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Research on Emotion Activation Efficiency of Different Drivers

Xiaoyuan Wang [1,2,*], Yaqi Liu [3], Longfei Chen [1], Huili Shi [1], Junyan Han [1], Shijie Liu [1] and Fusheng Zhong [1]

[1] College of Electromechanical Engineering, Qingdao University of Science & Technology, Qingdao 266000, China
[2] Collaborative Innovation Center for Intelligent Green Manufacturing Technology and Equipment of Shandong, Qingdao 266000, China
[3] School of Automotive and Traffic Engineering, Jiangsu University, Zhenjiang 212000, China
* Correspondence: wangxiaoyuan@qust.edu.cn; Tel.: +86-138-6445-5865

Abstract: Emotion is an implicit psychological characteristic that changes over time. When it accumulates to a certain extent, it will be accompanied by certain external manifestations. Drivers with different traits have different emotional performance, which leads to different effects from different driver traits on the driver's emotional activation efficacy. In this study, we thoroughly explore the effects of different genders, age, driving competence, driving anger tendency, driving safety attitude and stress state on driver's emotional activation efficacy. This paper selects 74 young and middle-aged drivers with an age distribution between 20 and 41 years old. The eight most typical driving emotions (anger, surprise, fear, anxiety, helplessness, contempt, ease and pleasure) were screened through questionnaires. An experimental framework for the emotional stimulation and measurement of eight driving emotions was designed based on multiple emotional stimulation methods and PAD emotional model. The effect of emotional activation on drivers of different genders, age, driving competence, driving anger tendency, driving safety attitude and stress state was explored in depth. The results show that gender, age, driving safety attitude, driving anger tendency, stress state, etc., all have different degrees of influence upon the activation efficacy of emotion. The research results reveal the rules for the generation of different driving emotions to a certain extent and provide a theoretical basis for further exploring the cognitive and behavioral characteristics of drivers with different emotions.

Keywords: drivers; emotions; activation efficiency; individual character; traffic safety

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1. Introduction

Human factors are considered to be more important factors affecting traffic safety than vehicle and road factors [1,2]. As a vital part of the human perceptual system, emotion, especially its impact on traffic safety, has attracted more and more attention [3]. The impacts of various emotions, such as anger [4–6], anxiety [7,8], fear [9,10], and pleasure [11], on driving safety have been explored. Some scholars have also investigated the different roles of positive and negative emotions on the driver's decision-making process from the dimension of valence [12,13]. At present, scholars generally accept the view that human behavior is coordinated by cognition and emotion [14]. Among them, cognition leads to the solution of practical problems, and emotion leads to the solution of psychological needs [15,16]. Ignoring the influence of emotion on driving behavior would lead to the disadvantage of taking the driver as a homogeneous individual in the driving behavior model. That is, it would lead to the application of the same behavior-prediction model to drivers with different emotions, which makes the models poorly adapted for drivers with various emotions. In a word, in-depth research on driving emotions is of great importance for improving traffic safety. However, up to now, there is no distinct conclusion about the correlation between driving emotions and driving safety. On the one hand, human emotions are

complex and diverse. The attentions of previous works were primarily focused on one or a few particular emotions or classifying the emotions into positive, neutral, and negative categories. On the other hand, the impacts of emotions on humans are visible in physiological, psychological, and many other aspects [17]. It is still unclear whether behavior is directly affected by emotions or indirectly affected through some other factors. One of the main reasons for the above situation is that emotions are time-varying and implicit psychological features, which results in challenges to capturing the driver's emotional response during driving activities. Thus, proposing effective activation and measurement methods for driving emotions is very important for the development of driving emotion research. In the field of affective computing, there are some common activating methods including video activation [18], personal memories activation [19], music activation [20], and image activation [21]. Among them, activation methods utilizing music, video and image, with success rate of over 75%, are believed to be ideal [22,23]. However, drivers need to focus most of their attention on driving tasks, and activation methods that occupy the driver's main focus cannot be directly applied to driving emotion activation. Additionally, accurate emotional measurement is a key and difficult point of driving emotion research. Measurement based on electroencephalogram (EEG) [24], electrocardiogram (ECG) [25], galvanic skin response (GSR) [26], respiration (RSP) [27], facial expression [28], or voice signal [29] are popular emotion identification methods. Among these methods, the ones based on the physiological indexes (EEG, ECG, GSR, and RSP) are acknowledged as the more effective [24–27,30]. While eight kinds of driving emotions were investigated in this paper, it seems impossible to find a measurement that effectively works for all of them with the mentioned methods. Motivated by this, we proposed an emotion activation and measurement method based on multiple emotion activation means and the PAD emotion model in our previous work [31–33]. This method can be employed to activate and measure eight kinds of emotions effectively and without disturbance to driving, and thereby provide feasible experimental means for relevant research. The generation of driving emotions is closely related to the physiological–psychological characteristics of individual drivers, and different driving emotions have different degrees of influence on driving safety. Accurately capturing the emotional responses of drivers during driving activities is helpful for carrying out relevant experimental research on driving emotions and exploring the efficacy of emotional activation among different drivers. Based on the above experimental framework, the purpose of this paper was to further explore the impacts of individual characteristics on drivers' emotion activation efficiency.

2. Literature Review and Hypothesis

Emotion plays a vital role in cognition. At present, many scholars have conducted research on driver emotions, mainly involving driving emotion generation mechanisms, driving emotion recognition, and the impact of emotion on drivers' physiological and psychological characteristics. Related works are shown in Table 1.

Table 1. Related works.

Author	Work and Contribution
Oehl M et al. [34]	the driver's grip on the steering wheel slightly increases when the driver is in a happy mood and significantly decreases when the driver is in an angry mood.
Schmidt-Daffy M et al. [9]	When the task requirements exceed the driver's perception ability, it will produce fear. The driver's anxiety intensity increases when there is a conflict between the driver's safety and speed goals. Reducing the vehicle speed significantly reduces the driver's fear but has no significant effect on anxiety.
Jallais C et al. [35]	Both anger and sadness significantly reduce the driver's positioning speed for road elements, and anger has a greater impact on the driver's road element positioning speed.

Table 1. *Cont.*

Author	Work and Contribution
Sullman M [36]	Male and young drivers are more inclined to vent their anger through aggressive behavior, and venting their anger through aggressive language and driving behavior can easily lead to traffic accidents.
Barnard M et al. [10]	the driver's fear level would increase with the increase of the driving accident risk level.
Zimasa T et al. [11]	Sadness has a greater impact on drivers than normal and pleasant emotions, and drivers experiencing sadness have longer reaction times and fixation duration.
Taylor J [37]	Drivers with higher levels of anxiety are more prone to road rage, feel less safe while driving, and have a higher probability of driving-related avoidance and negative perceptions.
Navon M et al. [38]	Reckless and careless, angry and hostile, and anxious drivers have more difficulty with emotion regulation and lower trait forgiveness, while patient- and cautious-style drivers have an easier time with emotional regulation and higher trait tolerance.
Kadoya Y et al. [39]	Negative emotions (anger and sadness) in taxi drivers had a significant effect on increased driving speed; neutral emotional states were associated with decreased speed, while happy and relaxed emotional states had no significant effect on driving speed.
Herrero-Fernández D et al. [6]	Emotion regulation significantly affects the relationship between trait anger and various aggressive behaviors (verbal, physical, etc.).

Emotions are an important part of the human perceptual system. Emotions include psychological processes such as subjective experience, evaluation, and motivation based on perception. In the process of perceiving and the cognition of things, people understand the demand relationship between subject and object, thereby generating emotions. In general scenarios, the driver's emotion is more stable than in traffic scenarios. When the driver is in the process of driving, there is constant interaction with the outside world. As a result, the driver tends to have more concerns about their own safety and is under greater pressure. Many emotions are more likely to be stimulated, and the degree of emotional arousal generally tends to be higher. This study also obtained the result that the anxiety activation efficacy of female drivers is higher than that of male drivers. Previous studies have primarily focused on the impact of driver emotions on driving safety and the recognition of driving emotions under static conditions. However, there are still many deficiencies in the research on dynamic measurement and calculation of the driver's emotional state relative to the active safety of the car and the emotional impact mechanism of the driver's situational awareness and cognition. This paper obtains the characteristic data of drivers' gender, age, driving competence, driving anger tendency, driving safety attitude, and stress state by carrying out driving experiments and physiological–psychological data collection experiments. By designing and implementing emotional stimulation–measurement experiments, the activation efficacy data of eight typical emotions of drivers were obtained, and the characteristics of the emotional activation efficacy of different types of drivers were thoroughly analyzed in order to explore the generation rules of driver emotions. The activation efficacy of an emotion was determined to be caused by the univariate through univariate *t*-test or one-way ANOVA. When the single-variable *t*-test or one-way ANOVA cannot eliminate the interference factor, then the independent-sample *t*-test or one-way ANOVA can be carried out using a single variable as the grouping variable and the interference variable as the test variable. If there are still variables that cannot be excluded, then it is necessary to further test the partial correlation between the variables that cannot be excluded and the emotional activation efficacy of the subjects by selecting variables that cannot be excluded as control variables. The results of our significance analysis prove that different individual characteristics have influence on the driver's emotional activation efficacy. The driving emotion stimulation and measurement method proposed in this paper and the research results of different types of drivers' emotion activation efficacy are of great significance in promoting the development of driving emotion research.

3. Methods

3.1. Participants

Seventy-four drivers (41 males and 33 females from Zibo City in China) aged from 20 to 41 (M = 29.26, SD = 4.85) were recruited to participate in this study. All of the participants were licensed drivers, and their driving experience ranged from 1 to 11 years (M = 3.65, SD = 2.53).

3.2. Experimental Framework and Process

The main steps included the driving experiment, physiological–psychological tests, emotion activation, and emotion measurement (Figure 1). The physiological–psychological tests were carried out in order to obtain the participants' gender (Ge), age (Ag), driving competence (DC), driving anger tendency (DAT), driving safety attitude (DSA), and stress state (SS) based on scales. The stress-state scale used in this paper requires the participants to evaluate their stress state based on the just-finished driving activity. Therefore, before the tests, the participants needed to complete the driving experiment. "Emotion activation" referred to activating the participants' 8 typical emotions based on various methods, and "emotion measurement" meant measuring the activation efficiency of emotions based on the PAD scale. Among the obtained individual characteristics, the stress state was an unstable characteristic. To ensure the timeliness of the tests, the emotion activation and measurement of each participant was completed within two days following the physiological–psychological tests.

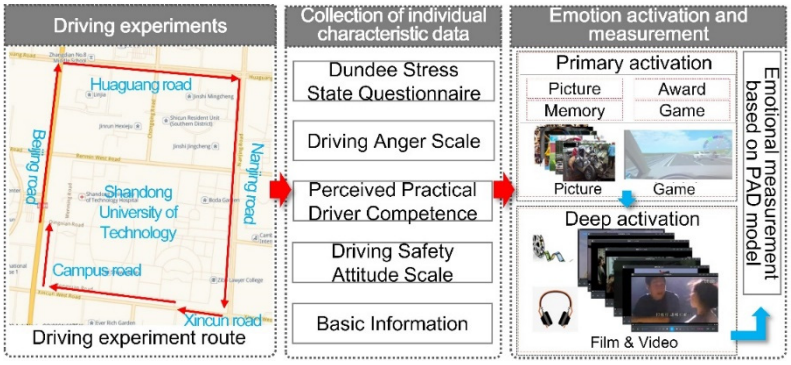


Figure 1. Framework and process of the experiments.

3.3. Driving Experiments

The driving experiments were carried out during non-commuting hours with good weather. The total length of the experimental route was about 7 km (Figure 1). The driving time for each participant was about 20 min. The participants were asked to drive the experimental route according to their daily habits and, in turn, fill in the scales after completing the driving.

3.4. Physiological–Psychological Test

3.4.1. Driving Competence

Driving competence refers to the ability of the driver to control the vehicle and make adaptive responses to the environment [40,41]. Perceived practical driver competence (PPDC) was proposed by Sundström A [42] to measure driving competence. The PPDC (in Chinese) employed in this study contains 11 questions involving the knowledge and manipulation of the vehicle, economical driving, traffic laws, traffic safety, and personal circumstances [43,44]. The 5-point Likert scale is employed in the PPDC, and all the questions have positive scoring. For each question, the participants were asked to choose the rating degree most consistent with their feelings, thoughts, and behaviors when driving from 1—very unconfident, 2—relatively unconfident, 3—somewhat confident, 4—relatively confident, and 5—very confident.

3.4.2. Driving Safety Attitude

Driving safety attitude refers to the driver's stable psychological tendency towards driving activities, which includes the participative evaluation and the resulting behavior [45]. The scale of the driving safety attitude was constructed by Ulleberg P. and Rundmo T. [46]. The scale (in Chinese) employed in this study contains 18 questions which are divided into three dimensions: unimpeded driving and rules compliance (questions 1 to 9), overspeed (questions 10 to 14), and passionate driving (questions 15 to 18) [47]. "Unimpeded driving and rules compliance" refers to the driver's attitude when unimpeded driving is in conflict with traffic rules. "Overspeed" refers to the conditions under which the drivers practice overspeed behavior and their attitude toward the range of overspeed. "Passionate driving" refers to the driver's pursuit of pleasure and excitement through driving. The 5-point Likert scale was employed, and all questions have positive scoring. The five options for each question are 1—always, 2—often, 3—sometimes, 4—occasionally, and 5—never, respectively.

3.4.3. Driving Anger Tendency

"Driving anger tendency" refers to the tendency of individuals to express anger during driving [48]. The revised Chinese Driving Anger Scale (DAS) was employed to measure the participants' driving anger tendency. The DAS was first proposed by Deffenbacher J. et al. [49], and the Chinese edition was revised by Guo S. et al. [50]. The revised DAS contains 22 questions which are divided into four dimensions: hostile gesture (questions 1, 8, 9, 14, 17, and 19), slow driving (questions 2, 5, 6, 7, and 11), impolite driving (questions 3, 4, 10, 13, 18, and 21), and traffic congestion (questions 12, 15, 16, 20, and 22). "Hostile gesture" refers to times when the behaviors of other drivers are infuriating or unpleasant. "Slow driving" means that driving behavior is hindered by other vehicles or pedestrians. "Impolite driving" refers to instances of uncivilized driving behavior from other drivers. "Traffic congestion" refers to the frustration of drivers due to events such as traffic jams. The 5-point Likert scale is employed in this scale, and all questions have positive scoring. The five options for each question are 1—not angry, 2—a little angry, 3—anger, 4—very angry, and 5—extremely angry.

3.4.4. Stress State

During driving activities, stress is a physical and psychological fatigue characterized by task induction and accompanied by complex psychological processes [51,52]. To measure the stress state of drivers, the Dundee Stress State Questionnaire (DSSQ) was proposed by Matthews G. et al. [53]. The revised DSSQ (in Chinese) employed in this research contains four subscales, which are the Task Emotion Scale, Task Motivation Scale, Cognitive Style Scale, and Task Cognition Scale [47]. On the Task Emotion Scale, questions 1 through 4 belong to the vitality and excitement dimension, questions 5 through 8 belong to the tension dimension, and questions 9 through 11 belong to the pleasure dimension. Among them, the questions in the pleasure dimension have reverse scoring, and the questions in the other dimensions have positive scoring. On the Task Motivation scale, questions 1 through 4 belong to the task interest dimension, questions 5 through 8 belong to the success motivation dimension, and all of the questions were positive scoring. On the Cognitive Style Scale, questions 1 through 4 belong to the self-attention dimension, questions 5 through 8 belong to the self-esteem dimension, questions 9 through 12 belong to the attentiveness dimension, and all of the questions have positive scoring. On the Task Cognition Scale, questions 1 through 3 belong to the task-related cognitive interference dimension, and questions 5 through 7 belong to the task-independent cognitive interference dimension; all of the questions in this scale have positive scoring. The above 10 dimensions are low-order dimensions, which in turn constitute the three high-order dimensions of task participation, pain, and worry. The task participation dimension is constructed by the dimensions of vitality and excitement, task interest, success motivation, and attentiveness; the pain dimension is constructed by the dimensions of tension and pleasure; and the worry dimension is constructed by the dimensions of self-attention, self-esteem, task-related cognitive interference,

and task-independent cognitive interference. The 4-point Likert scale is employed in DSSQ. Participants were asked to choose the state that best matched the state they were in when they had just finished driving, based on the content of the questions. For positive scoring, the four options for each question are 1—strongly agree, 2—relatively agree, 3—relatively disagree, and 4—strongly disagree. For reverse scoring, the order between the score and the status description is reversed.

3.4.5. Emotion Activation

The emotion activation methods applied in this study were referred to in references [31,33]. For each kind of emotion, the activation process included preliminary activation and deep activation. The activation methods involved in preliminary activation included picture activation (for the activation of anger, surprise, fear, and anxiety), personal memories activation (for the activation of helplessness and relief), virtual game activation (for the activation of contempt), and reward activation (for the activation of pleasure). On the basis of primary activation, deep activation was carried out. The activation method applied during deep activation was video activation. Prior to each instance of emotion activation, the participants calmed their minds through listening to soothing music (about 5 min in duration) in order to eliminate the influence of initial emotional differences on the activation. In order to avoid mutual interference among different emotions, the intervals between the excitation of different emotions for each subject were not less than 1 h.

3.4.6. Emotion Measurement

After the activation for each emotion, emotion measurement was carried out based on the PAD emotion scale (Figure 2). According to the PAD model, emotions are composed of three dimensions: pleasure–displeasure (P), arousal–non-arousal (A), and dominance–submissiveness (D). The value range of each dimension is $(-1, 1)$, and the three-dimensional vector composed of the dimension values can be used to express specific emotions. For ease of use in the experiment, each dimension was rated from 1 to 9 based on the strength of each dimension in this study. Before carrying out the experiment, participants were asked to keep in mind the meaning of PAD. During emotion measurement, participants were required to report the PAD value (between 1 and 9) that best matched their mental state from each dimension. The specific application methods of PAD emotional scale were detailed in references [31,33].

For the PAD data, the emotional state indicated in the PAD scale corresponded to a point in the PAD space. The Euclidean distance between this point and the emotion coordinate was used to represent the activation strength of the corresponding emotion [31,54]. For example, the anxiety state filled in by a participant was (3, 2, 6), which corresponds to the point $(-0.5, -0.75, 0.25)$ in PAD space. The distance between the point $(-0.5, -0.75, 0.25)$ and the coordinates of anxiety in the PAD space $(-0.24, 0.08, -0.16)$ could represented the activation efficacy of anxiety. The smaller the distance was, the higher the activation efficiency of anxiety was. The PAD scale can represent a total of 729 emotional states corresponding to 729 points in the PAD space. The distances between the 729 points and the coordinates of 8 typical emotions were sorted, and the corresponding emotional activation efficacy of each point was assigned according to the distance distribution (Table S1 in Supplementary Materials).

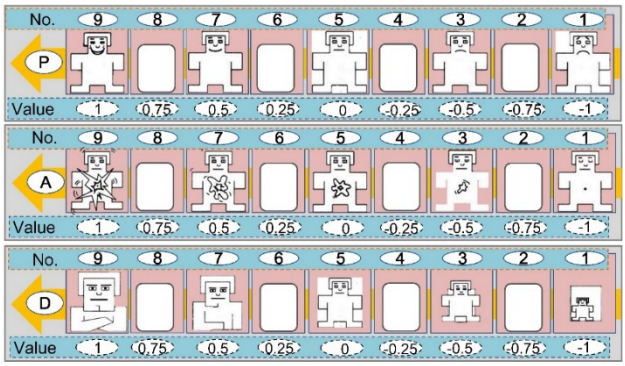


Figure 2. PAD emotion scale.

3.4.7. Data Preprocessing

The participants' individual characteristic data and emotion activation efficacy data were obtained through the above experiments. The gender of male and female participants was assigned as 1 and 2, respectively. The participants' age was divided into four age groups—20 to 25, 26 to 30, 31 to 35, and 36 to 41—which were assigned the values 1, 2, 3, and 4, respectively. For the data obtained through the PPDC, the statistical indicator was the average of the scores for each question (rounded to the nearest whole number) and took the value of 1, 2, 3, 4, or 5. For the data obtained through the driving safety attitude scale, the scores for each dimension were the mean of the question scores, and the value range for each dimension was 1 to 5.

The scores for each dimension were divided into five intervals—1 to 1.6 (excluding 1.6), 1.6 to 2.6 (excluding 2.6), 2.6 to 3.6 (excluding 3.6), 3.6 to 4.6 (excluding 4.6), and 4.6 to 5—which were assigned values of 1, 2, 3, 4, and 5, respectively. The overall driving safety attitude score was the sum of the three-dimensional values and fell within a range of 3 to 15. The overall score was further divided into five value ranges—3 to 5 (excluding 5), 5 to 8 (excluding 8), 8 to 11 (excluding 11), 11 to 14 (excluding 14), and 14 to 15—which were assigned values of 1, 2, 3, 4, and 5, respectively. For the data obtained through the DAS, the scores for each dimension were the mean of the question scores, and the value range for each dimension was 1 through 5.

The scores for each dimension were divided into five intervals—1 to 1.6 (excluding 1.6), 1.6 to 2.6 (excluding 2.6), 2.6 to 3.6 (excluding 3.6), 3.6 to 4.6 (excluding 4.6), and 4.6 to 5—and were assigned values of 1, 2, 3, 4, and 5, respectively. The overall driving safety attitude score was the sum of the four-dimensional values and fell within a range of 4 through 20. The overall score was further divided into five value ranges—4 to 7 (excluding 7), 7 to 11 (excluding 11), 11 to 14 (excluding 14), 14 to 18 (excluding 18), and 18 to 20—which were assigned the values of 1, 2, 3, 4, and 5, respectively. For the data obtained through the DSSQ, the score ranges of vitality and excitement, tension, pleasure, and task-related cognitive interference dimensions were all within the range of 3 to 12. The scores of the above dimensions were divided into four intervals, which were 3 to 5 (excluding 5), 5 to 8 (excluding 8), 8 to 11 (excluding 11), and 11 to 12, and were assigned values of 1, 2, 3, and 4, respectively.

The score ranges of task interest, success motivation, attentiveness, self-attention, self-esteem, and task-independent cognitive interference dimensions were all within the range of 4 to 16. The scores of the above dimensions were divided into four intervals, which were 4 to 7 (excluding 7), 7 to 11 (excluding 11), 11 to 15 (excluding 15), and 15 to 16, and were assigned values of 1, 2, 3, and 4, respectively.

The scores of the three higher-order dimensions were the sum of their lower-order dimension scores, and the overall DSSQ score was the sum of the scores of the three higher-order dimensions.

The overall DSSQ score was taken in the range of 10 to 40, and the overall score was further divided into five intervals—10 to 16 (excluding 16), 16 to 22 (excluding 22), 22 to 29

(excluding 29), 29 to 35 (excluding 35), and 35 to 40—which were assigned the values of 1, 2, 3, 4, and 5, respectively. According to the assignment rules, the participants' driving competence, driving safety attitude, driving anger tendency, and stress state were all divided into 5 levels with the values of 1, 2, 3, 4, and 5, respectively. The higher the participants' score on the corresponding scale was, the better their driving competence was, the better their safety attitude was, the higher their anger tendency was, or the more stress they had. The possible assignment values were 0, 1, 2, 3, 4, and 5. The larger the value was, the higher the activation efficiency of the emotion was. The individual characteristic data and emotion activation efficacy data of 74 participants are shown in Table 2.

Table 2. Description of individual characteristic data and emotion activation efficacy data.

Item	Mean	SD	Item	Mean	SD	Item	Mean	SD
Ge [1]	1.446	0.497	SS [6]	2.905	1.326	Help. [10]	2.068	1.348
Ag [2]	2.243	0.934	Ang. [7]	2.554	1.356	Cont. [11]	2.054	1.461
DC [3]	3.000	1.159	Surp. [8]	2.324	1.444	Rel. [12]	2.905	1.406
DSA [4]	3.014	1.116	Fear	2.419	1.508	Plea. [13]	2.649	1.447
DAT [5]	2.932	1.174	Anx. [9]	2.392	1.460			

[1] Ge, gender; [2] Ag, age; [3] DC, driving competence; [4] DSA, driving safety attitude; [5] DAT, driving anger tendency; [6] SS, stress state; [7] Ang., anger; [8] Surp., surprise; [9] Anx., anxiety; [10] Help., helplessness; [11] Cont., contempt; [12] Rel., relief; [13] Plea., pleasure.

Based on the experimental data, the internal consistency of each scale was tested. The Cronbach's alpha of PPDC was 0.887. The Cronbach's alpha of PPDC driving safety attitude scale was 0.818, and the Cronbach's alpha of the unimpeded driving and rules compliance, overspeed, and passionate driving dimensions was 0.720, 0.791, and 0.733, respectively. The Cronbach's alpha of DAC was 0.829, and the Cronbach's alpha of the hostile gestures, slow driving, impolite driving, and traffic congestion dimensions was 0.738, 0.802, 0.781, and 0.810, respectively. The Cronbach's alpha of DSSQ was 0.838, and the Cronbach's alpha of the task participation, pain, and worry dimensions was 0.703, 0.797, and 0.810, respectively. The correlation test results (Table 3) of the individual characteristics show that there was a positive correlation between gender and driving safety attitude (s = 0.313 **), which meant that female drivers had a better attitude towards driving safety, which was consistent with the research results of Lucas E. et al. [55]. Driving anger tendency was negatively correlated with gender (s = −0.245 *), which meant that male drivers had a higher tendency of driving anger, which was in agreement with the viewpoint of Sullman M. et al. [36]. Age and driving experience were positively correlated (s = 0.829 **), which corresponded to the reality. Driving experience was positively correlated with driving competence (s = 0.421 **) and negatively correlated with stress state (s = −0.285 *), indicating that driving competence significantly improved with increasing driving experience, while stress during driving activities significantly decreased. These results were consistent with the general perception that the accumulation of driving experience improves drivers' ability to control the vehicle and diminishes the psychological stress caused by driving tasks. Driving anger tendency and stress state were positively correlated (s = 0.400 **), which agreed with the viewpoint of McLinton S. et al. [56]. The above test results showed that the data obtained in this experiment have high accuracy and reliability.

Table 3. Correlation test results of individual characteristic data.

Item	Ge	Ag	DE	DC	DSA	DAT	SS
Ge [1]	1	−0.104	0.034	−0.068	0.313 **	−0.245 *	−0.146
Ag [2]	−0.104	1	0.829 **	0.141	0.064	−0.142	−0.214
DE [3]	0.034	0.829 **	1	0.421 **	0.172	−0.039	−0.285 *
DC [4]	−0.068	0.141	0.421 **	1	0.000	0.115	0.059
DSA [5]	0.313 **	0.064	0.172	0.000	1	−0.106	−0.037

Table 3. *Cont.*

Item	Ge	Ag	DE	DC	DSA	DAT	SS
DAT [6]	−0.245 *	−0.142	−0.039	0.115	−0.106	1	0.400 **
SS [7]	−0.146	−0.214	−0.285 *	0.059	−0.037	0.400 **	1

** means $p < 0.01$, * means $p < 0.05$. [1] Ge, gender; [2] Ag, age; [3] DE, driving experience; [4] DC, driving competence; [5] DSA, driving safety attitude; [6] DAT, driving anger tendency; [7] SS, stress state.

4. Results and Discussion

4.1. Results

Setting the gender as the grouping variable and the emotion activation efficiency as the test variable, an independent sample *t*-test was carried out on the emotion activation efficacy of male and female participants. According to the *t*-test results (Table 4), there were significant differences in the activation efficiency of anger ($t = 2.953$), fear ($t = -2.431$), anxiety ($t = -2.320$), and pleasure ($t = -3.188$) between male and female participants. The differences in activation efficiency of other emotions between male and female participants were not significant.

Table 4. *T*-test results of the emotion activation efficacy of male and female participants.

Emotion	*t*	df [1]	Sig. (2-Tailed)	MD [2]	SED [3]	CID [4]	
						LL [5]	UL [6]
Ang. [7]	2.953	72	**0.004**	0.891	0.302	0.289	1.492
Surp. [8]	−0.693	72	0.490	−0.253	0.339	−0.991	0.441
Fear	−2.431	72	**0.018**	−0.83	0.341	−1.511	−0.149
Anx. [9]	−2.320	72	**0.023**	−0.769	0.332	−1.431	−0.108
Help. [10]	0.212	72	0.833	0.067	0.317	−0.565	0.7
Cont. [11]	0.764	72	0.448	0.262	0.343	−0.421	0.945
Rel. [12]	−0.020	72	0.984	−0.007	0.331	−0.667	0.653
Plea. [13]	−3.188	72	**0.002**	−1.017	0.319	−1.653	−0.381

[1] df, degrees of freedom; [2] MD, mean difference; [3] SED, standard error difference; [4] CID, 95% confidence interval; [5] LL, lower limit; [6] UL, upper limit; [7] Ang., anger; [8] Surp., surprise; [9] Anx., anxiety; [10] Help., helplessness; [11] Cont., contempt; [12] Rel., relief; [13] Plea., pleasure. The numbers in bold mean that the activation efficiency of the emotion is significantly related to gender.

The average activation efficiency (AAE) of anger, fear, anxiety, and pleasure in male and female participants was shown in Figure 3. According to the statistics, the AAE of anger, fear, anxiety, and pleasure in male participants was 2.95 (SD = 1.36), 2.05 (SD = 1.53), 2.05 (SD = 1.41), and 2.20 (SD = 1.49), respectively, and the AAE of anger, fear, anxiety, and pleasure in female participants was 2.06 (SD = 1.20), 2.88 (SD = 1.36), 2.82 (SD = 1.42), and 3.21 (SD = 1.19), respectively.

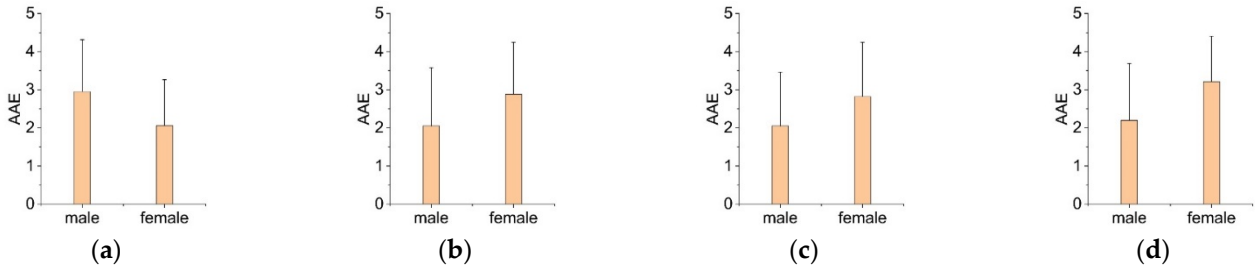


Figure 3. AAE of anger, fear, anxiety, and pleasure for male and female participants. (**a**) Anger; (**b**) fear; (**c**) anxiety; (**d**) pleasure.

One-way analysis of variance (ANOVA) was carried out in order to examine the role of participants' age on the activation efficacy of different emotions. In the one-way ANOVA, the participants' age was set as the factor variable, and the activation efficacy of different

emotions was set as the dependent variable. The results (Table 5) showed significant difference only in the activation efficiency of surprise among participants in different age groups (F = 4.399).

Table 5. One-way ANOVA of emotion activation efficacy for participants of different ages.

Emotion		SOS [4]	MS [5]	F	Sig.
Ang. [6]	BG [1]	4.417	1.472	0.794	0.502
	WG [2]	129.867	1.855		
	Tot [3]	134.284			
Surp. [7]	BG	24.144	8.048	4.399	**0.007**
	WG	128.072	1.830		
	Tot	152.216			
Fear	BG	1.372	0.457	0.194	0.900
	WG	164.642	2.352		
	Tot	166.014			
Anx. [8]	BG	2.361	0.787	0.359	0.782
	WG	153.274	2.190		
	Tot	155.635			
Help. [9]	BG	12.370	4.123	2.400	0.075
	WG	120.292	1.718		
	Tot	132.662			
Cont. [10]	BG	3.869	1.290	0.594	0.621
	WG	151.914	2.170		
	Tot	155.784			
Rel. [11]	BG	8.805	2.935	1.516	0.218
	WG	135.533	1.936		
	Tot	144.388			
Plea. [12]	BG	3.471	1.157	0.542	0.655
	WG	149.394	2.134		
	Tot	152.865			

[1] BG, between groups; [2] WG, within groups; [3] Tot, total; [4] SOS, sum of square; [5] MS, mean square; [6] Ang., anger; [7] Surp., surprise; [8] Anx., anxiety; [9] Help., helplessness; [10] Cont., contempt; [11] Rel., relief; [12] Plea., pleasure. The numbers in bold mean that the activation efficiency of the emotion is significantly related to age.

The AAE of the emotion surprise for participants in age groups 1, 2, 3, and 4 was 3.18 (SD = 1.43), 2.40 (SD = 1.43), 1.84 (SD = 1.21), and 1.38 (SD = 1.19), respectively. To further explore the impact of age on participants' emotional activation efficacy, multiple comparison analysis (MCA) was performed on the activation efficacy of surprise for participants in different age groups. The MCA methods utilized in this study were Tukey B's method and Waller–Duncan's method. Multiple comparison results were considered valid only when the two methods achieved consistent results. The MCA results (Figure 4 and Table 6) showed no significant differences in the activation efficacy of surprise between participants in age groups 1 and 2, and no significant differences between participants in age groups 2, 3, and 4. The MCA results also showed significant differences in the activation efficacy of surprise between participants in age groups 1 and 3, and significant differences between participants in age groups 1 and 4.

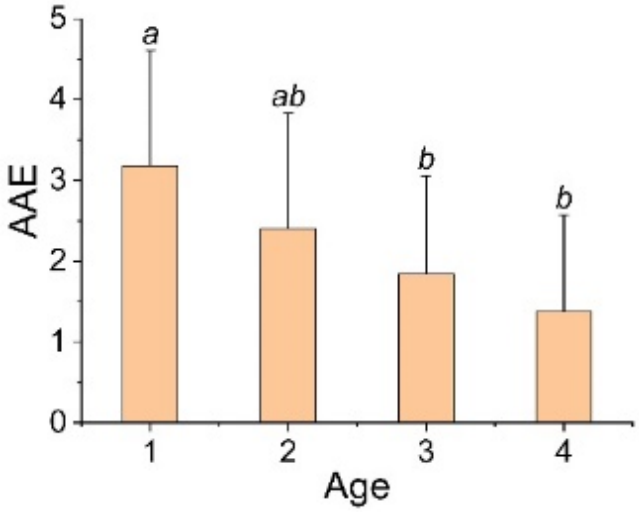


Figure 4. Multiple comparisons for the activation efficacy of surprise between participants of different ages. a and b represent two groups. ab indicates both group a and group b.

Table 6. Multiple comparison on activation efficacy of surprise for participants of different ages.

Ag [1]	CN [2]	AS [3] = 0.05	
		b	a
4	8	1.38	
3	19	1.84	
2	30	2.40	2.40
1	17		3.18

Sample size using harmonic mean = 14.826. [1] Ag, age; [2] CN, case number; [3] AS, Alpha's subset.

Setting the driving competence as the factor variable and emotion activation efficiency as the dependent variable, one-way ANOVA was carried out in order to examine the effect of driving competence on the activation efficacy of different emotions. The results (Table 7) showed significant differences in the activation efficacy of surprise (F = 5.146), helplessness (F = 3.223), contempt (F = 7.811), and relief (F = 4.491) between participants of different DC.

Table 7. One-way ANOVA of emotion activation efficacy for participants of different DC.

Emotion		SOS [4]	MS [5]	F	Sig.
Ang. [6]	BG [1]	3.100	0.775	0.408	0.803
	WG [2]	131.184	1.901		
	Tot [3]	134.284			
Surp. [7]	BG	34.977	8.744	5.146	**0.001**
	WG	117.239	1.699		
	Tot	152.216			
Fear	BG	3.423	0.856	0.363	0.834
	WG	162.591	2.356		
	Tot	166.014			
Anx. [8]	BG	2.000	0.500	0.225	0.924
	WG	153.636	2.227		
	Tot	155.635			
Help. [9]	BG	20.886	5.222	3.223	**0.017**
	WG	111.776	1.620		
	Tot	132.662			

Table 7. *Cont.*

Emotion		SOS [4]	MS [5]	F	Sig.
Cont. [10]	BG	48.556	12.139	7.811	**0.000**
	WG	107.228	1.554		
	Tot	155.784			
Rel. [11]	BG	29.814	7.454	4.491	**0.003**
	WG	114.524	1.660		
	Tot	144.388			
Plea. [12]	BG	4.527	1.132	0.526	0.717
	WG	148.338	2.150		
	Tot	152.865			

[1] BG, between groups; [2] WG, within groups; [3] Tot, total; [4] SOS, sum of square; [5] MS, mean square; [6] Ang., anger; [7] Surp., surprise; [8] Anx., anxiety; [9] Help., helplessness; [10] Cont., contempt; [11] Rel., relief; [12] Plea., pleasure. The numbers in bold mean that the activation efficiency of the emotion is significantly related to DC.

The AAE of surprise for participants with the driving competence levels 1, 2, 3, 4, and 5 was 3.13 (SD = 1.73), 2.13 (SD = 1.46), 2.96 (SD = 1.13), 1.43 (SD = 1.22), and 1.44 (SD = 1.24), respectively. The MCA results (Figure 5a and Table 8) showed that there were significant differences in surprise activation efficiency between participants with DC levels 1 and 4, between participants with DC levels 1 and 5, between participants with DC levels 3 and 4, and between participants with DC levels 3 and 5. The MCA results also showed there was no significant difference in surprise activation efficiency between participants with DC levels 1, 2, and 3, and between participants with DC levels 2, 4 and 5.

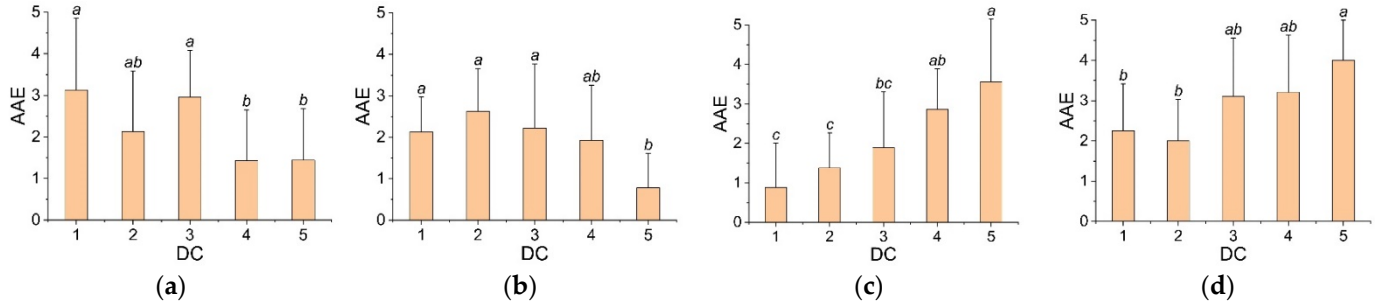


Figure 5. Multiple comparisons on the activation efficacy of surprise, helplessness, contempt, and relief for participants of different DC. (**a**) Surprise; (**b**) helpless; (**c**) contempt; (**d**) relief. a, b and c represent three groups. ab indicates both group a and group b. bc indicates both group b and group c.

Table 8. MCA of the activation efficacy of surprise, helplessness, contempt, and relief for participants of different DC.

Surprise				Helplessness			
DC [1]	CN [2]	AS [3] = 0.05		DC	CN	AS = 0.05	
		b	a			b	a
5	9	1.43		5	9	0.78	
4	14	1.44		4	14	1.93	1.93
2	16	2.13	2.13	1	8		2.13
3	27		2.96	3	27		2.22
1	8		3.13	2	16		2.63

Table 8. *Cont.*

Contempt					Relief			
DC	CN	AS = 0.05			DC	CN	AS = 0.05	
		c	b	a			b	a
1	8	0.88			2	16	2.00	
2	16	1.38			1	8	2.25	
3	27	1.89	1.89		3	27	3.11	3.11
4	14		2.86	2.86	4	14	3.21	3.21
5	9			3.56	5	9		4.00

Sample size using harmonic mean = 12.283. [1] DC, driving competence; [2] CN, case number; [3] AS, Alpha's subset.

The AAE of helplessness for participants with driving competence levels 1, 2, 3, 4, and 5 was 2.13 (SD = 0.84), 2.63 (SD = 1.03), 2.22 (SD = 1.55), 1.93 (SD =1.33), and 0.78 (SD = 0.83), respectively. According to the MCA results (Figure 5b and Table 8), there were significant differences in the activation efficacy of helplessness between participants of DC levels 1 and 5, between participants of DC levels 2 and 5, and between participants of DC levels 3 and 5. There was no significant difference in the activation efficacy of helplessness between participants of DC levels 1, 2, 3, and 4 and between participants of DC levels 4 and 5.

According to statistics, the AAE of contempt for participants with driving competence levels 1, 2, 3, 4, and 5 was 0.88 (SD = 1.13), 1.38 (SD = 0.89), 1.89 (SD = 1.42), 2.86 (SD = 1.03), and 3.56 (SD = 1.59), respectively. According to the MCA results (Figure 5c and Table 8), there were significant differences in the activation efficacy of contempt between participants of DC levels 1 and 4, between participants of DC levels 1 and 5, between participants of DC levels 2 and 4, between participants of DC levels 2 and 5, and between participants of DC levels 3 and 5. There was no significant difference in the activation efficacy of contempt between participants of DC levels 1, 2, and 3, between participants of DC levels 3 and 4, or between participants of DC levels 4 and 5.

The AAE of relief for participants with driving competence levels 1, 2, 3, 4, and 5 was 2.25 (SD = 1.17), 2.00 (SD = 1.03), 3.11 (SD = 1.45), 3.21 (SD = 1.42), and 4.00 (SD = 1.00), respectively. The MCA results (Figure 5d and Table 8) showed significant differences in the activation efficacy of relief between participants of DC levels 1 and 5 and between participants of DC levels 2 and 5. The MCA results showed no significant difference in the activation efficacy of relief between participants of DC levels 1, 2, 3, and 4, and between participants of DC levels 3, 4, and 5.

In order to test the impacts of driving safety attitude on emotion activation efficiency, the DSA was set as the factor variable, and the emotion activation efficiency was set as the dependent variable for the carried-out one-way ANOVAs. The results (Table 9) suggested that there were significant differences in the activation efficiency of anger (F = 3.038), contempt (F = 2.847), and pleasure (F = 4.069) between participants of different driving safety attitudes.

Table 9. One-way ANOVA of emotion activation efficacy for participants of different DSA.

Emotion		SOS [4]	MS [5]	F	Sig.
Ang. [6]	BG [1]	20.108	5.027	3.038	**0.023**
	WG [2]	114.175	1.655		
	Tot [3]	134.284			
Surp. [7]	BG	11.674	2.919	1.433	0.232
	WG	140.542	2.037		
	Tot	152.216			
Fear	BG	2.484	0.621	0.262	0.901
	WG	163.529	2.370		
	Tot	166.014			
Anx. [8]	BG	3.321	0.830	0.376	0.825
	WG	152.314	2.207		
	Tot	155.635			

Table 9. *Cont.*

Emotion		SOS [4]	MS [5]	F	Sig.
Help. [9]	BG	10.496	2.624	1.482	0.217
	WG	122.166	1.771		
	Tot	132.662			
Cont. [10]	BG	22.066	5.517	2.847	**0.030**
	WG	133.717	1.938		
	Tot	155.784			
Rel. [11]	BG	10.129	2.532	1.302	0.278
	WG	134.209	1.945		
	Tot	144.388			
Plea. [12]	BG	29.179	7.295	4.069	**0.005**
	WG	123.686	1.793		
	Tot	152.865			

[1] BG, between groups; [2] WG, within groups; [3] Tot, total; [4] SOS, sum of square; [5] MS, mean square; [6] Ang., anger; [7] Surp., surprise; [8] Anx., anxiety; [9] Help., helplessness; [10] Cont., contempt; [11] Rel., relief; [12] Plea., pleasure. The numbers in bold mean that the activation efficiency of the emotion is significantly related to DSA.

According to the statistical results, the AAE of anger for participants of DSA levels 1, 2, 3, 4, and 5 was 3.13 (SD = 1.64), 3.29 (SD = 1.20), 2.54 (SD = 1.00), 2.12 (SD = 1.36), and 1.57 (SD = 1.81), respectively. To further test the impacts of DSA on emotion activation efficacy, an MCA was performed on the activation efficacy of anger for participants of DSA. According to the MCA results (Figure 6a and Table 10), there were significant differences in anger activation efficacy between participants of DSA levels 1 and 5 and between participants of DSA levels 2 and 5. The MCA results also indicated that there was no significant difference in anger activation efficacy between participants of DSA levels 1, 2, 3, and 4, and between participants of DSA levels 3, 4, and 5.

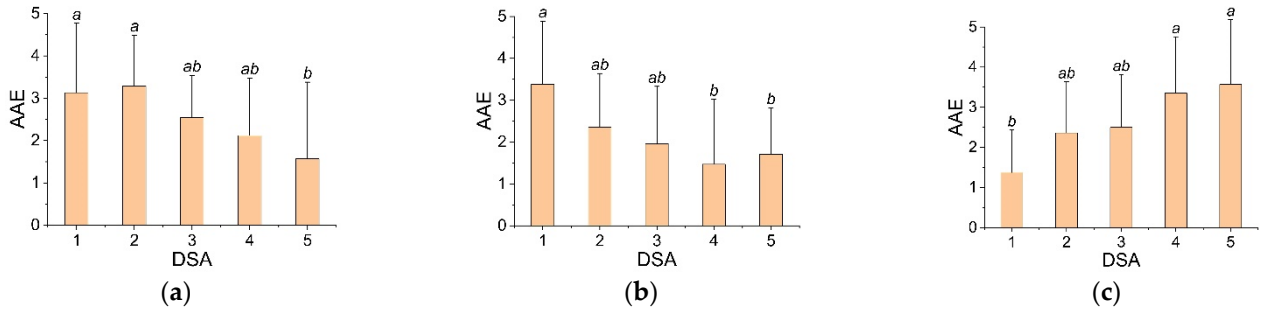


Figure 6. Multiple comparisons on the activation efficacy of anger, contempt, and pleasure for participants of different DSA. (**a**) Anger; (**b**) contempt; (**c**) pleasure. a and b represent two groups. ab indicates both group a and group b.

Table 10. MCA of the activation efficacy of anger, contempt, and pleasure for participants of different DSA.

Anger				Contempt				Pleasure			
DSA [1]	CN [2]	AS [3] = 0.05		DSA	CN	AS = 0.05		DSA	CN	AS = 0.05	
		b	a			b	a			b	a
5	7	1.57		4	17	1.47		1	8	1.38	
4	17	2.12	2.12	5	7	1.71		2	14	2.36	2.36
3	28	2.54	2.54	3	28	1.96	1.96	3	28	2.50	2.50
1	8		3.13	2	14	2.36	2.36	4	17		3.35
2	14		3.29	1	8		3.38	5	7		3.57

Sample size using harmonic mean = 11.525. [1] DSA, driving safety attitude; [2] CN, case number; [3] AS, Alpha's subset.

The AAE of contempt for participants of DSA levels 1, 2, 3, 4, and 5 was 3.38 (SD = 1.51), 2.36 (SD = 1.28), 1.96 (SD = 1.37), 1.47 (SD = 1.55), and 1.71 (SD = 1.11), respectively. According to the MCA results (Figure 6b and Table 10), there were significant differences in

contempt activation efficacy between participants of DSA levels 1 and 4 and between participants of DSA levels 1 and 5. There was no significant difference in contempt activation efficacy between participants of DSA levels 2, 3, 4, and 5, or between participants of DSA levels 1, 2, and 3.

The average activation efficiency of pleasure for participants of DSA levels 1, 2, 3, 4, and 5 was 1.38 (SD = 1.06), 2.36 (SD = 1.28), 2.50 (SD = 1.32), 3.35 (SD = 1.41), and 3.57 (SD = 1.62), respectively. The MCA results (Figure 6c and Table 10) indicate significant differences in pleasure activation efficacy between participants of DSA levels 1 and 4 and between participants of DSA levels 1 and 5. There was no significant difference in pleasure activation efficacy between participants of DSA levels 1, 2, and 3 or participants of DSA levels 2, 3, 4, and 5.

With the aim of testing the impacts of driving anger tendency on emotion activation efficiency, one-way ANOVA was carried out by setting the DAT as the factor variable and the emotion activation efficiency as the dependent variable. The results (Table 10) indicated that there were significant differences in the activation efficacy of anger (F = 4.834) and anxiety (F = 3.078) between participants of different DAT. However, there were no significant differences in the activation efficacy of surprise (F = 0.524), fear (F = 1.414), helplessness (F = 0.293), contempt (F = 0.360), relief (F = 0.681), or pleasure (F = 2.284) between participants of different DAT.

The average activation efficiency of anger for participants of DAT levels 1, 2, 3, 4, and 5 was 1.44 (SD = 1.42), 2.11 (SD = 1.37), 2.54 (SD = 0.83), 3.27 (SD = 1.34), and 3.50 (SD = 1.51), respectively. According to the MCA results (Figure 7a and Table 11), there were significant differences in anger activation efficacy between participants of DAT levels 1 and 4 and between participants of DAT levels 1 and 5 and between participants of DAT levels 2 and 5. Additionally, there was no significant difference in anger activation efficacy between participants of DAT levels 1, 2, and 3, between participants of DAT levels 2, 3, and 4, or between participants of DAT levels 3, 4, and 5.

Table 11. One-way ANOVA of emotion activation efficacy for participants of different DAT.

Emotion		SOS [4]	MS [5]	F	Sig.
Ang. [6]	BG [1]	29.392	7.348	4.834	**0.002**
	WG [2]	104.892	1.520		
	Tot [3]	134.284			
Surp. [7]	BG	4.491	1.123	0.524	0.718
	WG	147.725	2.141		
	Tot	152.216			
Fear	BG	12.580	3.145	1.414	0.238
	WG	153.433	2.224		
	Tot	166.014			
Anx. [8]	BG	25.757	6.439	3.421	**0.013**
	WG	129.878	1.882		
	Tot	155.635			
Help. [9]	BG	2.215	0.554	0.293	0.882
	WG	130.447	1.891		
	Tot	132.662			
Cont. [10]	BG	3.184	0.796	0.360	0.836
	WG	152.600	2.212		
	Tot	155.784			
Rel. [11]	BG	5.480	1.370	0.681	0.608
	WG	138.858	2.012		
	Tot	144.388			
Plea. [12]	BG	17.876	4.469	2.284	0.069
	WG	134.989	1.956		
	Tot	152.865			

[1] BG, between groups; [2] WG, within groups; [3] Tot, total; [4] SOS, sum of square; [5] MS, mean square; [6] Ang., anger; [7] Surp., surprise; [8] Anx., anxiety; [9] Help., helplessness; [10] Cont., contempt; [11] Rel., relief; [12] Plea., pleasure. The numbers in bold mean that the activation efficiency of the emotion is significantly related to DAT.

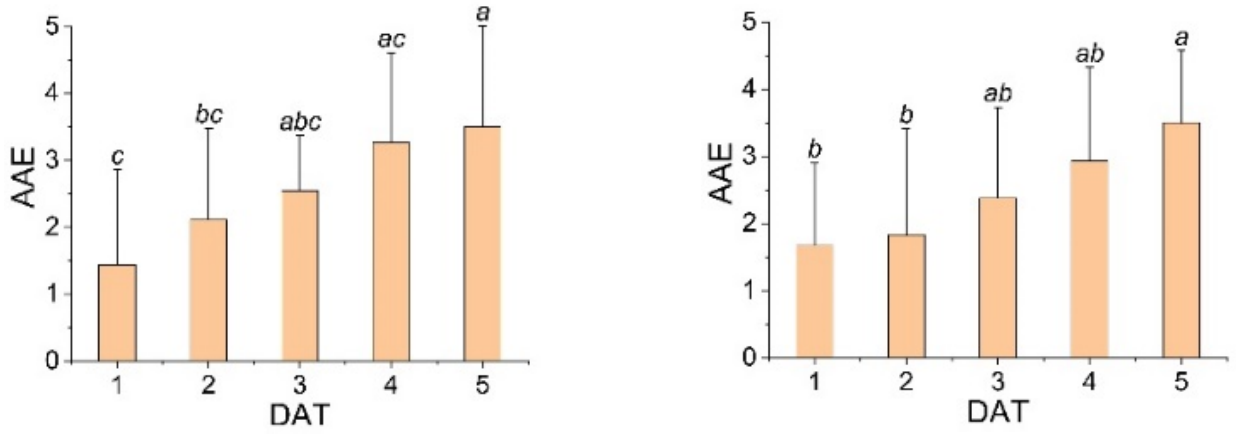


Figure 7. Multiple comparisons on the activation efficacy of anger and anxiety for participants of different DAT. (**a**) Anger; (**b**) anxiety. a and b represent two groups. ab indicates both group a and group b. abc indicates group a, group b and group c.

The AAE of anxiety for participants of DAT levels 1, 2, 3, 4, and 5 was 1.67 (SD = 1.23), 1.83 (SD = 1.58), 2.38 (SD = 1.35), 2.93 (SD = 1.39), and 3.50 (SD = 1.07), respectively. According to the MCA results (Figure 7a and Table 11), there were significant differences in anxiety activation efficacy between participants of DAT levels 1 and 5 and between participants of DAT levels 2 and 5. In addition, there was no significant difference in anxiety activation efficacy between participants of DAT levels 1, 2, 3, and 4 or between participants of DAT levels 3, 4, and 5 (Table 12).

Table 12. MCA of the activation efficacy of anger and anxiety for participants of different DAT.

Anger					Anxiety			
DAT [1]	CN [2]	AS [3] = 0.05			DAT	CN	AS = 0.05	
		c	b	a			b	A
1	9	1.44			1	9	1.67	
2	18	2.11	2.11		2	18	1.83	
3	24	2.54	2.54	2.54	3	24	2.38	2.38
4	15		3.27	3.27	4	15	2.93	2.93
5	8			3.50	5	8		3.50

Sample size using harmonic mean = 12.500. [1] DAT, driving anger tendency; [2] CN, case number; [3] AS, Alpha's subset.

Setting the stress state as the factor variable and the emotion activation efficiency as the dependent variable, one-way ANOVA was carried out in order to examine the impacts of stress state on emotion activation efficiency.

The results (Table 13) suggested that there were significant differences in the activation efficiency of anger (F = 9.351), fear (F = 2.812), anxiety (F = 11.315), helplessness (F = 4.528), relief (F = 4.399), and pleasure (F = 9.073). The AAE of anger for participants of stress state levels 1, 2, 3, 4, and 5 was 1.57 (SD = 1.22), 1.93 (SD = 1.39), 2.45 (SD = 0.83), 3.29 (SD = 1.14), and 3.91 (SD = 1.04), respectively. According to the MCA results (Figure 8a and Table 14), there were significant differences in anger activation efficacy between the participants of SS levels 1 and 4, between the participants of SS levels 1 and 5, between the participants of SS levels 2 and 4, between the participants of SS levels 2 and 5, and between the participants of SS levels 3 and 5. In addition, there was no significant difference in anger activation efficacy between the participants of SS levels 1, 2 and 3 between the participants of SS levels 3 and 4, or between the participants of SS levels 4 and 5.

Table 13. One-way ANOVA of emotion activation efficacy for participants with different SS.

Emotion		SOS [4]	MS [5]	F	Sig.
Ang. [6]	BG [1]	47.206	11.801	9.351	**0.000**
	WG [2]	87.078	1.262		
	Tot [3]	134.284			
Surp. [7]	BG	13.608	3.402	1.694	0.161
	WG	138.608	2.009		
	Tot	152.216			
Fear	BG	23.267	5.817	2.812	**0.032**
	WG	142.746	2.069		
	Tot	166.014			
Anx. [8]	BG	61.649	15.412	11.315	**0.000**
	WG	93.987	1.362		
	Tot	155.635			
Help. [9]	BG	27.584	6.896	4.528	**0.003**
	WG	105.079	1.523		
	Tot	132.662			
Cont. [10]	BG	14.328	3.582	1.747	0.150
	WG	141.456	2.05		
	Tot	155.784			
Rel. [11]	BG	42.280	10.570	7.146	**0.000**
	WG	102.057	1.479		
	Tot	144.388			
Plea. [12]	BG	52.688	13.172	9.073	**0.000**
	WG	100.177	1.452		
	Tot	152.865			

[1] BG, between groups; [2] WG, within groups; [3] Tot, total; [4] SOS, sum of square; [5] MS, mean square; [6] Ang., anger; [7] Surp., surprise; [8] Anx., anxiety; [9] Help., helplessness; [10] Cont., contempt; [11] Rel., relief; [12] Plea., pleasure. The numbers in bold mean that the activation efficiency of the emotion is significantly related to SS.

Table 14. MCA of the activation efficacy of six emotions for participants of different SS.

Anger					Fear				Anxiety				
SS [1]	CN [2]	AS [3] = 0.05			SS	CN	AS = 0.05		SS	CN	AS = 0.05		
		c	b	a			b	a			c	b	a
1	14	1.57			1	14	1.71		1	14	1.21		
2	15	1.93			2	15	1.93		2	15	2.07	2.07	
3	20	2.45	2.45		4	14	2.57	2.57	4	14	2.14	2.14	
4	14		3.29	3.29	3	29	2.60	2.60	3	20		2.60	
5	11			3.91	5	11		3.45	5	11			4.27
Helplessness					**Relief**				**Pleasure**				
SS	CN	AS = 0.05			SS	CN	AS = 0.05		SS	CN	AS = 0.05		
		c	b	a			c	b	a			c	b	a
2	15	1.20			5	11	1.64			5	11	1.18		
1	14	1.57	1.57		4	14	2.50	2.50		4	14	2.07	2.07	
3	20	2.25	2.25	2.25	3	20	2.75	2.75		3	20		2.75	
4	14		2.50	2.50	2	15		3.33	3.33	2	15		2.93	2.93
5	11			3.00	1	14			4.07	1	14			3.93

Sample size using harmonic mean = 14.268. [1] SS, state stress; [2] CN, case number; [3] AS, Alpha's subset.

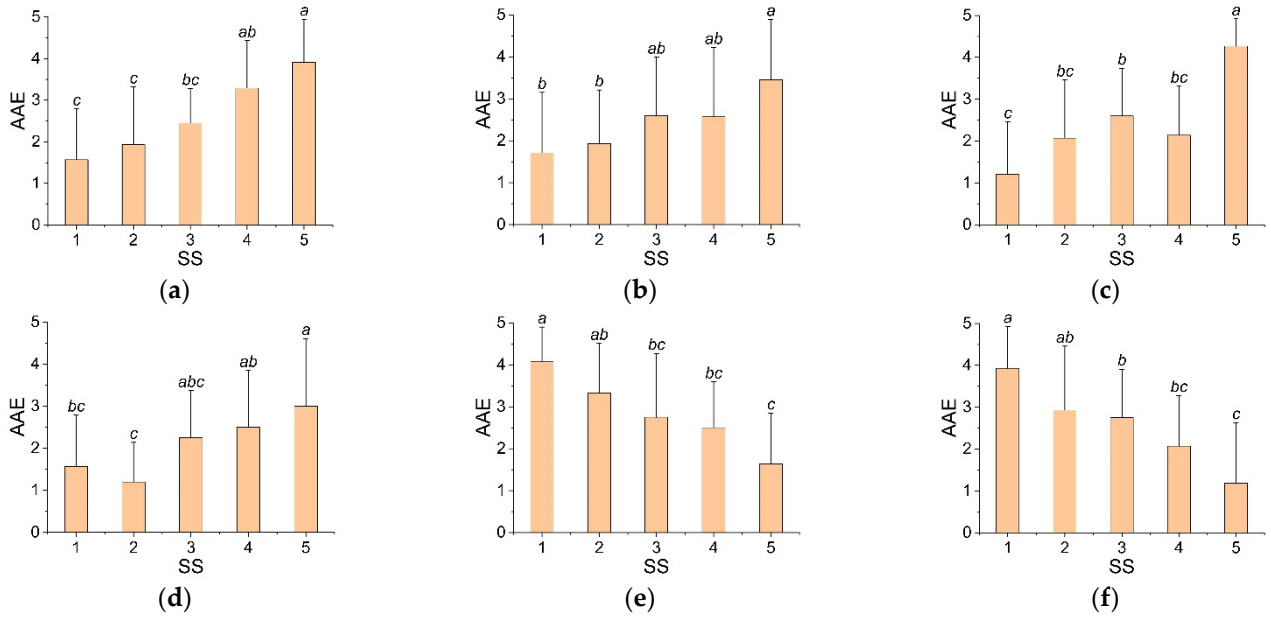


Figure 8. Multiple comparisons of the activation efficacy of six emotions for participants of different SS. (**a**) Anger; (**b**) fear; (**c**) anxiety; (**d**) helpless; (**e**) relief; (**f**) pleasure. a, b and c represent three groups. ab indicates both group a and group b. bc indicates both group b and group c. abc indicates group a, group b and group c.

The AAE of fear for participants of stress state levels 1, 2, 3, 4, and 5 was 1.71 (SD = 1.44), 1.93 (SD = 1.28), 2.60 (SD = 1.39), 2.57 (SD = 1.65), and 3.45 (SD = 1.44), respectively. According to the MCA results (Figure 8b and Table 14), there were significant differences in fear activation efficacy between participants of SS levels 1 and 5, and between participants of SS levels 2 and 5. There was no significant difference in fear activation efficacy between participants of SS levels 1, 2, 3, and 4 or between participants of SS levels 3, 4, and 5.

The average activation efficiency of anxiety for participants of SS levels 1, 2, 3, 4, and 5 was 1.21 (SD = 1.25), 2.07 (SD = 1.39), 2.60 (SD = 1.14), 2.14 (SD = 1.17), and 4.27 (SD = 0.65), respectively. The MCA results (Figure 8c and Table 14) showed significant differences in anxiety activation efficacy between participants of SS levels 1 and 3, between participants of SS levels 1 and 5, between participants of SS levels 2 and 5, between participants of SS levels 3 and 5, and between participants of SS levels 4 and 5. There was no significant difference in anxiety activation efficacy between participants of SS levels 1, 2, and 4 or between participants of SS levels 2, 3, and 4.

The AAE of helplessness for participants of SS levels 1, 2, 3, 4, and 5 was 1.57 (SD = 1.22), 1.20 (SD = 0.94), 2.25 (SD = 1.12), 2.50 (SD = 1.35), and 3.00 (SD = 1.61), respectively. According to the MCA results (Figure 8d and Table 14), there were significant differences in the activation efficacy of helplessness between participants of SS levels 1 and 5, between participants of SS level 2 and 4, and between participants of SS levels 2 and 5. Meanwhile, there was no significant difference in the activation efficacy of helplessness between participants of SS levels 1, 2, and 3, between participants of SS levels 1, 3, and 4, or between participants of SS levels 3, 4, and 5.

The AAE of relief for participants of SS levels 1, 2, 3, 4, and 5 was 4.07 (SD = 0.83), 3.33 (SD = 1.18), 2.75 (SD = 1.52), 2.50 (SD = 1.09), and 1.64 (SD = 1.21), respectively. The MCA results (Figure 8e and Table 14) demonstrated that there were significant differences in relief activation efficacy between participants of SS levels 1 and 3, between participants of SS levels 1 and 4, between participants of SS levels 1 and 5, and between participants of SS levels 2 and 5. There was no significant difference in relief activation efficacy between participants of SS levels 1 and 2, between participants of SS levels 2, 3, 4, and 3, or between participants of SS levels 4 and 5.

The average activation efficiency of pleasure for participants of SS levels 1, 2, 3, 4, and 5 was 3.93 (SD = 1.00), 2.93 (SD = 1.53), 2.75 (SD = 1.16), 2.07 (SD = 1.21), and 1.18 (SD = 1.45),

respectively. According to the MCA results (Figure 8f and Table 14), there were significant differences in the activation efficacy of pleasure between participants of SS levels 1 and 3, between participants of SS levels 1 and 4, between participants of SS levels 1 and 5, between participants of SS levels 2 and 5, and between participants of SS levels 3 and 5, while there was no significant difference in the activation efficacy of pleasure between participants of SS levels 1 and 2, participants of SS levels 4 and 5, or between participants of SS levels 2, 3, and 4.

In order to verify that the results obtained in the experiment were indeed caused by a single variable, we further conducted a test analysis to exclude the influence of other factors. The details are as follows:

To further examine the effect of gender on the activation efficacy of anger, fear, anxiety, and pleasure, the independent sample *t*-test was carried out setting the gender as the grouping variable and the other individual characteristics as the test variable. The results (Table 14) showed that there were significant differences in DSA ($t = -2.745$) and DAT ($t = 2.201$) between male and female participants, suggesting that the differences in emotion activation efficiency between male and female participants may also be caused by the DSA or DAT. By setting the DSA and DAT as the manipulated variable, the partial correlation between gender and the activation efficacy of anger, fear, anxiety, and pleasure was tested (Table 15). The results showed that gender was only significantly associated with the activation efficacy of fear (pc = 0.304) and anxiety (pc = 0.417) after excluding the effects of DSA and DAT. These results suggested that female drivers are more prone to fear and anxiety, which was in agreement with the view that females are more likely to be disturbed by anxiety [30].

Table 15. *T*-test results of individual characteristics between male and female participants.

Item	*t*	df [1]	Sig. (2-Tailed)	MD [2]	SED [3]	CID [4]	
						LL [5]	UL [6]
Ag [7]	0.756	72	0.452	0.166	0.219	−0.271	0.602
DC [8]	0.603	72	0.548	0.164	0.272	−0.378	0.707
DSA [9]	−2.745	72	**0.008**	−0.687	0.250	−1.185	−0.188
DAT [10]	2.201	72	**0.031**	0.589	0.268	0.055	1.123
SS [11]	1.217	72	0.227	0.376	0.309	−0.240	0.992

[1] df, degrees of freedom; [2] MD, mean difference; [3] SED, standard error difference; [4] CID, 95% confidence interval; [5] LL, lower limit; [6] UL, up limit; [7] Ag, age; [8] DC, driving competence; [9] DSA, driving safety attitude; [10] DAT, driving anger tendency; [11] SS, stress state. The numbers in bold mean that the activation efficiency of the emotion is significantly related to gender.

One-way ANOVA was carried out setting the age as the factor variable and the other individual features as test variables. The results (Table 16) showed no significant difference in individual features for participants of different ages, indicating that age was the factor leading to significant differences in surprise activation efficiency for participants of different ages. It could be deduced that the increase of age decreased the surprise activation efficiency based on MCA results (Table 17).

Table 16. Test results of partial correlation between gender and emotion activation efficacy.

MV [1]			Ang. [2]	Fear	Anx. [3]	Plea. [4]
DSA [5] & DAT [6]	Ge [7]	Correlation	−0.161	0.304	0.417	0.227
		Sig. (2-tailed)	0.176	**0.009**	**0.000**	0.055

[1] MV, manipulated variable; [2] Ang., anger; [3] Anx., anxiety; [4] Plea., pleasure; [5] DSA, driving safety attitude; [6] DAT, driving anger tendency; [7] Ge, gender. The numbers in bold mean that the activation efficiency of the emotion is significantly related to gender.

Table 17. One-way ANOVA of individual characteristics for participants of different ages.

Item		SOS [4]	MS [5]	F	Sig.
Ge [6]	BG [1]	0.447	0.158	0.624	0.602
	WG [2]	17.807	0.254		
	Tot [3]	18.284			
DC [7]	BG	6.358	2.119	1.619	0.193
	WG	91.642	1.309		
	Tot	98.000			
DSA [8]	BG	1.852	0.617	0.485	0.694
	WG	89.134	1.273		
	Tot	90.986			
DAT [9]	BG	2.472	0.824	0.587	0.625
	WG	98.190	1.403		
	Tot	100.662			
SS [10]	BG	6.648	2.216	1.275	0.290
	WG	121.690	1.738		
	Tot	128.338			

[1] BG, between groups; [2] WG, within groups; [3] Tot, total; [4] SOS, sum of square; [5] MS, mean square; [6] Ge, gender; [7] DC, driving competence; [8] DSA, driving safety attitude; [9] DAT, driving anger tendency; [10] SS, stress state.

A further one-way ANOVA was carried out setting the DC as the factor variable and the other individual characteristics as the test variable. The results (Table 18) revealed significant differences in driving safety attitude (F = 2.958) for participants of different DC, which indicated that the difference of emotion activation efficacy for participants of different DC may also be caused by driving safety attitude. Setting the driving safety attitude as the manipulated variable, the partial correlation between driving competence and the emotional activation efficiencies of surprise, helplessness, contempt, and relief was tested (Table 19). The partial correlation results showed that driving competence was significantly correlated with the activation efficiency of surprise (PC = −0.317), helplessness (PC = −0.311), contempt (PC = 0.577), and relief (PC = 0.425) after eliminating the influence of driving safety attitude, which indicated that driving competence was an influence on the activation efficacy of the above four emotions. It can be concluded that, with improvement of the DC, the activation efficiency of surprise and helplessness experienced a downward trend, while the activation efficiency of contempt and relief showed an upward trend.

Table 18. One-way ANOVA of individual characteristics for participants of different DC.

Item		SOS [4]	MS [5]	F	Sig.
Ge [6]	BG [1]	0.687	0.172	0.673	0.613
	WG [2]	17.597	0.255		
	Tot [3]	18.284			
Ag [7]	BG	1.554	0.389	0.432	0.785
	WG	62.067	0.900		
	Tot	63.622			
DSA [8]	BG	13.317	3.329	2.958	**0.026**
	WG	77.669	1.126		
	Tot	90.986			
DAT [9]	BG	5.950	1.488	1.084	0.371
	WG	94.712	1.373		
	Tot	100.662			
SS [10]	BG	3.247	0.812	0.448	0.774
	WG	125.091	1.813		
	Tot	128.338			

[1] BG, between groups; [2] WG, within groups; [3] Tot, total; [4] SOS, sum of square; [5] MS, mean square; [6] Ge, gender; [7] Ag, age; [8] DSA, driving safety attitude; [9] DAT, driving anger tendency; [10] SS, stress state. The numbers in bold mean that the activation efficiency of the emotion is significantly related to DC.

Table 19. Partial correlation between driving competence and emotion activation efficacy.

MV [1]			Surp. [2]	Help. [3]	Cont. [4]	Rel. [5]
DSA [6]	DC [7]	Correlation	−0.317	−0.311	0.577	0.425
		Sig. (2-tailed)	**0.006**	**0.007**	**0.000**	**0.000**

[1] MV, manipulated variable; [2] Surp., surprise; [3] Help., helplessness; [4] Cont., contempt; [5] Rel., relief; [6] DSA, driving safety attitude; [7] DC, driving competence. The numbers in bold mean that the activation efficiency of the emotion is significantly related to DC.

To further test the effect of DSA on participants' emotion activation efficacy, one-way ANOVA was carried out setting the DSA as the factor variable and the other individual characteristics as the test variable. The results (Table 20) showed that there was no significant difference in the individual characteristics of participants of different DSA, which indicated that driving safety attitude was the key influencing factor that led to the significant difference in the activation efficiency of anger, contempt, and pleasure. According to the MCA results, it can be deduced that the better the driving safety attitude was, the lower the activation efficiency of anger and contempt was and the higher the activation efficiency of pleasure was.

Table 20. One-way ANOVA of individual characteristics for participants of different DSA.

Item		SOS [4]	MS [5]	F	Sig.
Ge [6]	BG [1]	1.991	0.498	2.108	0.089
	WG [2]	16.293	0.236		
	Tot [3]	18.284			
Ag [7]	BG	2.259	0.565	0.635	0.639
	WG	61.362	0.889		
	Tot	63.622			
DC [8]	BG	3.416	0.854	0.623	0.648
	WG	94.584	1.371		
	Tot	98.000			
DAT [9]	BG	3.596	0.899	0.639	0.636
	WG	97.066	1.407		
	Tot	100.662			
SS [10]	BG	0.377	0.094	0.051	0.995
	WG	127.961	1.855		
	Tot	128.338			

[1] BG, between groups; [2] WG, within groups; [3] Tot, total; [4] SOS, sum of square; [5] MS, mean square; [6] Ge, gender; [7] Ag, age; [8] DC, driving competence; [9] DAT, driving anger tendency; [10] SS, stress state.

Setting the DAT as the factor variable and the other individual characteristics as the test variable, one-way ANOVA was carried out to further verify the effects of driving anger tendency on emotion activation efficacy. The results (Table 21) suggested that DAT was significantly correlated with anger (PC = 0.313) and anxiety (PC = 0.244) after excluding the influence of stress state, which indicated that DAT was the influencing factor for the activation efficacy of anger and anxiety. The results (Table 22) showed that there were significant differences in the stress state (F = 3.817) of participants of different driving anger tendencies, which suggested that it is also possible that the difference of emotion activation efficacy for participants of different DAT was caused by stress state. Setting the stress state as the manipulated variable, the partial correlation between DAT and the activation efficacy of anger and anxiety was tested. This led to the conclusion that the level of DAT was directly proportional to the activation efficiency of anger and anxiety based on the MCA results (Table 21).

Table 21. Partial correlation test between driving anger tendency and emotion activation efficacy.

MV [1]			Ang. [2]	Anx. [3]
SS [4]	DAT [5]	Correlation	0.313	0.244
		Sig. (2-tailed)	**0.007**	**0.038**

[1] MV, manipulated variable; [2] Ang., anger; [3] Anx., anxiety; [4] SS, stress state; [5] DAT, driving anger tendency. The numbers in bold mean that the activation efficiency of the emotion is significantly related to DAT.

Table 22. One-way ANOVA of individual characteristics for participants of different DAT.

Item		SOS [4]	MS [5]	F	Sig.
Ge [6]	BG [1]	1.920	0.480	2.024	0.101
	WG [2]	16.364	0.237		
	Tot [3]	18.284			
Ag [7]	BG	3.122	0.780	0.890	0.475
	WG	60.500	0.877		
	Tot	63.622			
DC [8]	BG	1.767	0.442	0.317	0.866
	WG	96.233	1.395		
	Tot	98.000			
DSA [9]	BG	4.420	1.105	0.881	0.480
	WG	86.567	1.255		
	Tot	90.986			
SS [10]	BG	23.252	5.813	3.817	**0.007**
	WG	105.086	1.523		
	Tot	128.338			

[1] BG, between groups; [2] WG, within groups; [3] Tot, total; [4] SOS, sum of square; [5] MS, mean square; [6] Ge, gender; [7] Ag, age; [8] DC, driving competence; [9] DSA, driving safety attitude; [10] SS, stress state. The numbers in bold mean that the activation efficiency of the emotion is significantly related to DAT.

Setting the stress state as the factor variable and the other individual characteristics as test variables, a one-way ANOVA was carried out to further test the impacts of stress state on emotion activation efficiency. The results (Table 23) showed that there were significant differences in anger tendency (F = 3.753) for participants of different stress states, which suggested that the difference of emotion activation efficacy between participants of different SS may also be caused by DAT. Setting the DAT as a manipulated variable, the partial correlation between SS and the activation efficacies of anger, fear, anxiety, helplessness, relief, and pleasure was tested. The results (Table 24) suggested that SS was significantly correlated with anger (PC = 0.496), fear (PC = 0.330), anxiety (PC = 0.450), helplessness (PC = 0.399), ease (PC = −0.521), and pleasure (PC = −0.548) after eliminating the influence of DAT. The results indicated that the stress state was the influencing factor of the above six emotion activation efficacies. Therefore, it can be inferred that with the increase of stress level, the activation efficiencies of anger, fear, anxiety, and helplessness showed an upward trend, while the stress state was inversely proportional to the activation efficacies of relief and pleasure according to the MCA results.

Table 23. One-way ANOVA of individual characteristics for participants of different SS.

Item		SOS [4]	MS [5]	F	Sig.
Ge [6]	BG [1]	0.648	0.162	0.634	0.640
	WG [2]	17.646	0.256		
	Tot [3]	18.284			
Ag [7]	BG	3.359	0.840	0.962	0.434
	WG	60.263	0.873		
	Tot	63.622			

Table 23. *Cont.*

Item		SOS [4]	MS [5]	F	Sig.
DC [7]	BG	5.062	1.266	0.940	0.446
	WG	92.938	1.347		
	Tot	98.000			
DSA [8]	BG	6.003	1.501	1.218	0.311
	WG	84.984	1.232		
	Tot	90.986			
DAT [9]	BG	17.989	4.497	3.753	**0.008**
	WG	82.673	1.198		
	Tot	100.662			

[1] BG, between groups; [2] WG, within groups; [3] Tot, total; [4] SOS, sum of square; [5] MS, mean square; [6] Ge, gender; [7] Ag, age; [8] DC, driving competence; [9] DSA, driving safety attitude; [10] DAT, driving anger tendency. The numbers in bold mean that the activation efficiency of the emotion is significantly related to SS.

Table 24. Test of partial correlation between SS and emotion activation efficacy.

MV [1]			Ang. [2]	Fear	Anx. [3]	Help. [4]	Rel. [5]	Plea. [6]
DAT [7]	SS [8]	Correlation	0.496	0.330	0.450	0.399	−0.521	−0.548
		Sig. (2-tailed)	**0.000**	**0.004**	**0.000**	**0.000**	**0.000**	**0.000**

[1] MV, manipulated variable; [2] Ang., anger; [3] Anx., anxiety; [4] Help., helplessness; [5] Rel., relief; [6] Plea., pleasure; [7] DAT, driving anger tendency; [8] SS, stress state. The numbers in bold mean that the activation efficiency of the emotion is significantly related to SS.

4.2. Discussions

In this study, we analyzed the five influencing factors of the eight emotional activation efficacies, respectively. We determined by *t*-test or one-way ANOVA that the activation efficacy of each emotion was caused by the variable we selected and not related to other factors. However, it is sometimes impossible to exclude all of the interference factors only through the *t*-test or one-way ANOVA of a single factor on the emotional activation efficacy, and there may be other factors not selected by us in the results that also affect the emotional activation efficacy. Therefore, we further used the selected variables as grouping variables and other variables that may cause interference as test variables and conducted independent-sample *t*-test or one-way ANOVA. If this process was able to eliminate all interfering factors, then it meant that the influencing factors we selected were the only ones that had an impact on the efficacy of emotional activation. If there were still interfering factors that could not be excluded in this process, then we selected the variables that cannot be excluded as control variables in order to test their partial correlation with the subjects' emotional activation efficacy. Interfering factors were excluded by partial correlation test. The conclusion shows that, except for the variables we selected, the activation efficacy of emotion is not related to other variables.

Although some scholars' studies have revealed the relationship between emotions and different characteristics of people, there is no research on the relationship between emotions and drivers' characteristics in the field of transportation. Our study comprehensively investigated the differences in the efficacy of emotional activation among drivers of different genders, ages, driving abilities, driving safety attitudes, driving anger tendencies, and stressful states.

Compared with male drivers, female drivers have higher anxiety activation efficacy, indicating that female drivers are more prone to anxiety. This is consistent with the conclusion drawn by Burani K. et al. [57] that women are more likely to be disturbed by anxiety than men.

Age is an influential factor leading to differences in the activation efficacy of surprise. The activation of surprise decreased with increasing age. However, the activation efficacy of surprise only showed significant difference when the age difference is large. This is due to the increased driving experience as the driver gets older, resulting in a more traffic-experienced drivers who are less likely to be surprised. However, the accumulation of

experience takes a long time to complete, so the difference in the activation efficacy of surprise only occurs when the age difference is large.

Drivers with different driving abilities have different activation effects of surprise, helplessness, contempt, and relief. With the improvement of driving competence, the driver's emotion activation efficacy for surprise and helplessness decreases, while the activation efficacy for contempt and relief increases. The greater the difference in driving competence, the greater the difference in the activation efficacy of helplessness and contempt. The higher the driver's driving competence, the more confident he will be in the process of driving, and more he will be able to deal with various driving scenarios calmly. This results in the driver being less likely to feel surprised and helpless. When the driver has a high driving competence, he becomes too confident in himself, which makes him more prone to contempt. The activation efficacy of relief is only significantly different when the driving competence gap is too large. For example, the relief of driving is very different between a novice driver and an experienced driver. Novice drivers tend to have low driving competence and drive cautiously, while experienced drivers usually have high driving competence and can drive easily.

Drivers with different driving safety attitudes have different activation effects for anger, contempt, and pleasure. The higher the level of driving safety attitude, the lower the activation efficacy of the driver's anger and contempt and the higher the activation efficacy of pleasure. However, the activation efficacy of the three emotions are significantly different only when the driving safety attitudes are quite different. Drivers who pay more attention to driving safety have higher willingness and ability to control their negative emotions during driving and are less susceptible to negative emotions. Therefore, people with higher levels of driving safety attitude are less likely to experience anger and contempt, but more likely to be pleasant.

Drivers with different driving anger tendencies have different activation efficacies for anger and anxiety. This conclusion is consistent with research on road rage. The greater the driver's tendency to anger, the more likely he is to be angry, which is accompanied by anxiety. However, the differences in the activation efficacy of anxiety among people with a small differences in anger tendencies are not large.

Drivers in different stress states have different activation efficacies for anger, fear, anxiety, helplessness, relief, and pleasure. When the driver's stress state level increases, the activation efficacies of anger, fear, anxiety, and helplessness are higher, and the activation efficacies of relief and pleasure are lower. However, the activation efficacies of fear and relief are significantly different only when the difference in stress state is large. The reason for this is that as the level of the driver's stress state increases, negative emotions are more likely to be activated, and positive emotions are less likely to be activated. Slight changes in stress state level have little effect on fear and relief. Once the stress state is too high, the driver will easily appear fearful and will rarely appear relaxed.

The research method for emotional activation efficacy proposed in this paper is comprehensive. The factors influencing the activation efficacy of the eight emotions have all undergone detailed and in-depth research, through which the relationship between the activation efficacy of each emotion and the characteristics of drivers is revealed. This provides an effective reference method for accurately measuring drivers' emotions in driving experiments, and is of great significance for advancing research on driving emotions. However, we only analyzed the relationship between emotion activation efficacy and drivers with different characteristics in a qualitative manner, and we do not further propose the quantitative relationship between emotion activation efficacy and driver characteristics. Subsequent research can further carry out driving experiments in order to study the quantitative relationship between emotion and driver characteristics. It can be improved by measuring emotion and eliminating interfering factors in driving emotion experiments.

5. Conclusions

Emotion is the psychological scale that reflects the relationship between objective things and subjects' needs. During driving activities, when the external environment can meet the current driving needs, it is easy for drivers to have positive emotions. When the contrary is true, drivers are prone to negative emotions. The generation of driving emotion is closely related to the physiological and psychological characteristics of the driver, and different driving emotions have different effects on driving behaviors. As emotion is time-varying and implicit, there are many challenges to capturing the emotion-reactive fragments of drivers and carrying out relevant driving emotion studies. In this study, the individual characteristic data and activation efficiency data of 8 typical driving emotions were obtained through a series of experiments, and multiple mathematical statistical methods were employed to explore the relationship between emotion activation efficiency and drivers' individual characteristics. The results are of great significance to understanding the laws generating driving emotion and provide reference for further research on drivers' cognition and behaviors in various emotional states.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su142113938/s1. Table S1. Emotional activation efficacy level corresponding to each point in PAD space. Abbreviation for Table S1: DR, distance range; AV, assigned value, CN, case number.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee at the College of Electromechanical Engineering, Qingdao University of Science & Technology.

Informed Consent Statement: The Ethics Committee at the College of Electromechanical Engineering, Qingdao University of Science & Technology supports the practice of the protection of human participants in this research. All participants were informed of the research process and provided written informed consent in accordance with the Declaration of Helsinki. The three items involving humans included: driving experiment, questionnaire survey, emotion induction and measurement. Before the experiments, all participants were explicitly told the experimental process and that their data would be recorded. The participations were solicited, yet strictly voluntary.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Conflicts of Interest: The authors declare no conflict of interest.

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