving context [6]. Stress processes were generated when the changing driving context exceeded the driver's coping capability [39–41].

From this perspective, most studies concentrated on the association pattern between personality traits and stress vulnerability [42–44]. Drivers with positive personality traits (including optimism, enthusiasm, assertiveness, planning, and problem-solving orientation) were less vulnerable to stress and stress-related reactions and might be more able to quickly adapt to changing driving contexts without compromising driving behavior [45, 46]. On the contrary, drivers with negative experiences (e.g., neuroticism and negative affectivity) were more vulnerable to stress and more likely to react negatively to stressors (physically, emotionally, and behaviorally) [44, 47, 48]. These findings were usually derived from the occupational studies addressing the case of professional drivers (e.g., cargo/freight drivers, taxi drivers, and public transport drivers) [6, 49, 50]. In consideration of their specific task-related conditions, some specific personality traits fit better with driving stress, which could be applied to predict unsafe/risky driving behavior in professional drivers accurately [51, 52], such as physiological hyper-responsiveness to stress [53], exaggerated defensive engagement [54], and attentional biases [55].

Apart from professional drivers, stressful driving conditions also strongly affect private drivers' driving behavior [56]. In particular, faced with snowfalls during morning peak hours, private drivers, as the major group of drivers, are required to continuously monitor surrounding traffic conditions and the route progress to make efficient and safe driving decisions [57, 58]. Their driving tasks (e.g., arriving at the workplace on time) are engaging in nature, and the changed roadway-surface conditions combined with traffic congestion would easily make private drivers irritable [59, 60] and stressful [61, 62]. Nevertheless, the case of private drivers' stress levels has remained unattended mainly, especially in view of this changing driving context. This study addressed this gap in the literature by examining how snow weather conditions influenced private drivers' stress levels while commuting driving. This is one of the critical contributions of this study.

Self-reporting was deemed as the most common method for collecting the data on drivers' stress levels. However, by only using the self-reported questionnaires, drivers tend to forget their stress levels after some time. Therefore, naturalistic driving studies (NDSs) through the use of global positioning systems (GPSs), video cameras, accelerometers, and other in-vehicle technologies have made significant strides in capturing and recording drivers' behavior in the real world, which could solve this question. Drivers could drive as they normally would (i.e., without specific experimental or operational protocols and not in a simulator or test track). The period of observation can vary from several weeks to a year or more. In the last decade, NDS, such as the 100-car naturalistic driving study [63], LongROAD study [64], and the SHRP2 study [65], has presented an unparalleled opportunity for a greater understanding of driving behavior. Several studies have used the naturalistic driving studies to explain nuances of driving behavior, such as distracted driving behavior and collisions [66–68]. The second essential contribution of this study is to create a naturalistic driving study (NDS) database for getting back the participants' natural driving behaviors. By watching the commuting driving videos in various scenarios (clear or snow weather conditions) in the latest month, participants were asked to report their stress levels at that moment, which ensured the resulting self-reported data of stress levels were more reliable, valid, and accurate.

Although previous studies explored a broader range of the association pattern between personality traits and stressed vulnerability, it was unclear whether and why drivers felt more stressed or nervous while commuting driving in a specific scenario (i.e., snow weather conditions and morning peak hour). In particular, relatively little is known about how drivers' psychometric properties were associated with their stress levels. Unlike personality traits, psychometric properties (such as the cognitive bias for commuting time) are related to the drivers' predisposition to perceive and react to the changing weather, road surface, and traffic conditions. In reality, considering all personality traits to conduct safety education for drivers is not feasible. Therefore, focusing on the targeted psychometric property, the evidence collected from this study (e.g., an application of a reminder message) can be beneficial for relieving drivers' stress levels (e.g., by correcting their cognitive bias for commuting time) while commuting or driving in various scenarios. It has further been considered as the contributing factor to reducing stress-related risky driving behavior, which is the third vital contribution of this study.

2. Methods

2.1. Participants. For this study, a sample of 985 private drivers in the city of Harbin (Heilongjiang Province, China) was gathered. A random sampling method was employed for the participant selection. The following inclusion criteria were used: (a) to be 18–55 years of age (people could apply for the driving license after 18 years of age and retire after 55 years of age); (b) to have a valid driver's license at the time of the study; (c) to own a vehicle; (d) to have a dashcam in the vehicle; (e) to drive to the workplace during the morning peak hour in both clear weather and snow weather conditions; and (f) to have a fixed arrival time in the morning (compensation deductions for late arrivals). The exclusion criteria included chronic or acute mental health disorders and/or physical diseases assessed using an author-developed questionnaire. All participants were anonymous and volunteered, and all responses were confidential. Any reward or compensation was not offered.

Given that all participants have experienced snowfalls during their commuting driving, it can be concluded that snowfalls are the common experiences among residents who drive to/from the workplace in Harbin. From 1st October 2020 to 31st January 2022, the most recent snowfall during one's commute was relatively deep. For example, from 18th November 2020 to 19th November 2020, the average snowfall in 24 hours reached 25.5 millimeters. In the wintertime of 2021, the average snowfall reached 38.9 millimeters. The questionnaire data suggested that in all participants, the most recent snowfalls often occurred on the way to the workplace, not on the return home journey. Therefore, in this study, we set the observation period to be the morning peak hour (07:00–09:00 AM) on weekdays from 1st October 2020 to 31st January 2022.

2.2. Study Variables and Measurement Instruments

2.2.1. Basic Information Questionnaire. From 1st October 2020 to 31st January 2022, a questionnaire survey was conducted on 985 participants who drove to the workplace during morning peak hours in both clear and snow weather conditions. In the survey administration, six different locations of business districts (Qiulin, Huizhan, Central Street, Aijian, Westred Square, and Wangfujing Department Store) were selected as survey location sites in the city of Harbin (latitude 44°04′N-46°40′N and longitude 125°42′E-130°10′E). Figure 1 shows the geographical location of the research area and the survey sites in Harbin. The locations were selected based on areas with a large concentration of office workers with fixed working hours. Moreover, the locations' proximity to the workplace ends of commuting driving would increase the participation rate of the survey.

The questionnaire was designed to identify the participants' sociodemographic characteristics (represented as gender and age), driving experience (represented as years licensed), and commuting driving (represented as drive frequency and commuting trip distance). At the start of the questionnaire, specific attention was directed toward their flexibility to adjust arrival time at the workplace. Therefore, questions about whether employers penalized participants for arriving late were also included. The participants with the fixed arrival time or compensation deductions for late arrivals were selected to continue the questionnaire.

2.2.2. Driving Stress Level Measurement. To evaluate the participants' stress levels while commuting driving in various scenarios (clear or snow weather conditions), the shortened and adapted version of the Perceived Stress Scale (PSS) [69–71] was used. These items were combined with the suggested items from a panel of 50 experts (including 30

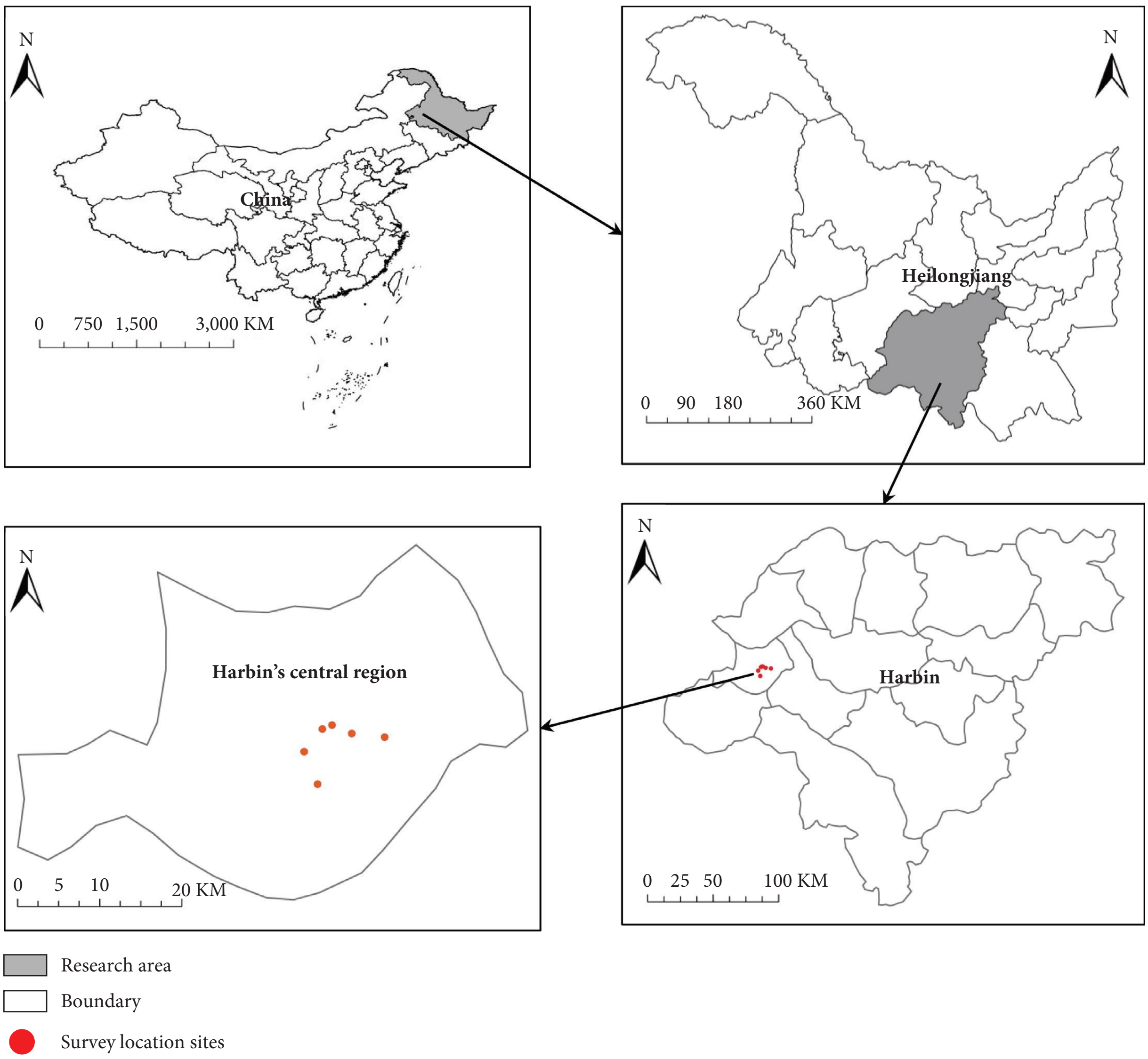

Figure 1: The geographical location of the research area and survey sites in Harbin.

professionals in traffic safety and 20 traffic police officers). Through focus groups with these experts and an extensive literature review, a 7-item questionnaire was designed. Moreover, the original PSS item was used to measure the degree to which situations in one's life were appraised as stressful [72]. The modification of the selected 7-item was carried out to consider the specific driving condition. For example, an item such as "In the last month, how often have you been upset because of something that happened unexpectedly" was modified to "When driving, how often have you been upset because of some unexpected driving events?" These modified items were used to identify and measure how often the participants felt stressed and nervous while commuting driving in various scenarios, respectively. The comparative table between the original 14-item of the Perceived Stress Scale (PSS) [72] and the modified 7-item used for driving stress level measurement in this study is available in Table 1.

The exclusive use of self-report measure increases the risk of biased results, since it just provides the participants' overall perception of their stress levels while commuting driving. However, it could not reflect the participants' stress characteristics that fluctuate day-to-day. To overcome this limitation, naturalistic driving study (NDS) records the participants' driving behavior over the course of several days through the years, producing a large amount of data with a nested or multilevel data structure (i.e., multiple commuting driving trips within each participant). Through observing the real driving behavior data during each commuting trip, participants could self-report their stress levels from both subjective and objective aspects to form a large amount of self-reported stress data for multiple commuting driving trips, which could further provide valuable information on variability in participants' stress levels while commuting driving in various scenarios (clear or snow weather conditions, with and without reminding the arrival time).

Table 1: Original 14-item of the Perceived Stress Scale (PSS) and modified 7-item.

No.	Original 14-item	No.	Modified 7-item
1	In the last month, how often have you been upset because of something that happened unexpectedly?	1	When driving, how often have you been upset because of some driving events that happened unexpectedly?
2	In the last month, how often have you felt that you were unable to control the important things in your life?	2	When driving, how often have you felt that you were unable to control the vehicle?
3	In the last month, how often have you felt nervous and stressed?	3	When driving, how often have you felt nervous and stressed?
4	In the last month, how often have you dealt successfully with irritating life hassles?		
5	In the last month, how often have you felt that you were effectively coping with important changes that were occurring in your life?	4	When driving, how often have you felt that you were unable to cope with the changing traffic conditions?
6	In the last month, how often have you felt confident about your ability to handle your personal problem?		
7	In the last month, how often have you felt that things were going your way?		
8	In the last month, how often have you found that you could not cope with all the things that you had to do?	5	When driving, how often have you found that you could not cope with the driving events?
9	In the last month, how often have you been able to control irritations in your life?		
10	In the last month, how often have you felt that you were on top of things?		
11	In the last month, how often have you been angered because of things that happened that were outside of your control?		
12	In the last month, how often have you found yourself thinking about things that you have to accomplish?		
13	In the last month, how often have you been able to control the way you spend your time?	6	When driving, how often have you felt that you were unable to control the arrival time?
14	How often have you felt that difficulties were piling up so high that you could not overcome them?	7	When driving, how often have you felt difficulties in the traffic conditions that were piling up so high that you could not overcome them?

In this paper, naturalistic driving data collected by the dash cams in participants' vehicles were used to conduct the naturalistic driving study (NDS). All participants had the dash cams (as the driving recorders) mounted on the windshield of their vehicles. As a video camera, these dash cams were used to monitor the commuting driving environment, track and record participants' natural driving behavior, and analyze their interaction behavior with the surroundings in various scenarios. All participants voluntarily provided the commuting driving videos in various scenarios in the latest month. All videos were assured of anonymity and confidentiality. Furthermore, more than 12000 commuting driving videos comprised this NDS database.

Three expert analysts manually coded and inspected all videos in various scenarios (clear or snow weather conditions, with and without reminding the arrival time). All videos were grouped and named for each participant. These grouped videos were arranged based on random order, which might avoid the fixed and same viewing orders affecting the participant's judgment. The participants received instructions on the first day of training. Based on the NDS database, all participants watched their commuting driving videos in various scenarios and self-reported the 7-item questionnaire on a 5-point Likert scale where 0 = never, 1 = almost never, 2 = sometimes, 3 = fairly often, and 4 = very often. Each participant was assigned three videos in each scenario to self-report, and then a discussion was held to ensure that all items in the questionnaire were understood. A random sample of eight videos was processed by each participant in order to initially evaluate the consistency of participants' self-reported stress levels in various scenarios. Then, the modified 7-item of Perceived Stress Scale (PSS) was examined by viewing, coding, and analyzing video recordings. All items were averaged to obtain an overall stress score. Overall, it took three weeks to complete this self-reported questionnaire process.

2.2.3. Commuting Time Gap Measurement. Through the unstructured interviews (i.e., "Why you felt more nervous and stressed when driving to the workplace during the morning peak hour in the snow weather condition?"), we uncovered "hidden" information if and what might affect the participants' stress levels while commuting driving in snow weather conditions. Most participants were more worried that they did not know how long the commuting time will be increased in the snow weather conditions, which may induce compensation deductions for late arrivals. They all felt more stressed to rush to the workplace and were motivated to drive as quickly as possible. Therefore, worries about the inaccurately estimated commuting time would be associated with higher stress levels, which further induced a dysfunctional concentration in drivers' own thoughts. This distraction may, in turn, heighten drivers' risk and accident propensity. The inaccurately estimated commuting time could be defined as the cognitive bias for commuting time, which was the commuting time gap between the perceived and actual commuting time. In the unstructured interviews, there was a section to identify the participants' cognitive bias for commuting time by measuring the commuting time gap. Through watching their commuting driving videos in various scenarios in the latest month, these 985 participants were questioned (i.e., "When you were driving, how long did you think it would take you to get to workplace?") to assess their commuting time (as the perceived commuting time (PCT)) during each commuting trip. Furthermore, each commuting driving video was observed and analyzed by the expert analysts to record and calculate the participants' real commuting time (as the observed commuting time (OCT)) during each commuting trip. Then, differentiating between PCT and OCT with the commuting time gap could be used to express the participants' cognitive bias for commuting time. To reduce most participants' stress levels, it was essential to examine the association between the cognitive bias for commuting time and stress level in snow weather conditions.

2.2.4. Driving Message Reminding the Arrival Time. Various previous studies have proposed that a driving assistance system could improve the driving behavior and assist in avoiding safety-critical events, while it has been still vague whether and how this system could affect the drivers' stress levels. To investigate this, the reminder message, as a type of driving aid, was applied to adjust the baseline and comparative driving scenarios. Each participant received a reminder message reminding them of his/her arrival time while commuting driving in both adjusted baseline driving scenarios (clear weather conditions with a reminder of the arrival time) and adjusted comparative driving scenarios (snow weather conditions with a reminder of the arrival time). Furthermore, in each adjusted scenario, multiple reminding intervals (including 2 mins, 5 mins, 10 mins, and 15 mins) were set, which were used to explore what was the best time interval to disseminate a reminder message. The navigation system in Baidu Map, a mobile phone-based app, captured the location of vehicles and sent a reminder message with a deep sound to each participant. Moreover, the dash cams in participants' vehicles collected the commuting driving videos in all adjusted scenarios. The participants were questioned to report the 7-item scale by watching these commuting driving videos. Therefore, this driving assistance reminded the arrival time cloud to be used to understand whether the participants effectively relieved their stress levels when their cognitive bias for the commuting time was corrected.

2.3. Procedure. All participants were asked to voluntarily complete the questionnaires, which contained questions about their sociodemographic characteristics (represented as gender and age), driving experience (represented as years licensed), and commuting driving (represented as drive frequency and commuting trip distance). The participants were informed of their rights and the protection of their personal information through an informed consent form. All participants were anonymous and volunteered, and all responses were confidential.

Various (clear or snow weather conditions) scenarios were defined to capture the stress level variations of participants while commuting driving. These scenarios involved a baseline driving scenario (clear weather condition) and a comparative driving scenario (snow weather condition). All participants were asked to voluntarily provide the commuting driving videos in these scenarios in the latest month. All videos were assured of anonymity and confidentiality.

As the naturalistic driving data, these commuting driving videos were collected by the dash cams in participants' vehicles. A 7-item questionnaire was designed to evaluate participants' stress levels while commuting driving in various scenarios. Through watching their commuting driving videos in various scenarios in the latest month, participants were questioned about their stress-related emotional state by reporting these seven items on a 5-point Likert scale ($0 = \text{never}$; $4 = \text{very often}$), and they also provided feedback about their perceived commuting time (PCT).

The driving message reminded the arrival time with multiple reminding intervals (including 2 mins, 5 mins, 10 mins, and 15 mins) which were applied for the participants while commuting driving in four adjusted baselines (clear weather condition with reminding the arrival time) and four comparative (snow weather condition with reminding the arrival time) driving scenarios, respectively. These participants were questioned to report the 7-item scale by watching these commuting driving videos in all adjusted scenarios.

2.4. Statistical Analysis. Descriptive statistics were obtained for the participants' stress levels and commuting time gap in various scenarios (clear or snow weather conditions). Internal consistency was estimated with composite reliability indexes (CRIs) to overcome the limitations of Cronbach's alpha. The comparisons of participants' stress levels and commuting time gap among various scenarios were performed using paired sample t-tests, and $p < 0.05$ was considered statistically significant.

Hierarchical linear multiple regression analysis was constructed to evaluate the different validity of the adapted PSS for participants in various scenarios. In each driving scenario (including the baseline driving scenario in clear weather condition and the comparative driving scenario in snow weather condition), we designed the hierarchical linear multiple regression models to explore if the cognitive bias for commuting time (represented as the commuting time gap) could statistically and significantly explain the variances in overall stress scores beyond that explained by sociodemographic characteristics (represented as age and gender), driving experience (represented as years licensed), and commuting driving (represented as drive frequency and commuting trip distance) in both baseline (clear weather condition) and comparative (snow weather condition) driving scenarios. Therefore, we used the overall stress scores as criterion variables, and the participants' age, gender, years licensed, drive frequency, commuting trip distance, and commuting time gap as predictors. Four regression models were designed, respectively, following the same criteria: sociodemographic characteristics (represented as age and gender) were entered in the first step, with driving experience (represented as years licensed) entered in the second step. In the third step, commuting driving (represented as drive frequency and commuting trip distance) were entered. Finally, in the fourth step, the cognitive bias for commuting time (represented as the commuting time gap) was entered.

3. Result

3.1. Characteristics of the Participants. For this study, a total of 985 participants were selected and gathered. The minimum sample size ($N = 315$) was estimated using the statistical power analysis, with an anticipated effect size of 0.2, a statistical power level of 0.8, and a probability level of 0.05. Therefore, to ensure adequate statistical power for this study, we tripled the minimum sample size up to $N = 985$.

Among the sample, there were 537 males (54.5%) and 448 females (45.5%), and the age ranged from 20 to 53 years ($M = 32.16$, $SD = 9.89$). Regarding their driving experience, the participants had a valid driving license between 2 and 30 years ($M = 9.58$, $SD = 8.49$). Furthermore, regarding their commuting driving, the participants drove to/from the workplace between 1 and 20 times per week ($M = 6.30$, $SD = 9.19$), and commuting trip distance was between 20 and 280 km per week ($M = 75.20$, $SD = 346.87$). The participants had no history of neurological or psychiatric disorders.

3.2. Self-Reported Stress Scores. Table 2 provides the descriptive statistics of participants' self-reported stress levels, which showed the means and standard deviations of each item and the overall stress scores in various scenarios. When looking at the raw data on the Likert scale from 0 (never) to 4 (very often), the higher the items' scores of a participant, the more frequently he/she felt stressed when commuting driving. Cronbach's alpha coefficient values of the items ranged from 0.85 to 0.92 in the baseline driving scenario and from 0.83 to 0.90 in the comparative driving scenario. These overall stress scores had an alpha reliability of 0.88 in the baseline driving scenario and 0.85 in the comparative driving scenario. The composite reliability index (CRI) of the overall stress scores was 0.86 and 0.85 in the baseline and comparative driving scenarios, respectively. These all indicated adequate internal consistency. The differences in overall stress scores were statistically significant between baseline and comparative driving scenarios at the $p < 0.01$ level.

Overall, in the baseline driving scenario (clear weather condition), participants had an overall stress score of 1.392, indicating a moderately low stress level for commuting driving. The most frequently reported items were from unexpected driving events (no. 1, $M = 2.397$) while commuting driving. Compared with the baseline driving scenario, participants had significantly higher stress levels while commuting driving in a comparative driving scenario (snow weather condition). These results captured the effect of snow

Table 2: Descriptive statistics of participants' self-reported stress levels in various scenarios.

No.	Items	Baseline driving scenario (clear weather conditions) Mean	Comparative driving scenario (snow weather conditions) Mean (% changes)
1	When driving, how often have you been upset because of some driving events that happened unexpectedly?	2.397	3.886 (+62.12%)
2	When driving, how often have you felt that you were unable to control the vehicle?	1.359	3.598 (+164.75%)
3	When driving, how often have you felt nervous and stressed?	1.158	3.885 (+235.49%)
4	When driving, how often have you felt that you were unable to cope with the changing traffic conditions?	1.298	3.157 (+143.22%)
5	When driving, how often have you found that you could not cope with the driving events?	1.169	2.968 (+153.89%)
6	When driving, how often have you felt that you were unable to control the arrival time?	1.168	3.986 (+241.27%)
7	When driving, how often have you felt difficulties in the traffic conditions that were piling up so high that you could not overcome them?	1.195	2.175 (+82.01%)
	Overall stress scores	1.392	3.379 (+142.74%)

weather condition on participants' stress levels to be particularly strong, which induced the mean stress scores of each item to increase (range: 62.12%–241.27% increased) and the overall stress score to increase by almost 1.5 times ($M = 3.379$, 142.74% increased). Furthermore, there were statistical and significant differences in some specific items between the baseline driving scenario and the comparative driving scenario. For example, participants self-reported highly increased nervous and stressed feelings (no. 3, $M = 3.885$, 235.49% increased, $p < 0.001$) and were unable to control the arrival time (no. 6, $M = 3.986$, 241.27% increased, $p < 0.001$) in comparative driving scenarios. It reinforced the earlier conclusions that the snow weather condition significantly impacted participants' perception of commuting time. Moreover, these induced distractions were intuitively anticipated to enhance the nervous and stressed feelings and increase the overall stress level.

3.3. Assessed Commuting Time Gap. Table 3 provides the descriptive statistics of the commuting time gap, which showed the means and standard deviations of perceived commuting time (PCT), observed commuting time (OCT), and commuting time gap in various scenarios. Cronbach's alpha coefficient values of the PCT and OCT were 0.87 and 0.84 in the baseline driving scenario and 0.85 and 0.86 in the comparative driving scenario. The composite reliability index (CRI) of the PCT and OCT was 0.82 and 0.80 in the baseline driving scenario and 0.83 and 0.84 in the comparative driving scenario. The differences in commuting time gap were statistically significant between baseline and comparative driving scenarios at the $p < 0.01$ level. Compared with the baseline driving scenario (clear weather condition), these results indicated that both the perceived commuting time (PCT) (as the self-assessed commuting time, which participants assessed through watching their commuting driving videos) and the observed commuting time (OCT) (as the actual commuting time, which was measured from the participants' commuting driving videos in the NDS database) have increased in a comparative driving scenario (snow weather condition). Furthermore, compared with the observed commuting time (OCT) (increased by 1.2 (109.09%) mins/km), the significantly increased perceived commuting time (PCT) (increased by 2.3 (121.05%) mins/km, $p < 0.001$) induced the higher commuting time gap (as the differentiation between PCT and OCT) in the comparative driving scenario. These results suggested that the commuting time gap was prone to the snow weather condition, resulting in the increased participants' cognitive bias for commuting time. Moreover, the content analysis of interviews revealed that the work commitments, as manifested in fixed arrival time and compensation deductions for late arrivals, significantly impacted the likelihood of participants rushing to the workplace, especially in snow weather conditions. However, this impact was less favorable. The highest increased "nervous and stressed feelings" and "unable to control the arrival time" caused most participants to overestimate the commuting time in snow weather conditions. In this situation, it was not surprising that these participants experienced elevated stress levels while commuting driving in the comparative driving scenario.

3.4. Predicted Overall Stress Scores. Table 4 summarizes the results of these hierarchical linear multiple regression models for predicting the overall stress scores in various scenarios. The significant increase of R_2 ($\triangle R_2$) in each step was analyzed, as well as the Akaike Information Criteria (AIC) [73], whereas R_2 has the advantage of being a standardized value and having a significance test associated, and the AIC has the advantage of considering both the contribution of independent variables and the complexity of the model [74]. Both in the baseline and comparative driving scenarios, the AIC decreased in every step concerning the previous one, and the lowest AIC value was attained in the fourth step. The lower the AIC value, the better the model fit.

During Step 1, the results of each model showed that gender (1 = male and 2 = female) had positive and significant associations. These results indicated that female participants were more likely to feel stressed or nervous while commuting driving in both baseline and comparative driving scenarios. During Step 2, years of license were added to each model. Drive frequency and commuting trip distance were entered following age, gender, and years of license during Step 3. Furthermore, overall stress scores were found to be affected by both of these two added variables in both baseline and comparative driving scenarios. Specifically, drive frequency significantly predicted the participants' stress levels while commuting driving, such that their overall stress scores decreased statistically and significantly as drive frequency increased. During step 4, the added commuting time gap induced R_2 to increase by 0.22 ($\triangle R_2 = 0.22$ in the baseline driving scenario) or 0.31 ($\triangle R_2 = 0.31$ in the comparative driving scenario), which suggested that the commuting time gap was the most crucial variable to statistically and significantly explain the variances in the overall stress scores. The commuting time gap remained the most significant and positive association with overall stress scores in all models. This finding indicated that participants with a more significant commuting time gap were most likely to feel stressed or nervous while commuting driving in both baseline and comparative driving scenarios. Therefore, the commuting time gap was shown to be the strongest predictor of overall stress scores, which confirmed that the participants' stress levels were statistically and significantly affected by their cognitive bias for commuting time.

By comparing the results of hierarchical linear multiple regression models in the comparative driving scenario with that in the baseline driving scenario, the considerable differentiation might detect whether and why the participants' stress levels were much higher while commuting driving in snow weather conditions. These results implied that participants were more sensitive to feeling stressed or nervous while commuting driving in the comparative driving scenario. This was because the effects of variables positively associated with overall stress scores increased more dramatically in all models than those negatively associated with

Table 3: Descriptive statistics of the commuting time gap in various scenarios.

	Baseline driving scenario (clear weather conditions) Mean (mins/km)	Comparative driving scenario (snow weather conditions) Mean (mins/km)
Perceived commuting time (PCT)	1.90	4.20
Observed commuting time (OCT)	1.10	2.30
Commuting time gap	0.80	1.90

overall stress scores, except drive frequency. In particular, the mean value of the commuting time gap, which had the most significant and positive association with overall stress scores during Step 4, increased by 1.38 times (1.1 mins/km) in the comparative driving scenario. After controlling other variables, only this increased commuting time gap was expected to increase the overall stress scores by almost four times in snow weather conditions. Therefore, the participants' highly increased stress levels while commuting driving in snow weather conditions seemed to be shaped by their increased cognitive bias for commuting time, meaning that the perceived commuting time tends to be increased more significantly than the actual commuting time because of snowfalls.

3.5. Corrected Cognitive Bias for Commuting Time. These results offered concrete evidence that the participants' cognitive bias for commuting time had a statistically significant impact on their stress levels in both baseline (clear weather condition) and comparative (snow weather condition) driving scenarios. After applying the reminder messages with multiple reminding intervals (including 2 mins, 5 mins, 10 mins, and 15 mins), Tables 5 and 6 provide the descriptive statistics of participants' self-reported stress levels in adjusted baseline and comparative driving scenarios, respectively, which showed the mean scores and changes (compared with the baseline and comparative driving scenarios) of each item and the overall stress scores. Cronbach's alpha coefficient values of these items ranged from 0.83 to 0.91 in four adjusted baseline driving scenarios and from 0.85 to 0.93 in four adjusted comparative driving scenarios. These overall stress scores had an alpha reliability from 0.86 to 0.89 in four adjusted baseline driving scenarios and from 0.87 to 0.90 in four adjusted comparative driving scenarios. The composite reliability index (CRI) of the overall stress scores were from 0.80 to 0.86 in four adjusted baseline driving scenarios and from 0.81 and 0.85 in four adjusted comparative driving scenarios, respectively. The overall stress scores were all statistically significant among the four adjusted baseline and comparative driving scenarios below the $p < 0.01$ level.

Results in Tables 5 and 6 suggested that the mean scores of all seven items and the overall stress scores were reduced in each adjusted driving scenario, which revealed that the participants with the reminder message had lower stress levels while commuting driving in both clear and snow weather conditions, compared to that without the reminder message. Therefore, the reminder message, which provided the arrival time information to participants, was expected to help participants correct their cognitive bias for commuting time, thereby relieving their stress levels. More specifically, it was anticipated that the effect of reminder messages was more prominent in adjusted comparative driving scenarios. The mean scores of all seven items (range: 0.18%–61.64% reduced) and the overall stress scores (range: 16.22%–24.80% reduced) were reduced more significantly in each adjusted comparative driving scenario, compared to those in each adjusted baseline driving scenario. In the routine driving situations, participants mainly relied on their rich experiences to accurately estimate the arrival time while commuting driving in clear weather conditions. The commuting time gap was smaller and induced participants' lower overall stress levels. Therefore, the effect of reminder messages on relieving stress levels was less significant.

However, in snow weather condition, the uncertainty of road surface and traffic conditions might exceed participants' capabilities, resulting in a highly increased commuting time gap, which was significantly associated with increased stress levels. Therefore, the reminder message of arrival time could help participants minimize their commuting time gap while commuting driving in snow weather conditions, leading to significantly reduced stress levels. Such findings were consistent with hierarchical linear multiple regression models during Step 4, in which the commuting time gap had the most significant and positive association with overall stress scores in the comparative driving scenario.

Due to the different reminding intervals in each adjusted driving scenario, the mean scores of all seven items and the overall stress scores were reduced differently. For example, in both adjusted baseline and comparative driving scenarios, the mean scores of all seven items and the overall stress scores had the lowest reduction rate with 2 and 20 mins reminding intervals. This finding reflected that the participants might ignore the reminder message when the time interval was so long (20 mins). In comparison, the mental workload of participants might increase if the reminder message was provided too often (2 mins). On the other hand, the mean scores of all seven items and the overall stress scores maintained the highest reduction rate with 10 mins reminding interval in the adjusted baseline driving scenario and with 5 mins reminding interval in the adjusted comparative driving scenario. Many participants commented that this reminder message, which reminded them of the arrival time every 10 mins, was more comfortable and suitable for relieving stress levels while commuting driving in clear weather condition. Participants said that they felt more stressed and nervous while commuting driving in snow weather condition, thereby utilizing the same reminder message but more frequently (5 mins) to relieve their significantly increased stress levels.

Table 4: Hierarchical linear multiple regression models for predicting the overall stress scores in various scenarios.

Variables (mean values)	Baseline driving scenario (clear weather conditions)					Comparative driving scenario (snow weather conditions)				
	β	t	p	$\triangle R^2$	AIC	β	t	p	$\triangle R^2$	AIC
Step 1: sociodemographic characteristics ($F = 10.56$, $p < 0.001$)				0.00	1011				0.00	956
Age	−0.04	0.61	0.550			−0.06	−0.83	0.412		
Gender (1 = male, 2 = female)	**1.92***	1.99	0.046			**3.56***	2.32	0.025		
Step 2: driving experience ($F = 25.91$, $p < 0.001$)				0.02**	985				0.03**	883
Age	−0.03	0.94	0.351			−0.06	−1.19	0.233		
Gender (1 = male, 2 = female)	**1.72***	2.01	0.041			**3.85***	2.33	0.020		
Years licensed	−0.02	−1.08	0.282			−0.03	−1.28	0.205		
Step 3: commuting driving ($F = 19.48$, $p < 0.001$)				0.07**	963				0.09**	851
Age	−0.03	−1.31	0.194			−0.05	−1.56	0.120		
Gender (1 = male, 2 = female)	**1.78***	2.31	0.027			**3.92***	2.53	0.011		
Years licensed	−0.02	−1.27	0.219			−0.03	−1.38	0.170		
Drive frequency	**−2.14****	−2.73	0.006			**−3.96****	−2.91	0.004		
Commuting trip distance	0.18	0.01	0.988			0.33	0.09	0.924		
Step 4: cognitive bias for commuting time ($F = 17.59$, $p < 0.001$)				0.22***	927				0.31***	829
Age	−0.03	1.39	0.169				−1.59	0.113		
Gender (1 = male, 2 = female)	**1.76***	2.48	0.013			**3.98***	2.59	0.011		
Years licensed	−0.02	1.81	0.072			−0.04	1.88	0.064		
Drive frequency	**−3.05****	−2.93	0.003			**−5.16****	−3.39	0.001		
Commuting trip distance	0.20	0.13	0.901			0.30	0.19	0.855		
Commuting time gap	**5.19*****	3.76	0.000			**5.20*****	4.94	0.000		

Overall stress scores in baseline driving scenario (clear weather conditions): $R^2 = 0.41$ ($p < 0.001$). Overall stress scores in comparative driving scenario (snow weather conditions): $R^2 = 0.43$ ($p < 0.001$). $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 5: Descriptive statistics of participants' self-reported stress levels in adjusted baseline driving scenarios.

No.	Items	Adjusted baseline driving scenario 1 (reminding the arrival time every 2 mins)		Adjusted baseline driving scenario 2 (reminding the arrival time every 5 mins)		Adjusted baseline driving scenario 3 (reminding the arrival time every 10 mins)		Adjusted baseline driving scenario 4 (reminding the arrival time every 15 mins)	
		Mean	Changes (%)	Mean	Changes (%)	Mean	Changes (%)	Mean	Changes (%)
1	When driving, how often have you been upset because of some driving events that happened unexpectedly?	2.359	−1.59	2.315	−3.42	2.281	−4.84	2.336	−2.54
2	When driving, how often have you felt that you were unable to control the vehicle?	1.343	−1.18	1.296	−4.64	1.257	−7.51	1.312	−3.46
3	When driving, how often have you felt nervous and stressed?	1.096	−5.35	0.845	−27.03	0.802	−30.74	0.834	−27.98
4	When driving, how often have you felt that you were unable to cope with the changing traffic conditions?	1.288	−0.77	1.267	−2.39	1.219	−6.09	1.225	−5.62
5	When driving, how often have you found that you could not cope with the driving events?	1.142	−2.31	1.106	−5.39	1.091	−6.67	1.099	−5.99
6	When driving, how often have you felt that you were unable to control the arrival time?	0.953	−18.41	0.827	−29.20	0.759	−35.02	0.816	−30.14
7	When driving, how often have you felt difficulties in the traffic conditions that were piling up so high that you could not overcome them?	1.194	−0.08	1.190	−0.42	1.187	−0.67	1.192	−0.25
	Overall stress scores	1.339	−3.81	1.255	−9.84	1.217	−12.57	1.259	−9.55

Table 6: Descriptive statistics of participants' self-reported stress levels in adjusted comparative driving scenarios.

No.	Items	Adjusted comparative driving scenario 1 (reminding the arrival time every 2 mins)		Adjusted comparative driving scenario 2 (reminding the arrival time every 5 mins)		Adjusted comparative driving scenario 3 (reminding the arrival time every 10 mins)		Adjusted comparative driving scenario 4 (reminding the arrival time every 15 mins)	
		Mean	Changes (%)	Mean	Changes (%)	Mean	Changes (%)	Mean	Changes (%)
1	When driving, how often have you been upset because of some driving events that happened unexpectedly?	3.665	−5.69	3.586	−7.72	3.628	−6.64	3.784	−2.62
2	When driving, how often have you felt that you were unable to control the vehicle?	3.369	−6.36	3.257	−9.48	3.341	−7.14	3.452	−4.06
3	When driving, how often have you felt nervous and stressed?	2.426	−37.55	1.658	−57.32	1.958	−49.60	2.375	−38.87
4	When driving, how often have you felt that you were unable to cope with the changing traffic conditions?	2.958	−6.30	2.868	−9.15	2.918	−7.57	3.009	−4.69
5	When driving, how often have you found that you could not cope with the driving events?	2.907	−2.06	2.729	−8.05	2.919	−1.65	2.957	−0.37
6	When driving, how often have you felt that you were unable to control the arrival time?	2.259	−43.33	1.529	−61.64	1.831	−54.06	2.069	−48.09
7	When driving, how often have you felt difficulties in the traffic conditions that were piling up so high that you could not overcome them?	2.165	−0.46	2.159	−0.74	2.168	−0.32	2.171	−0.18
	Overall stress scores	2.821	−16.51	2.541	−24.80	2.680	−20.69	2.831	−16.22

4. Discussion

Several studies proposed the negative association between neuroticism and driving performance [43]; that is, the high neuroticism diminishes one's driving capacity by decreasing cognitive capacities and diverting attention to personal concerns rather than the driving environment [75]. As known as cognitive interference, personal thoughts are likely to disrupt driving-related behaviors and may disable one's adjustment to the current driving environment [76]. The findings of this study could support and extend this argument, which indicated that the cognitive bias for commuting time is the most significant contributing factor influencing the drivers' stress levels while commuting driving, especially in snow weather condition. Drivers with higher cognitive bias for commuting time are disturbed by thoughts of potential compensation deductions for late arrivals and are stressed while commuting driving. In particular, the higher cognitive bias for commuting time induced the drivers to overestimate the commuting time more seriously in snow weather condition. The effect of cognitive bias has a more permanent action on negative emotional activation (such as stress), which would have a more immediate and ephemeral impact [77]. Repeated or chronic exposure to stressful situations leads to fatigue [78] and driving risk behaviors [79]. From this perspective, the evidence on the significant and positive relationships between cognitive bias for commuting time and stress levels in participants while commuting driving in various scenarios can be used in the design of safety interventions.

Despite the growing evidence on the association between stress and driving risk behaviors, there are very few intervention studies focused on the cognitive bias and stress [80]. This study developed a safety intervention (the reminder message, combined with the driver assistance system) to understand and manage the specific stressors of drivers while commuting driving in various scenarios. This combined driver assistance system can effectively reduce the drivers' stress levels, which further optimizes their response while commuting driving. Especially, the safety implications of such a combined driver assistance system may be more evident in snow weather conditions. It can also be leveraged in some educational campaigns to be organized to release the drivers' stress by correcting their cognitive bias for commuting time. More attention should be paid to female drivers, with shorter driving years or less frequently to/from the workplace, who were more likely to feel stressed or nervous while commuting driving in snow weather conditions. In practical terms, these findings support the design of organizational and individual safety interventions focused on correcting cognitive bias for commuting time to further reduce drivers' stress. As stress level and commuting time gap were measured and assessed using generic measurements and the driving environment is similar for professional drivers in the ground transportation industry of Harbin, this combined driver assistance system could be extended to design the occupational safety and health intervention for the professional drivers, focused on job strain management and WTC prevention. Moreover, future research could also be devoted to add this combined driver assistance system into the communication technologies, such as the vehicle-to-infrastructure or intervehicle communication systems, which can be leveraged in conditionally or fully autonomous vehicles.

5. Conclusion

As a traditional adverse weather condition, the snow weather condition severely impacts the safety, mobility, and reliability of transportation networks, especially during the morning peak hour. For example, multiple contributing factors such as roadway characteristics, environmental characteristics, crash characteristics, temporal characteristics, vehicle characteristics, and driver characteristics significantly influence adverse weather-related crash injury outcomes [81]. Several influential factors such as the skidding vehicles, high-speed roadways, high engine capacities of vehicles, tree-related collisions, and pedestrian involvement have consistent effects on accident injury severities across various adverse weather conditions [82]. Among these factors mentioned above, recent studies revealed that the drivers' stress levels, as a critical negative emotion, significantly affected their driving behaviors and were related to driving safety issues, such as traffic flow, visibility, and speed levels change correspondingly [83]. Therefore, measuring the impact of snow weather conditions on private drivers' stress levels accurately was critical for improving traffic safety. Despite the growing evidence on the association between job stress and professional drivers' driving behaviors [84, 85], very few studies have focused on private drivers' stress levels while commuting driving in snow weather conditions. In particular, no previous study has resolved whether and why private drivers felt more stressed and nervous in a specific driving scenario (i.e., snow weather conditions and morning peak hour). This study aimed to shed more light on this question, and four main conclusions could be derived from this study.

First, the 7-item questionnaire was designed to evaluate the participants' stress levels while commuting driving in various scenarios (clear or snow weather conditions) after applying the shortened and adapted form of the Perceived Stress Scale (PSS). Based on the naturalistic driving study (NDS) database, the participants self-reported the scores of all seven items and overall stress scores in various scenarios, respectively. These results (i) identified if the participants' stress levels differed in various scenarios and (ii) quantified those differences. In comparing the mean scores of all seven items and overall stress levels, statistical and significant increases were detected in the comparative driving scenario. Consistent with the previous literature [86–88], these results confirmed that the snow weather conditions affected the participants' stress levels while commuting driving in snow weather conditions. In particular, the findings emphasized that some specific items, involving nervous and stressed feelings (no. 3) and unable to control the arrival time (no. 6), had a significant impact.

Second, the unstructured interviews were conducted to understand the reason for participants' statistical and significantly increased stress levels in the comparative driving scenario. The findings implied that all participants' ($N = 985$) increased nervous and stressed feelings were due to their subjective perceptions of highly increased commuting time while commuting driving in snow weather conditions. Compared with the observed commuting time (OCT), the significantly increased perceived commuting time (PCT) induced a higher commuting time gap in the comparative driving scenario. Furthermore, the higher commuting time gap reflected a highly increased cognitive bias for commuting time. These findings supported the suggestion of other authors [89, 90] that the work commitments (as manifested in fixed arrival time and compensation deductions for late arrivals) imposed a significant time constraint on participants, which directly triggered the greater cognitive bias for commuting time while commuting driving in snow weather conditions, thereby generating the increased stress levels' outcomes.

Third, hierarchical linear regression models were developed to capture the variables to predict overall stress scores and their relative importance to determine the most influential variable in various scenarios. The estimation results supported the suggestion of other authors [91, 92] that age and years licensed were negatively associated with overall stress scores, while commuting trip distance was positively associated with overall stress scores in both baseline and comparative driving scenarios. Moreover, such associations were more significant in gender (with a positive association) and drove frequency (with a negative association).

Therefore, female participants with shorter driving years, who drove less frequently to/from the workplace, were more likely to feel stressed or nervous. Such feelings were stronger while commuting driving. In practical terms, these findings supported the design of some organizational and individual safety interventions focused on specific groups, which could relieve their stress levels, enhance their coping strategies, and potentially prevent risky driving behaviors [47, 78]. In particular, the commuting time gap was the most significant and positive predictor of overall stress scores, especially in the comparative driving scenario. As the most influential variable, the participants' highly increased commuting time gap could significantly increase their stress levels while commuting driving in snow weather conditions. Therefore, some intervention strategies focused on correcting participants' cognitive bias for commuting time could effectively reduce their stress levels.

Fourth, considering the commuting time gap as the most influential variable in predicting participants' stress levels, it could be critical to address and design effective intervention strategies to correct participants' cognitive bias for commuting time, further relieving their stress levels. It was known that the driving assistance system could help drivers achieve optimal or at least acceptable driving behaviors [93, 94]. Our findings highlighted that the reminder message as a type of driving aid had an exciting and significant effect on reducing participants' stress levels. The mean scores of all seven items and the overall stress scores were reduced in both adjusted baseline and comparative driving scenarios, compared to that without the reminder message. Specifically, we found that, with the implication of different reminding intervals, the mean scores of all seven items and the overall stress scores were reduced to a greater extent in adjusted comparative driving scenarios. In addition, it was worth noting that the most significant effect of the reminder message was reminding the arrival time every 10 mins in adjusted baseline driving scenarios and every 5 mins in adjusted comparative driving scenarios. It was possible that these reminding intervals were more comfortable and suitable to help drivers correct cognitive bias for commuting time, thereby relieving their stress levels while commuting driving in both clear and snow weather conditions.

Finally, the current study has some limitations. Self-reported questionnaires were designed to evaluate participants' stress levels and perceived commuting time (PCT), which were difficult to observe and analyze objectively as it might result in social desirability bias. However, as anonymity and confidentiality were guaranteed, we expected low social desirability bias in our study. This study reassured the participants that all data would be anonymized and treated confidentially. The questionnaire was designed to combine various instruments, a proven method of reducing social desirability bias [95–97]. However, in terms of precision and reliability, the physiological measurements (i.e., heart rate, blood pressure, and brain wave) could be an efficient complementary and objective measurement for the self-reported questionnaire [98]. Regarding future research, it is worth highlighting the use of both objective and subjective measures for assessing drivers' stress levels, which could minimize the social desirability bias typically from the self-reported questionnaires [99]. Furthermore, the naturalistic driving study (NDS) database has been used to get back the participants' natural commuting driving behaviors in the latest month, which could help participants self-report their stress levels and perceived commuting time (PCT) more accurately. However, based on the retrospective evaluation, participants' previous evaluations might affect the following judgments. Therefore, for each participant, these commuting driving videos in various scenarios were arranged based on a random order to avoid this bias. In addition, the sampling substantially affected the generalizability of the findings on a population level. This study was conducted with commuting drivers only in Harbin, China, not addressing other specific groups (such as professional drivers). The current results should also be verified in other cities or countries. Finally, future research is worth exploring the different impacts of other possible explanatory variables specific to snow weather conditions and road surface conditions on drivers' stress levels and the influence of different driving scenarios (such as congestion and traffic accidents) on the commuting time gap.

Data Availability

The raw data supporting the conclusions of this article will be made available on request.

Ethical Approval

The content related to the questionnaire of this study was approved by the Institutional Review Committee, and there is no violation of ethical and legal prohibitions in this research.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by the Natural Science Foundation of Heilongjiang Province of China (Grant no. YQ2020G001) and the Scientific Research Foundation for Heilongjiang Postdoctoral (Grant no. LBH-Q21054).

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