The Effect of Emotion Induction on Situation Awareness and Driving Performance

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Abstract

This study investigates the effects of pre-induced emotions on situation awareness (SA) and driving performance. Twelve male students (mean age of 23.9 ±1.8 years old) with a valid driving license participated and attended two driving simulation sessions on separate days. Participants drove a driving scenario for each session after being presented with a series of pictures to induce positive or negative emotion. Participants' SA was measured by quantitative analysis of situation awareness (QASA). Driving performance was determined in terms of the collisions' number. The result showed that emotion induction significantly affected driving performance (p =0.005). The collisions' number was higher after the induction of negative emotion than after positive emotion induction. Participants' SA level 1 was also affected by the emotion inductions (p = 0.042), where the SA level 1 after the induction of negative emotion was higher than that after the positive emotion induction. These results indicate that SA partially mediates the effect of emotion on driving performance. Our findings demonstrate the emotion induction effects on situation awareness and driving performance. The results of this study imply that an emotional state before driving is essential for transportation safety.

Keyword
Pre-induced emotion, situation awareness, driving performance, collisions

1. Introduction

Nass et al. (2005) stated that people could not think or perform anything without engaging their emotional system, at least implicitly. It is the same thing as driving. People cannot drive without engaging their emotions. Driving is a complex activity that entails a complex and fast repeating cycle that necessitates a level of skill as well as the capability to engage with both the vehicle and the external environment at the same time. However, the emotion of the driver can impair the driving activity. Wickens et al. (2016) found that negative emotion during driving can occur the aggressive driving, leading to an increasing in accident probability. In another study, emotion has been stated to impair driving behaviour (Hu et al. 2013), risk perception sensitivity (Jones et al. 2014), and driving performance (Zimasa et al. 2019). Furthermore, emotion is included as one of the human factors related to driving behaviour. According to Setiawan et al. (2017), the human factor accounts for 93.52% of all traffic incidents, while traffic factors, road and environmental factors accounted for 2.76%, 3.23%, and 0.49% of traffic accidents, respectively. Some studies related to the effect of emotion on driving performance result in a contradictive conclusion. For example, a driver with negative emotion reportedly tends to slow down the driving speed (Chan dan Singhal 2013 2015), while Steinhauser et al. (2018) reported that the driving speed of driver with negative emotion was higher with more significant variability than the driver of positive emotion. Meanwhile, Rhodes et al. (2015) stated no difference in driving speed

between drivers with negative or positive emotions. It indicates that some research related to the effect of emotion on driving performance has been inconsistent. Therefore, further research on that topic is needed.

Situation awareness (SA) is also one of the human factors that are essential for driving activity. According to Endsley (1995), SA is a form element's perception in the environment within a volume of time and space, comprehension of the meaning, and projecting their status in a brief period. As mentioned before, driving is an activity that needs to engage with both vehicle and the external environment. Then, people need SA while driving, not only to run the vehicle and avoid objects around them but also to drive strategically. SA framework introduced by Endsley (1995) stated that SA affected task performance, while Briggs et al. (2018) and Jeon et al. (2015) also stated that SA affected driving performance.

Related to emotion, Jeon et al. (2014) and Jeon et al. (2015) discovered that angry emotion on the driver has an adverse impact on SA and driving performance. Meanwhile, Steinhauser et al. (2018) reported that emotion to SA has no significant effect. However, how emotions are related in the SA framework introduced by Endsley (1995) has not been explored much further. So far, there has not been much research about the effect of emotion on SA, particularly the relationship between emotion, SA, and driving performance.

This study investigates the effects of pre-induced emotions on situation awareness (SA) and driving performance. A quantitative analysis of situation awareness (QASA) was used to measure participants' SA. The collisions' number was used to assess driving performance. The proposed research framework of the relationship between those variables is shown in Figure 1.

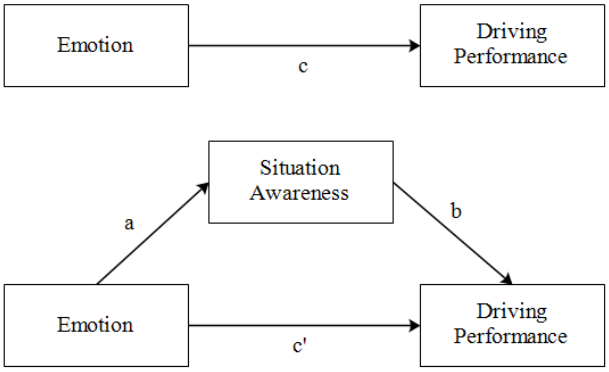

Figure. 1. The proposed research framework of emotion, situation awareness, and driving performance. (c) represents a direct effect of emotion on driving performance; (a) represents the effect of emotion on situation awareness; (b) indicates the effect of situation awareness on driving performance; (c') represents an indirect effect of emotion on driving performance.

2. Methods and Data collection

2.1 Participants

Twelve young male drivers with an average age of 23.92 ± 1.78 years old participated in this study. Participants had valid driving licenses for an average of 4.88 ± 2.20 years. They had normal eyes or visual impairment corrected with glasses. Written informed consent was obtained before the participation of the present study.

2.2 Apparatus and materials

City car driving v1.5.9, Forward Development Rusia, was used in this study and was projected in a large 32-inch Samsung personal computer. The driving simulator was equipped with manual transmission gear, a steering wheel system, a pedal controller, and a driver seat (Logitech G27).

2.3 Emotion induction stimuli

A double mood induction technique that combined a series of images and music induction was used in the present study. The image stimuli were 40 images (20 negative and 20 positive images) selected from the Open Affective

Standardized Image Set (OASIS) introduced by Kurdi et al. (2017). The mean OASIS normative valence ratings (Kurdi et al. 2017) of the selected images in the present study were 1.89 for negative images and 5.82 for positive images. The music induction was A Little Serenade by Wolfgang Amadeus Mozart for negative emotion induction and Night on Bald Mountain by Modest Mussorgsky for positive emotion induction (Steinhauser et al., 2018). The music that induced negative or positive emotion was played during the driving session to maintain the induced emotion.

2.4 Experimental procedures

Participants attended two driving simulation sessions on separate days. The sessions were differentiated based on the emotional induction scenario. In the first session, the participants used a driving simulator to become familiarized with a modern district setting. That session lasted at least 10 minutes or until they could operate the simulator well. The participants then continued to take part in the main experiment.

Before each driving scenario, participants were asked to rate their initial valence level using the Self-Assessment Manikin (SAM). Participants then received either negative or positive emotion induction in random order and on separate days. The emotion induction began with the image presentations following the protocol by Choi et al. (2015). The selected 20 OASIS images were presented twice, and a yellow circle to sustain participants' attention were presented ten times (a total of 50 presentations). Each presentation began with a cross shape for 500 ms, followed by an OASIS image or a yellow circle for 2000 ms. The participants were instructed to immediately respond to the circle by pressing a button with their right hand. The following presentation was restarted 1000 ms after participants' responses. After image presentations, participants were asked to rate their valence level using SAM.

After being induced randomly, either with positive or negative emotions, participants performed the driving task. They were asked to act as an online driver and drove a virtual car using a driving simulator for 15 minutes to pick up and drop off passengers. The driving scenario was set at 50% traffic density, normal traffic behaviour, and rare emergency. During the driving simulation session, the participant was instructed to obey the traffic rules depending on the road signs and situation. The driving area and starting points were similar. Because the driving simulator provides dynamic situation, participants might encounter various driving situation. The experimental setting is depicted in Figure 2. After finishing the driving task, they were asked to rerate their valence level using SAM.

Figure 2. Experimental setting

2.5 Driving performance measures

The measurement of driving performance employed in this study is the number of collisions. The total collisions were automatically recorded by driving simulator software. The collision is counted when participants' vehicle collided with other vehicles or objects while performing the task. A higher driving performance score indicated poor driving performance.

2.6 Situation awareness measures

Quantitative analysis of situation (QASA) was used to assess participant SA throughout the experiment. A freeze probing technique was used to deliver the probes where the driving session was frozen five times randomly. The simulation software was paused, and the display screen was then powered off. For each freezing period, the 6 of 30 SA true/false probes were asked to the participants. The probes were targeting all levels of SA. For example, participants were asked to identify the colour of the traffic light in front of them (level 1 of SA) and to assess whether they need to drive carefully or not based on the current traffic light (level 2 of SA). Finally, they were asked to determine whether they needed to slow down their speed to avoid any accident or traffic violation (SA level 3). Following each probe, participants were asked about their response confidence by giving a rate ranging from 1 to 5 indicate from very low to a high level of confidence. After responding to all six probes, the monitor was turned on, and the participants continued their driving where they had left off.

In this study, QASA provided two measures: the actual SA and the perceived SA. The actual SA was a parameter that measures an individual's ability to distinguish the correct information (signal) from false information (noise) in the current situation. The correct information was based on the record of simulation software. The perceived SA was a parameter that measures individuals' perception of the level of confidence in answering the questions given. The QASA true/false probes were examined using signal detection theory according to Edgar et al. (2017) to calculate the actual SA. The average of participants' confidence rate was used to determine the perceived SA. For simplicity of analysis, all actual and perceived SA scores were rescaled from -10 to +10.

2.7 Statistical Data Analysis

Results' values are shown as mean and standard deviation. The Shapiro-Wilk test was used to verify the collected data for normal distribution. The rating of valence, number of collisions, actual SA level 1, actual SA level 2, actual SA level 3, and perceived SA were not normally distributed, while actual SA was normally distributed. The paired t-test was used to assess the effect of emotion on collected data that had normal distribution, and Wilcoxon used collected data that had no normal distribution as the parametric assumption. Statistical significance was set at $p < 0.05$.

A mediation analysis using Bias-corrected bootstrap protocol (Hayes's Model 4, Hayes 2013) was employed to test the model in Figure 1 which represent a direct effect of emotion on driving performance (c); represent the effect of emotion on situation awareness (a); indicates the effect of situation awareness on driving performance (b); and represents an indirect effect of emotion on driving performance (c'). The emotion induction was set as the predictor variable (X; positive = 1, negative = -1). The collision number was set as the outcome variable (Y), and the actual SA was set as the mediation variables (M). Statistical significance has been determined for $P < 0.05$. JASP v.0.13.1.0 was used for statistical analysis, and G-power 3.1 software was utilized to determine whether the sample size employed in this study was adequate to provide sufficient statistical power. The calculated statistical power result showed that a sample of 12 participants produced a statistical power ($1-\beta$) of 0.81, which was greater than the minimum statistical power of 0.8 suggested by Faul et al. (2009).

3. Result and Discussion

3.1 Manipulation check

The overall mean valence rating scores before and after emotion induction and after the driving session are shown in Figure 3. Figure 3 shows that positive induction did not change the participants' valence rating, while negative induction reduced participants' valence rating. Statistical analysis revealed no significant difference between positive and negative emotion before emotion induction ($p = 0.89$), indicating that the participants had the same emotional level before emotion induction. There was a significant difference in valence rating between positive and negative emotion after induction ($p = 0.05$) and after the driving section ($p = 0.034$). The valence rating after positive emotion induction (7.5±1.17) and after the driving session under positive emotion stimulation (7.42 ± 1.68) were higher than after negative emotion induction (5.5± 2.24) and after the driving session under positive emotion stimulation (5.67± 1.56). These results demonstrated that the emotion induction in this study successfully manipulated participants' emotion levels before and during the driving session.

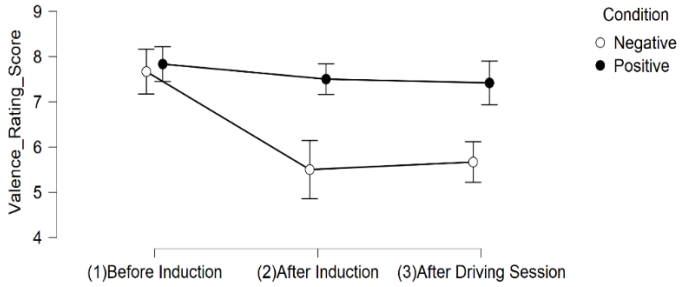

Figure 3. Valence rating scores across rating timings in two emotion inductions (positive and negative)

3.2 Driving performance

The number of collisions in the positive emotion condition (2.1±1.6 events) was lower than in the negative emotion condition (3.8±1.7 events). Based on statistical analysis, it showed an effect of emotion induction on driving performance in terms of collisions' number significantly (p = 0.005). These results indicated that driving under a negative emotion condition significantly reduced driving performance.

These results matched well with the previous studies. Earlier studies stated that negative emotion on drivers had already been identified with a decrease in driving performance. Jeon et al. (2014) stated that anger drivers had more traffic violations during driving activity than happy drivers. Jeon et al. (2014) mentioned that induced anger negatively affected subjective safety levels and decreased driving performance. Similar to Zimasa et al. (2019), it was discovered that drivers induced by positive emotions (neutral and happy) had a positive effect but were limited to driving performance, while drivers induced by negative emotions (sad and angry) had a negative effect and were much more certain on driving performance.

3.3 Situation awareness

Table 1 shows that level 1 of actual SA, level 2 of actual SA, level 3 of actual SA, and overall actual SA in the negative emotion condition were higher than in the positive emotion condition. Statistical analysis showed a significant effect of emotion induction on level 1 of actual SA (p = 0.042). No significant differences were observed for level 2 of actual SA (p = 0.838), level 3 of actual SA (p = 0.53), and overall actual SA (p = 0.082). There was also no significant difference between the conditions on perceived SA (p = 0.262).

Tabel 1. SA parameters in two induced emotion condition

SA Parameters	Positive Induction	Negative Induction
Level 1 of Actual SA	0.3 ± 4.5[a]	3.8 ± 3.9
Level 2 of Actual SA	3.1 ± 0.7	6.4 ± 2.6
Level 3 of Actual SA	4.3 ± 4.6	5.5 ± 2.0
Overall Actual SA	4.96 ± 2.92	6.1 ± 2.6
Perceived SA	0.9 ± 0.1	0.9 ± 0.1

[a] Shows a significant difference between the two conditions

3.4 Mediation analysis

Figure 4, which represents a direct effect of emotion on the performance of driving (c); represents the effect of emotion on situation awareness (a); indicates the effect of situation awareness on performance of driving (b); and represents an indirect effect of emotion on driving performance (c') has depicts the result of the mediation analysis to test whether SA mediates the effect of emotion on driving performance. Since the significant difference was found in level 1 of SA, this level was employed as the mediating variable. The mediation analysis shows a significant inverse relationship between emotion and driving performance (c = -0.34, p = 0.0017), showing that the more positive emotion condition is associated with decreasing the number of collisions. A significant inverse relationship between emotion condition and actual SA level 1 (a = -1.75, p = 0.055) was observed, indicating that the more positive emotion condition is, the less value of actual SA level 1. Finally, the number of collisions were predicted inversely by the actual SA level 1 (b

= -0.20, p = 0.0138) and by emotion condition (c' = -1.22, p = 0.0012) at the same time. These results revealed that the number of collisions was predicted by the emotion participant condition and the participant's actual level 1 of SA.

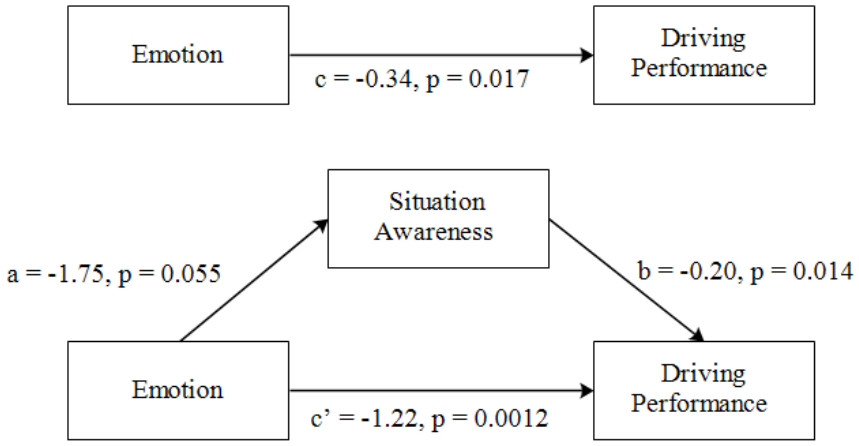

Figure 4. The mediation of situation awareness on the relationship between emotion and driving performance. (c) represents a direct effect of emotion on the performance of driving; (a) represents the effect of emotion on situation awareness; (b) indicates the effect of situation awareness on performance of driving; (c') represents an indirect effect of emotion on driving performance.

Mediation analysis using bias-corrected bootstrap protocol also revealed the bootstrap standardized indirect effect (0.82), and the 90% confidence interval (CI) range from 0.02 to 0.41. Since zero was not included in the 90% of the CI range, it was then indicated that there was a significant mediation effect of emotion participant condition on driving performance in terms of collision's number through the Level 1 of actual SA.

According to the result, we observed that SA increased when driving in a negative emotion condition. The result differs from previous studies' results (Jeon et al. 2015; Steinhauser et al. 2018). Jeon et al. (2015) found that an angry driver had a negative effect on SA, while Steinhauser et al. (2018) found no significant difference in SA among emotional conditions. However, Zimasa et al. (2017) revealed that the negative emotion condition had the longest fixation duration while driving compare with another condition. The longer time spent viewing the driving scene was correlated with improved SA (Liang et al. 2021). Then, this negative emotion condition might improve the SA due to the longest fixation duration, while the positive emotion condition decreased the SA score.

Negative emotion also induced sympathetic and parasympathetic withdrawal (Fernandez et al. 2012). The sympathetic division controls the utilization of metabolic resources and coordinates the body's emergency response to potentially life-threatening conditions (Feher 2012). Activation of the sympathetic nervous system (SNS) produces a state of arousal and readiness. The readiness of humans might affect their awareness and the increase of SA level 1 score. Then, this negative emotion condition might also improve the SA level 1 score due to the activation of SNS.

The increasing of SNS is also associated with increasing LF/HF ratio and psychological stress of humans (Kim et al., 2018). Stress can affect poor concentration or alertness (Sneddon et al. 2013) and decrease human performance. In this study, we showed that the number of collisions increased when driving following negative emotion induction. It could be said that driving performance decreased when the participants drove in a negative emotional condition. The decreasing performance in a negative emotion of driver might be due to SNS activation, which caused stress. It also matched very well with previous studies. Some studies stated that negative emotion on drivers had already been identified with decreased driving performance (Jeon et al. 2014; Zimasa et al. 2019). Furthermore, Zimasa et al. (2017) reported that the subjects in negative emotion conditions took a long time to respond to hazards. The longer time in hazards responses possibly leads to a high number of collisions.

The mediation analysis of this study also found that the decrement of SA was significantly correlated with the errors of driving performance. This finding aligns with a previous study reporting that a decrease in SA contributes to a higher number of collisions (Wijayanto et al. 2020). According to Gugerty (2011), a decreasing SA is one of the

common factors of driving failure and can cause more accidents to occur. Mediation analysis also found a partial mediation effect of SA for emotion and collision. While more negative emotions provide a direct explanation of the increased number of collisions, the mediating effect of 1st level SA is also attributed. Several studies have reported the mediation effect of SA on driving performance (Sneddon et al. 2013; Wijayanto et al. 2020). Sneddon et al. (2013) found that SA mediates the effect of stress on unsafe behaviour. Wijayanto et al. (2020) reported that SA mediates the effect of sleep deprivation and collisions. This study also found that SA mediates the effect of emotion on driving performance partially. This indicates that driving performance degradation was caused by emotion only and by a reduction of SA.

4. Conclusion

This study concludes that driving under an emotional state can degrade driving performance significantly. Reduced SA in the emotional state was one aspect that contributed to the poor driving performance success found in the current study. The SA was found to mediate the effect of emotion on driving performance partially.

As with all research, this study has several limitations to consider in interpreting the result. First, using OASIS to induce the Asian's participants in this study is one of its limitations. Other induction tools may be better performance in inducing the emotion of Asian's participants. A future study could investigate the appropriate tools for inducing participants based on their profiles. Second, the measurement used was only measuring SA is also a limitation in this study. Other cognitive functions affected by emotion might impair driver performance. A future study might look at the correlation between cognitive function related to SA and driving performance impairment in emotion. It is possible to get a more comprehensive prediction model for driver emotion.

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Biography

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