Left-Turn Driving Behavior Based On Situational Anger: Day Or Night

Jingjing Xiong
Sichuan Normal University

Yan Mao (maoyy85@163.com)
Sichuan Normal University

Xuan Wang
Sichuan Normal University

Wu He
Sichuan Normal University

Research Article

Keywords: anger, conditions, emotional, encroachment

Posted Date: December 3rd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1094199/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License
Abstract

Anger is a key factor affecting drivers' subjective judgment and driving skills. The influence of anger on driving behavior has been widely studied, but there is a lack of comparative research under different lighting conditions. Through driving simulation experiment, this paper studies the influence of anger on left-turn driving behavior under two light conditions of day and night. In the experiment, 32 licensed participants were divided into two groups, one in emotional neutrality and the other in anger. Among them, the emotional state of anger is induced by a traffic related video. The results showed that compared with daytime participants, participants at night had higher anger intensity, shorter gap acceptance and post encroachment time (PET) when left-turn driving. In addition, compared with emotion neutral participants, angry participants tended to accept shorter gap acceptance and post encroachment time (PET) when turning left. This indicates that participants failed to respond correctly to left-turn driving behavior in a state of anger. However, the response of gender differences to situational driving anger was not affected by light conditions. The anger intensity of male participants during the day and night was higher than that of female participants, and the gap acceptance and post encroachment time (PET) during left-turn were shorter than that of female participants. This shows that male participants are more likely to produce high-intensity anger and are more likely to make dangerous driving decisions in a state of anger. This paper puts forward some suggestions on the identification of anger and the prevention of angry driving.

Full Text

Traffic deaths are one of the leading causes of death worldwide. It is estimated that 1.35 million people die in road traffic accidents and more than 5 million are injured globally each year\textsuperscript{6}. Intersections are high-risk areas with high traffic accidents\textsuperscript{6}. compared with about 42% in Japan, the United States, Europe, and other countries 50% and 43%\textsuperscript{51,44,41}. Left-turn driving is an important cause of traffic accidents at intersections\textsuperscript{6}.

Left-turn driving can cause impact movements on the front or side of vehicles, increasing the risk of traffic accidents\textsuperscript{33}. Of these, about 90% of personal injury or death is caused by human factors\textsuperscript{20}. Driver's anger is a key factor in traffic accidents\textsuperscript{50}.

Anger is an emotional state characterized by annoyance and anger\textsuperscript{58}. Although anger is an adaptive and functional emotion, it can also lead to many bad outcomes, such as traffic accidents caused by aggressive driving and angry driving\textsuperscript{38}. Studies have shown that anger increases the risk of traffic and road traffic accidents\textsuperscript{2}. Anger can hurt speeding, lane departures, and traffic violations, driving performance, and risky behavior\textsuperscript{36}. Drivers in angry states drive faster, drive closer to the vehicle in front, and accept shorter gaps when turning left\textsuperscript{58}. Studies have shown that angry drivers exhibit more violations than neutral drivers\textsuperscript{51}. As the human-car-road conflict intensifies, angry driving behavior is increasing\textsuperscript{7} and the phenomenon of angry driving "road rage" caused by anger is becoming more
Relevant studies show that our country is about 60.72% of motor vehicle drivers have experienced "road rage". Therefore, it is necessary to study the effect of anger on left-turn driving behavior.

Spielberger’s State-The Character Anger Model is a well-known theoretical framework about the impact of anger on traffic safety. Spielberger defines the tendency to frequent and intense anger as characteristic anger, and from the temporary state of physical feelings and anger to state anger. According to this theory, Deffenbacher, Getting, and Lynch distinguish between two modes of driving anger, which are trait driving anger and situational (state) driving anger. Trait driving anger refers to the tendency of the driver to become angry while driving, while state driving anger refers to the physical arousal and anger of the driver in the event of irritable situations. Trait-based driving anger is a relatively persistent and stable personality, while situational driving anger is an emotional state. Although many studies have shown that trait anger has a significant impact on driver behavior, drivers are also directly affected by situational driving anger. Ho Dong Chao, Līva Ābele based on situational (state) driving anger patterns on the driver's driving performance, road decision-making, driving style, visual attention distribution, and other studies also show that situational driving anger will hurt the driver's driving behavior. However, there has been limited research on the effects of situational anger on left-turn driving behavior.

In China's traffic environment, traffic scenes such as vehicle lane change without turning lights, vehicles in intersection lane white solid line change, non-motorized traffic lanes, or even retrograde are very common in daily life and can arouse the anger of the majority of drivers to varying degrees. Sullman is based on the Driving Anger Scale defines four types of driving-related anger-inducing situations: impaired progress, dangerous driving, hostile gestures, and impolite driving. Wickem also points out that behaviors such as walking back and forth (33%) and driving slowly (20%) tend to cause anger among drivers. Anger is an important cause of drivers' angry driving. Most traffic accidents caused by angry driving behavior occur at night. However, there has never been an investigation into whether lighting conditions can cause changes in drivers' anger.

In addition, the night driving environment is also a key factor affecting driving behavior. Night driving is dangerous for all road users. Although only 21%-23% of vehicle mileage is required to travel at night, 51% of fatal accidents and 29.5% of accidental injuries occur at night. Road users have three times the mortality rate at night. Joanne M. Wood points out that dim lighting conditions can lead to a significant reduction in the driver's reaction time and pedestrian identification distance, thereby increasing the risk of driving at night. Second, driver drowsiness at night is also a major cause. Influenced by circadian rhythms, people will become more sleepy at night, and drowsiness leads to reduced drivers' awakening and functional sensory-motor skills, leading to poor driving decisions. However, there is little research on the effect of lighting conditions on left-turn driving behavior.

In the study of situational driving anger, the previous methods of inducing anger mainly included experience recall, story situation, and film induction. In recent years, the film-induced method has been
widely used in the study of situational driving anger, Zhang Tingru\textsuperscript{58}, No Dongchao\textsuperscript{27}, Li\textsuperscript{2} also demonstrated that the effectiveness of film-induced methods in the induction of anger.

In this paper, the driving simulator experiments under different light conditions were carried out by using the film induction method to induce the participants' anger, so as to solve the following problems: first, will the anger be affected by the light conditions? Second, is the left turn driving behavior of participants affected by light conditions under the state of anger? The results of this study contribute to a deeper understanding of the mechanism and consequences of situational driving anger, and put forward some suggestions to control the negative effects of situational driving anger.

**Method**

**Participants**

In this research, a total of 32 participants with normal vision or correction, no color blindness or other eye diseases, and who had a driver's license and at least one year of driving experience were interviewed anonymously and voluntarily. They were randomly divided into 2 groups of 16 people, equally male to female. All the participants were persuaded that their information will remain anonymous and the total data will be applied in research, increasing the traffic safety knowledge. Each participant is paid CNY 50. The participants were informed that they could quit the experiment at any time and were asked to sign an informed consent form before the experiment began. The study was approved by the Ethics Committee of Sichuan Normal University and all experimental procedures were performed in accordance with the Declaration of Helsinki.

**Experimental equipment**

The current study is carried out using a fixed base all-instrument open cab simulator system. The driving simulator cab uses three 42-inch LED screens to provide a 180-degree horizontal view, one screen for the front view image, and two screens for the side mirror display. The simulator includes all automotive controls, such as a 1060-degree rotating feedback-powered steering wheel, clutch, brake and accelerator pedals, shifter (for manual transmissions), mirrors and side mirrors, steering signal lights, similar to actual cars. The simulator is equipped with a screen panel that displays the speedometer, tachometer, steering signal indicator, and the audio system in the simulator is connected to the analog scene, providing traffic sound and engine noise to reproduce the actual vehicle's surroundings, thereby enhancing the authenticity of the driving experience on the simulator.

**Experimental design**

This study was designed using a 2(control group/anger group) * 2(day/night) hybrid experiment design. The internal factor of the participant is the emotional state. In the experiment, we used a five-minute traffic-related movie clip taken from the driver's point of view to induce the anger of the participants. Before the experiment, participants were shown a five-minute-long daytime and night video video clip taken
from the driver's point of view to induce anger. Participants were asked to imagine themselves driving in the video clip vehicle. Half of the participants performed left-turn tasks in anger-driven situations, while the other half completed the same tasks without anger-induced neutral emotions. The factor between the participants is the lighting conditions of the driving. Each group of participants was required to complete the left-turn driving task under different lighting conditions.

**Experimental materials**

The first video is in the daytime: The participant's vehicle is driving normally in the inner lane of a four-lane city road. After about 30 seconds, a car overtakes the participant's vehicle in the outside lane and cuts in without using a turn signal. Participants honked their horns to warn the driver that such behavior was dangerous. But the vehicle in front began to deliberately block the participants' progress at a very slow pace. When the participant tries to get rid of the vehicle in front by changing the lane, the vehicle in front suddenly accelerates. This continued for about 3 minutes, with the driver of the vehicle in front throwing debris out of the window and accelerating away.

The second video is at night: The participant's vehicle is driving normally in the inner lane of a four-lane city road. After about 30 seconds, the vehicle in front suddenly changes lanes without turning the lights, and the participants honk their horns to indicate that the driver is dangerous. But the vehicle in front started deliberately blocking the participants' progress at a very slow speed. When the participant tries to get rid of the vehicle in front by changing the lane, the strong high beam of the vehicle coming in the opposite direction affects the participant's sight. This continued for about 3 minutes, with the driver of the vehicle in front throwing debris out of the window and accelerating away.

In the experiment, the difference between the two videos was that the night participants were not only affected by the rude behavior of the vehicle in front but also by the vehicle coming in the opposite direction, while the participants were mainly affected by the rude behavior of the vehicle in front. Chen Yu⁷, Zhang Tingru⁵₈, Feng Zhong, Xiang¹⁹, Deng Yuan chang¹³, Ren Wei wen⁴₀. The above driving behavior will arouse the driver's anger.

**Experimental scenarios**

In the virtual environment we built, we designed a three-lane city road about 8000 meters long and 3.5 meters wide. According to the speed limit for intersections under traffic regulations, we set the same speed (30 km/h) for the through train and the left turn. At the same time, to create traffic conflicts, we have designed different starting points for the through train and the left-turn train, as shown in Figure 1. The test area of the experiment were points A³₀m and B⁶₄ m which far from the conflict area. In the experiment, the left-hander drove into the test area at a speed of 30 km/h. To avoid the perceived effect of speed changes on participants, the through train also needs to pass through the intersection at 30 km/h. In addition, participants can see that the pass-through vehicle is approaching. In this study, the conflict area is defined as the overlapping area between the left vehicle track and the straight vehicle track.
The experimental scenario is shown in Figure 1: (Green indicates the direction of travel of the left-turn; yellow indicates the direction of travel of the straight car, and the red flag indicates the area of conflict).

**Procedure**

Participants arrive at the lab to sign an informed consent form for the experiment and fill in the relevant personal information (age, gender, driving experience) anonymously. The experimenters then divided participants into two groups on average, and everyone has 15 minutes to practice driving to familiarize themselves with the simulator's operation and simulation environment. The variables involved in our experiment are summarized in Table 1.

Table 1-Description of the experimental variable
| Variables                  | Variable description                                                                                       | MAD (SD) | MAD (SD) | MAD (SD) | MAD (SD) |
|----------------------------|-----------------------------------------------------------------------------------------------------------|----------|----------|----------|----------|
|                            |                                                                                                           | Calm     | Anger    | Gap      | PET      |
| **Experiment phase**       |                                                                                                           |          |          |          |          |
| Pre-induction              | Participants were neutral and did not watch the video clip                                               | 5.34(0.94)| 3.25(1.14)| 2.53(1.14)| 6.06(0.92)|
| Post-induction             | Participants had watched the video clips and become angry                                                | 2.53(1.14)| 6.06(0.92)|          |          |
| Post-drive                 | Participants completed the left-turn driving experiment                                                   | 3.19(1.38)| 4.09(0.82)|          |          |
| **Experiment conditions**  |                                                                                                           |          |          |          |          |
| Day                        | Left-turn driving in daytime                                                                            | 4.21(1.53)| 3.96(1.56)| 6.28(1.25)| 4.47(1.10)|
| Night                      | Left-turn driving at night                                                                              | 3.17(1.66)| 4.98(1.31)| 4.75(1.05)| 3.38(1.13)|
| **Traffic operation variables** |                                                                                      |          |          |          |          |
| Gap acceptance             | The time interval between the opposite vehicles(s)                                                       |          |          |          |          |
| Post Encroachment Time (PET) | The time interval when the first car leaves the cross conflict point and the second car enters the conflict point(s) |          |          |          |          |
| **Demographic variables**  |                                                                                                           |          |          |          |          |
| Female                     | Female participants perform driving tasks                                                                  | 4.25(1.67)| 4.15(1.46)| 6.06(1.34)| 4.53(1.14)|
| Male                       | Male participants perform driving tasks                                                                   | 3.13(1.48)| 4.79(1.53)| 4.97(1.12)| 3.31(1.03)|

Before the start of the experiment, a group of participants needed to complete the emotional assessment of the intensity of the three emotions (calm, anger, and fear) that they felt at the time, with a score of 7 (1 was not at all and 7 was very strong). In the experiment, we recorded and managed the emotional scores of the participants. Among them, fear was not scored and managed in this experiment, because fear was not involved in this experiment.

At the beginning of the experiment, the experimenters showed one group of participants a video clip of the daytime situation, re-evaluated the participants' emotional state after watching, and then conducted a
simulated driving experiment. When participants completed daytime driving tasks, they needed a five-minute break to complete the emotional score after the first experiment and calm their emotions.

The second experiment began. The experimenters were asked to focus again on video clips from the night-time situation and repeat the emotional score, followed by a night-time simulated driving experiment. The third emotional score was performed after the end of the experiment. The other group was an experimental control group that conducted simulated driving experiments without watching videos and mood scores. In the experiment, each group of participants was required to complete two consecutive driving sessions, one in the daytime and one at night. The flow of the experiment is shown in Table 2:

| Table 2: Experimental Procedure |
|----------------------------------|
| Beginning | Grouping | 5 min | Emotion evaluate | Emotion evaluate | Driving experiment |
| watch video | Yes | Anger group | Control group |

Data Analysis

Situational Driving Anger Effectiveness Analysis

The effectiveness of emotional induction affects the effectiveness of experimental results. In this study, we used the Jeon experiment method to ask participants to complete an emotional assessment (7 out of 1) of the intensity of the three emotions they felt before, after, and after the experiment (The score is 7, with 1 not at all and 7 very strong) and collect the relevant data. The emotion evaluation data from 16 participants were analyzed by using a 3(experiment phases)

Table 3: A variance analysis of emotional intensity at different experimental phase
P<α=0.05

*2(lighting conditions) mixed ANOVA for each participant. As shown in Table 3.

It can be seen in this table that compared to pre-experiment and post-experiment, the emotional intensity of participants during the experiment had changed significantly. Specially, we can find out that though participants had completed the experiment, the anger intensity of participants is still higher than they do not watch the video, this suggests that the anger that is aroused will last for some time, just as shown in Figure 2.

Our experiment focused on the intensity of participants' anger. We rated emotions 2(emotion state: anger/calm) *2(experiment phase: Pre-induction/post-induction) mixed ANOVA between the participants. In terms of the scores of calm emotion state, there were significant differences in emotional intensity between participants during different experiment stages (F(2,93)=51.11,p=1.06E-15,Fcrit=3.09), participants had lower levels of calm emotional intensity (5.34 vs 2.53) after watching the video compared to the emotional intensity before the experiment; there were also significant differences in anger intensity (F(2,93)=71.58,p=1.51E-19,Fcrit=3.09), participants had a higher intensity of anger (3.25 vs. 6.06) after watching the video compared to the pre-experiment emotional intensity. These results showed that the intensity of anger changed significantly after the participants began the experiment, and it proved the effectiveness of the film-induced method used in this paper in the study of situational driving anger. As shown in Figure 3.

**Analysis of participants' emotional intensity**

First, we analyzed the mixed variance of the emotional scores between the participants on gender and emotions 2(emotion state: anger/calm) *2(gender: male/female). In terms of calm intensity, the gender difference had a significant effect on the participants' emotional intensity (F(2,93)=12.19,p=0.0007,Fcrit=3.94). Female participants had a higher level of calm than male participants (4.25 points vs
3.13 points); in terms of anger intensity, the gender difference also had a significant effect on participants' emotional intensity (F(2,93)=4.48, p=0.04, Fcrit=3.94). Male participants had a higher intensity of anger than female participants (4.79 points vs 4.15 points). These results showed that male participants were more likely than female participants to develop anger and have a higher intensity of anger. As shown in Figure 4:

At the same time, we also performed an ANOVA of light and emotion (emotion state: anger/ calm) * 2 (lighting conditions: day/night). In terms of calm intensity, the lighting conditions had a significant effect on the participants' emotional intensity (F(2,93)=10.26, p=0.002, Fcrit=3.94), participants in the daytime had a higher level of calm intensity (4.21 points vs 3.17 points) compared to participants in the night, and lighting conditions also had a significant effect on participants' emotional intensity in terms of anger intensity (F(2,93)=12.06, p=0.0008, Fcrit=3.94), participants at night had a higher intensity of anger (4.98 points vs 3.96 points) than participants in the daytime. These results showed that participants were more likely to develop anger and have a higher intensity of anger at night. As shown in Figure 4.

Finally, a mixed ANOVA between light and gender (lighting conditions: day/night) * 2 (gender: male/female) showed that there was no interaction between light and gender on the intensity of calm (F(2,93)=0.59, p=0.44, Fcrit=3.94); but a significant interaction between light and gender on anger intensity (F(2,93)=6.01, p=0.02, Fcrit=3.94). As shown in Table 4.

Table 4: Analysis of the variance between light, gender, and emotional intensity

| Variables       | Anger |         | Clam-ness |         |
|-----------------|-------|---------|-----------|---------|
|                 | F     | P-value | F-crit    | F       | P-value | F-crit |
| Light           | 12.06 | 0.0008  | 3.94      | 10.26   | 0.002   | 3.94   |
| Gender          | 4.48  | 0.04    | 3.94      | 12.19   | 0.0007  | 3.94   |
| Light*Gender    | 6.01  | 0.02    | 3.94      | 0.59    | 0.44    | 3.94   |

P<a=0.05

Regardless of lighting conditions, male participants had a higher intensity of anger than female participants (4.33 points vs 3.58 points; 5.25 points vs 4.71 points). These results showed that male participants were more likely than female participants to have a higher intensity of anger. As shown in Figure 5.

**Analysis of the effect of situational driving anger on left-turn behavior**

The driving data from the 32 participants were analyzed by using a 2 (emotional state)

Table 5: Participants’ left-turn behavior variance analysis results
Variables | Gap acceptance | PET |
---|---|---|
Emotion state | Control | Mean | 5.97 |
| | | SD | 1.28 |
| Anger | Mean | 5.06 |
| | SD | 1.27 |
| ANOVA | F | 8.08 |
| | P-value | 0.0006 |
| | Fcrit | 3.99 |
Lighting condition | Day | Mean | 6.28 |
| | SD | 1.25 |
| Night | Mean | 4.75 |
| | SD | 1.05 |
| ANOVA | F | 30.42 |
| | P-value | 7.21E-07 |
| | Fcrit | 3.99 |
| Emotion*Light | Mixed ANOVA | F | 0.13 |
| | P-value | 0.71 |
| | Fcrit | 4.001 |

P<0.05

*2(lighting conditions) mixed ANOVA for each traffic experiment. As shown in Table 5.

First, we did a variance analysis of gap acceptance and post encroachment time (PET) between the subjects on the left-turn behavior 2 (emotion state: anger/control). The results showed that in terms of the gap acceptance of the left-turn task, there are significant post encroachment time (PET) cant differences in emotion (F (1,62) =8.08, p=0.006, Fcrit=3.99). In terms of the post encroachment time (PET), differences in emotion can also cause significant differences (F(1,62)=4.76,p=0.032,Fcrit=3.99). These results showed that participants who were in situational driving anger had shorter gap acceptance (5.06s vs 5.97s) in left-turn tasks and shorter post encroachment time (PET) (3.59s vs 4.25s). As shown in Figure 6:

Secondly, the results show that the difference in lighting conditions also has a significant effect on the left-turn behavior of the participants. From the gap acceptance of the left-turn task, there are significant differences in the different lighting conditions (F(1,62)=30.42,p=7.21E-07, Fcrit=3.99). In terms of the post encroachment time (PET) of the left-turn task, there are also significant differences in lighting conditions
These results showed that participants at night had shorter gap acceptance (4.75s vs 6.28s) and shorter post encroachment time (PET) (3.38s vs 4.47s) when turning left than participants in the daytime. As shown in Figure 7:

We also tested 2 (emotion state: anger/control) * 2 (lighting conditions: day/night) * 2 (behavior: gap acceptance/ post encroachment time) to investigate whether different emotions and light conditions interact on left turn behavior. The results showed that there was no interaction between different emotions and light conditions on gap acceptance of the participants' left turn behavior ($p=0.72> a=0.05$); there was also no interaction between the different emotions and light conditions on the post encroachment time (PET) of the participants' left turn behavior ($p=0.42> a=0.05$). These results indicated that participants showed no significant differences in left-turn driving behavior during daytime and nighttime anger. As shown in Figure 8:

Finally, to test the differences in gender in the experiment, we conducted four variables 2 (emotions: anger/control) *2(lighting conditions: day/night) *2(behavior: gap acceptance/ post encroachment time) *2(gender: male/female) mixed variance analysis. The experimental results show that the gender difference is not significant.

**Discussion**

**Analysis of the effectiveness of the film-induced method**

The focus of this study was the intensity of anger among participants before and after the start of the experiment. In the experiment, we observed a decrease in calm emotional intensity (5.34 points vs 2.53 points) and an increase in anger intensity (6.06 points vs 3.25) after watching the video clip. The results indicate that the participants’ anger was successfully aroused. This is consistent with the study of Zhang Tingru, that is, the film-induced method is effective in situational driving anger research.

Compared to other interaction methods, the experimental method based on the driving simulator may be considered to lack ecological effectiveness. Our experiment is very similar to the experience of anger while driving. In actual traffic, although an event that provokes anger usually lasts only a few minutes, the anger it had aroused may continue into a subsequent driving situation and has an impact on driving behavior. Some people may think that the anger may quickly disappear when performing demanding driving tasks. However, the results showed that despite the decrease in anger intensity during the driving simulation experiment (4.09 vs 6.06 points), however, the anger is still significantly higher than before the anger induction (4.09 points vs 3.25 points).

**Effect of lighting conditions on situational driving anger**

In conclusion, the results of this study show that the anger intensity of participants at night is significantly higher than that during the day. Because the risk of driving at night is higher than that during the day, and the reduced visibility at night increases participants’ cognitive burden on the environment, participants are more likely to have a high degree of anger. Relevant studies show that drivers will not
reduce their speed due to reduced visibility at night. Therefore, participants need to focus on the surrounding environment to ensure the safety of driving behavior. When this attention is interrupted by sudden rude behavior, participants will instinctively produce stress psychological response, resulting in the increase of angry emotional intensity. At the same time, due to the influence of circadian rhythm, humans usually become more sleepy at night. Driving for a long time makes the participants bear both physical and mental pressure. Participants need to maintain a high degree of tension to deal with various possible situations. When the front party suddenly rude driving behavior, participants will be more sensitive to rude provocation, resulting in an increase in anger. This is consistent with Li Ming's research, that is, before the outbreak of "road rage", the actor's individual psychology mostly had adverse tendencies and pathological signs such as anxiety, tension, irritability, depression, impetuosity, anger, evasion and jealousy. Chen Yu also pointed out that the more frequent you drive, the more mileage you drive, the easier it is to drive angrily.

The results showed that male participants were more angry than female participants regardless of light conditions. The main reasons for this difference between male and female subjects are as follows: First, women are more likely than men to predict the potential risks and future consequences of their behavior. They will avoid any violent behavior that may cause each other's anger to form a self-protection mechanism. Secondly, female drivers respect the rules more than male drivers. Meanwhile, compared with female drivers, male drivers have relatively low public self-awareness, which leads male participants to pay more attention to their emotions and have a higher degree of anger when encountering abnormal driving behavior. Finally, compared with male participants, female participants were more likely to adopt a more adaptive attitude to express anger, while male participants were more aggressive. The research of Li Ming, Yan Lixin and others shows that male participants have a higher probability of anger during driving than female participants. But Bjorklund, Cong Haozhe, LivaBele and others pointed out that female drivers are more likely to produce road anger. Pelin Deniz also showed that masculinity and femininity regulate the relationship between driving anger and driving anger expression of young drivers. It can be seen that the impact of gender differences on anger is controversial. In this study, our experimental results show that gender differences have a significant impact on the degree of anger of participants.

The effect of situational driving anger on left-turn behavior

The results of this paper showed that participants who were in a situational driving rage had shorter gap acceptance and post encroachment time (PET) when turning left than participants with neutral emotions. This is consistent with studies by Zhang Tingru, in which participants in anger had shorter wait times when turning left, resulting in shorter acceptable gaps. Beatriz González-Iglesias points out that anger can lead to traffic violations by drivers. Li, Zhang, Sawyer, Zhang, and Hancock. It is also confirmed that angry drivers tend to show a higher risk-taking tendency. From a behavioral perspective, driving anger can adversely affect driving behavior, increasing the risk of traffic accidents. Secondly, visual perception is the main source of driving information. Easterbrook pointed out that high awakening negative emotions
(such as anger) can lead to tunnel vision, a peripheral vision loss, but the central vision remains the same. Therefore, the horizons of drivers in situational driving anger will be narrow, and participants will focus mainly on traffic events ahead and miss safety-critical information in the surrounding view. All of these factors lead to wrong driving behavior decisions. Zhang Tingru\textsuperscript{58} also pointed out that situational driving anger reduces the range of the driver's visual attention. Taken together, anger leads to incorrect driving decisions made by participants that increase the risk of traffic accidents.

**Effect of lighting conditions on left-turn behavior**

The experimental results showed that the gap acceptance and post encroachment time (PET) was shorter when the participants performed left-turn driving at night (6.06s vs 5.5s; 4.06s vs 4.53s). The main reasons are as follows: First, visual perception is the main source of driving information. The limited exposure range of vehicle headlights reduces participants' visibility on the road at night, resulting in reduced awareness of other vehicles on the road and the surrounding environment, resulting in incorrect decisions. Second, participants' drowsiness at night was also a major cause. Horne's\textsuperscript{25}; Lowden, Arne's\textsuperscript{35} research shows that drowsiness can lead to reduced wake-up and functional sensory-motor skills, leading to more dangerous driving behavior. Influenced by circadian rhythms, participants become sleepier at night, leading to poor driving decisions. At the same time, the lucky mentality and the safe enclosed interior space also make participants more likely to take a chance at night. Research by Li Ming\textsuperscript{32} also points out that accidents caused by road rage occur mostly at night. Finally, the intersection is a complex part of the road network, where participants need to make multiple decisions at considerable temporal pressure and high speed\textsuperscript{57}, while the dim environment at night increases the cognitive burden of participants, causing participants being unable to make correct decisions promptly. In conclusion, participants had shorter gap acceptance and post encroachment time (PET) when turning left at night.

**Limitation**

This study has some limitations but they could be addressed in the future. First, the driver's reaction in the simulator differs from the real world, and the adopted simulator adopted reduces the authenticity and effectiveness of the experimental results. In the future, the comprehensive use of modern technologies such as VR and EEG can be used to reduce the authenticity of the experimental results and the real-world difference.

Second, the participants' emotional scores were mainly self-reported data, and it was not possible to determine whether the participants had the mentality to meet social expectations. The study could consider objective data collection methods to minimize data errors. Third, other situations besides state driving anger that could cause participants' anger was also not considered, and the impact of verbal aggression on driver driving anger is an interesting topic of future research. Finally, most of the study samples are young drivers with a small sample size, and the experimental results are not generally representative. In the future, the study sample size should be considered to expand, and more participants
with different driving experiences should be selected for experiments. In the future, we will work to provide a dynamic traffic model based on the situational driving rage to predict changes in driving behavior as participants drive continuously in the lane.

**Conclusions**

The purpose of this study was to study the effect of situational driving anger on left turn driving behavior under different lighting conditions. The unique contribution of this study is that by improving the experimental design and strictly controlling the potential confounding factors, it provides some causal relationships among illumination, situational driving anger and left turn driving behavior. The study successfully proved that light conditions significantly affected the anger intensity of participants. However, light conditions do not necessarily affect gender's response to anger situations. In addition, the study found that the gap acceptance and post encroachment time (PET) of angry participants at night were shorter than that during the day. This shows that drivers in angry state are more careless at night than drivers in emotional neutral state.

The results showed that angry participants were more likely to drive dangerously at night. Based on the results of this study, we put forward the following suggestions to reduce the adverse effects of situational driving anger. First, develop real-time anger recognition technology and necessary mitigation strategies to help drivers manage emotions. Second, the driver's negative attitude in the state of anger is the key to affect the accident risk caused by anger. Therefore, we can increase the learning of correctly identifying and dealing with negative driving attitudes in driver education. Third, a hazard warning system can be installed in the vehicle to help angry drivers effectively obtain road information. Finally, the driving anger intervention strategy should be applied to different light environments.

**Declaration**

**Data availability**

The data and material of the current study will be available from the corresponding author upon reasonable request.

**References**

1. Abdu Rotem, etc. Situational (state) anger and driving. *Transportation Research: Part F, 15* (5), 575–580 (2012).

2. Abele Liva, etc. Links between observed and self-reported driving anger, observed and self-reported aggressive driving, and personality traits. *Accident Analysis & Prevention, 140* (2020).

3. Alberto, Miron-Juarez, etc. Approaching a structural model of impulsivity and driving anger as predictors of risk behaviors in young drivers. *Transportation Research: Part F, 72*: 71–80 (2020)
4. Bernoulli etc. Driving anger, emotional and instrumental aggressiveness, and impulsiveness in the prediction of aggressive and transgression driving. *Accident Analysis & Prevention, 50*, 758–767 (2013).

5. Bjorklund Gunilla, etc. Driver irritation and aggressive behaviour. *Accident Analysis & Prevention, 40* (3), 1069–1077 (2008).

6. Calvi Alessandro, etc. Evaluation of augmented reality cues to improve the safety of left-turn maneuvers in a connected environment: A driving simulator study. *Accident Analysis & Prevention, 148*, 105793 (2020).

7. Chen, Y. Pang Yu, Li Yang, etc. Current Status and Prospects of Vehicle Drivers' Angry Driving Research. *J. Injury Medicine Electronic Edition, 4* (3), 54–59 (2015).

8. Cong Haozhe, etc. Road rage in China: An exploratory study. *Journal of transportation safety & security, 13* (5), 503–524 (2021).

9. Deffenbacher, J. etc. Driving anger as a psychological construct: Twenty years of research using the Driving Anger Scale. *Transportation Research: Part F, 42*, 236–247 (2016).

10. Deffenbacher JL, etc. Development of a driving anger scale. *Psychological Reports, 74*(1):83–91 (1994).

11. Deffenbacher, J. L. etc. The Driving Anger Expression Inventory: a measure of how people express their anger on the road. *Behavior Research and Therapy, 40* (6), 717–737 (2002).

12. Deffenbacher, J. L. etc. Anger, aggression, and risky behavior: a comparison of high and low anger drivers. *Behavior Research and Therapy, 41* (6), 701–718 (2003).

13. Deng Yuanchang, J. Review of the Study on Driver's "Road Rage" (J. Chongqing Jiaotong University Journal. *Natural Science Edition, 37* (11), 105–111 (2018).

14. DePasquale etc. Measuring road rage - Development of the propensity for angry driving scale. *Journal of safety research, 32* (1), 1–16 (2001).

15. Duy Quy, Nguyen-Phuoc, etc. Turn signal use among motorcyclists and car drivers: The role of environmental characteristics, perceived risk, beliefs and lifestyle behaviors. *Accident Analysis & Prevention, 144*, 105611 (2020).

16. Eagle, A. H. Steffen, etc. Gender and aggressive behavior: a meta-analytic review of the social psychological literature. *Psychological Bulletin, 100* (3), 309–30 (1986).

17. Eastbrook etc. The effect of emotion on cue utilization and the organization of behavior. *Psychol. Rev, 66* (3), 183–201 (1959).

18. Fan, X. etc. Investigating the effect of personality on left-turn behaviors in various scenarios to understand the dynamics of driving styles. *Traffic Injury Prevention, 20*(8):801-806 (1900).

19. Feng Zhongxiang, L. & Yewei Zhou Muxiong, etc. Analysis of the effectiveness of the revised driving anger scale among Chinese drivers. *Journal of Chongqing Jiaotong University: Natural Science Edition, 35* (4), 141–145 (2016).

20. Gonzalez-Iglesias Beatriz, etc. Driving anger and traffic violations: Gender differences. *Transportation Research: Part F, 15* (4), 404–412 (2012).
21. Gunson Henry, etc. Road-related anger in motorcyclists versus car drivers. Transportation Research: Part F, 62(Apr.): 327–338 (2019).

22. Guo & Shuang Chang Rusong. Research methods on the effects of driving anger on driving safety. *Human Ergonomics*, 21(1), 66–68 (2015).

23. Healey JA, etc. Detecting stress during real-world driving tasks using physiological sensors. IEEE Transactions on intelligent transportation systems, 6(2): 156–166 (2005).

24. Hewig J, etc. A revised film set for the induction of basic emotions. *Cognition & emotion*, 19(7), 1095–1109 (2005).

25. Horne, J. S. Awake, stay alive. New Scientist, 133(1802): 20-24 (1992).

26. Huang YuWen, etc. The influence of bus and taxi drivers’ public self-consciousness and social anxiety on aberrant driving behaviors. Accident Analysis & Prevention, 117: 145-153 (2018).

27. Huo & Part, F. Dongchao, etc. Lane-changing-decision characteristics and the allocation of visual attention of drivers with an angry driving style. Transportation research. Traffic psychology and behavior, 71: 62-75 (2020).

28. Jagerbrand Annika, etc. Effects of weather conditions, light conditions, and road lighting on vehicle speed. SpringerPlus, 5(1): 505–505 (2016).

29. Katsis Christos, etc. Toward emotion recognition in car-racing drivers: A bio signal processing approach. IEEE Transactions on Systems, Man, & Cybernetics, 38(3): 502-512 (2008).

30. Keall etc. The contribution of alcohol to nighttime crash risk and other risks of night driving. *Accident Analysis & Prevention*, 37(5), 816–824 (2005).

31. Khorashadi A, etc. Differences in rural and urban driver-injury severity in accidents involving large trucks: An exploratory analysis. *Accident Analysis & Prevention*, 37(5), 910–921 (2005).

32. Li, M. The Basic Characteristics of Road Rage and its Criminal Law System. *Journal of Jiangsu Police Academy*, 36(2), 84–89 (2021).

33. Li, Z. & Part, F. Driving anger scale validation: Relationship of driving anger with the aberrant driving behavior of truck drivers. Transportation research. Traffic psychology and behavior, 81: 364–372 (2021).

34. Li & Shuling, etc. Angry Drivers Take Risky Decisions. Evidence from Neurophysiological Assessment. *International Journal of Environmental Research and Public Health*, 16(10), 1701 (2019).

35. Lowden Arne, etc. Wakefulness in young and elderly subjects driving at night in a car simulator. Accident Analysis & Prevention, 41(5): 1001-1007 (2009).

36. Jeon Myounghoon. Effects of specific emotions on subjective judgment, driving performance, and perceived workload. *Transportation Research: Part F*, 24, 197–209 (2014).

37. Pawar, N. etc. Modeling braking behavior and accident probability of drivers under increasing time pressure conditions. Accident Analysis & Prevention, 136 (2020).

38. Pelin, Deniz Timo etc. Masculinity, femininity, and angry drivers: Masculinity and femininity as moderators between driver anger and anger expression style among young drivers. *Accident Analysis...*
39. Precht Lisa, etc. Effects of driving anger on driver behavior - Results from naturalistic driving data. *Transportation Research: Part F, 45*, 75–92 (2017).

40. Ren Weiwen, L., Wei, Z. & Wei etc." Study on the internal and external logic and influencing factors of Road Rage". *China Safe Production Science and Technology, 17* (7), 162–166 (2021).

41. Rieger etc. Centralized MPC for autonomous intersection crossing. In: IEEE International Conference on Intelligent Transportation Systems, Rio de Janeiro, Brazil, 1372–7 (2016).

42. Roedl Ernst etc. Introducing a multivariate model for predicting driving performance: The role of driving anger and personal characteristics. *Journal of Safety Research, 47*, 47–56 (2013).

43. Sagar Rajesh etc. Road rage: An exploratory study on aggressive driving experience on. *Indian roads. International Journal of Social Psychiatry, 59* (4), 407–412 (2013).

44. Sander Ulrich etc. Opportunities and limitations for intersection collision intervention-A study of real-world 'left turn across path' accidents. *Accident Analysis & Prevention, 99* (Pt A), 342–355 (2017).

45. Shen Sijun etc. Comparing distance and time as driving exposure measures to evaluate fatal crash risk ratios. *Accident Analysis & Prevention, 142*, 105576 (2020).

46. Spielberger, C. D. State-trait anger expression inventory, 1st ed. Psychological Assessment Resources, Odessa, FL (1988).

47. Stephens, A. N. & Groeger J.A. Anger congruent behavior transfers across driving situations. *Cognition & Emotion, 25*, 1423–1438 (2011).

48. Suliman Awadwh. Aggressive driving is a major cause of traffic accidents and road rage in Jordan//Driving Assessment 2003: The Second International Driving Symposium on Human Factors in Driver Assessment. Training and Vehicle Design, 182-187 (2003).

49. Sullman, MJM. Anger amongst New Zealand drivers. *Transportation Research: Part F*, 9(3):173–184 (2006).

50. TÜİK (Turkish Statistical Institute). Traffic Accident Statistics (Karayolu Trafik Kaza İstatistikleri,) 2019. Retrieved from http://www.tuik.gov.tr/PreHaberBult enter.do.id:33628 (2020).

51. Wang, J., Xue, X., Chai, R. & Cao, N. Atemporal-spatial collision warning method at the non-signalized intersection. *ProcEng, 137*, 827–35 (2016).

52. Wickens Christine etc. Anger-provoking events in driving diaries: A content analysis. *Transportation Research: Part F*, 19(Jul.):108–120 (2013).

53. Wood Joanne etc. Night-time driving visibility associated with LED streetlight dimming. *Accident Analysis & Prevention, 121* (Dec.), 295–300 (2018).

54. Wood Joanne etc. Nighttime driving: visual, lighting and visibility challenges. *Ophthalmic and Physiological Optics, 40* (2), 187–201 (2020).

55. Yang Lixin, W., Chaozhong & Anger Gao Hao, etc. Study on the Relationship between Individual Driver Factors and Driving (2013).
56. Yang Runan. etc. Safety effects of street lighting on roadway segments: Development of a crash modification function[J]. *Traffic Inj. Prev.*, 20 (3), 296–302 (2019).

57. Young Kristie, etc. At the cross-roads: An on-road examination of driving errors at intersections. *Accident Analysis & Prevention*, 58:226-234 (2013).

58. Zhang etc. Situational driving anger, driving performance and allocation of visual attention[J]. *Transportation Research: Part F*, 42, 376–388 (2016).

59. Zhang Tingru, etc. Driving anger and its relationship with aggressive driving among Chinese drivers. *Transportation Research: Part F*, 56, 496–507 (2018).

**Figures**

![Experimental scenario diagram](image)

**Figure 1**

Experimental scenario diagram
**Figure 2**

The changes of emotion intensity in different experiment phase
**Figure 3**

Changes in participants' emotional intensity

**Figure 4**

The effect of light and gender on emotional intensity

**Figure 5**
Effects of different lighting conditions on emotion

**Figure 6**

The influence of different emotional states on left-turn behavior

![Bar chart showing gap acceptance and PET for day and night conditions.]

**Figure 7**

The effect of light and sex on left-turn behavior

**Figure 8**

The effect of different lighting conditions on left-turn behavior