Relation between Driver's Anxiety and Unsafe Conditions - Risk Assessment of Potential Traffic Accidents –

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Abstract: This paper analyzed relationships between driver's anxiety and unsafe traffic conditions in order to enable risk assessment of potential traffic accidents. By an indoor driving test using the driving simulator, we collected the vehicle behavior data. Additionally, we collected levels of anxiety by conducting the questionnaire after the completion of every test run. The examinees were classified via cluster analysis (Ward's method) using their level of anxiety. We focused on the examinees who changed their level of anxiety drastically between the different courses conditions. Based on the results of the analysis of variance of jerk and distance from the center of the lane, we confirmed positive relationships between anxiety and unsafe traffic conditions. Additionally, on the basis of analysis of maximum acceleration, we confirmed that unsafe traffic conditions tended to be the source of unsafe behavior, though this tendency was only partially verified.

Keywords: Anxiety, Unsafe Traffic Conditions, Unsafe Behavior, Jerk, Maximum Acceleration

1. BACKGROUND AND PURPOSE OF STUDY

In Japan, the number of traffic accidents is declining. However, in 2018, the annual number of accidents was more than 430 thousand, which is still high. The number of injuries and deaths was approximately 520 and 3.5 thousand, respectively, indicating that further reduction of traffic accidents is required (National Police Agency, 2019). Many of the present traffic accident prevention measures and safety policies implemented by road administrators are ex-post facto or symptomatic, i.e., they focus on accidents or hazard prone zones (Osaki, 2013). While we continue to implement these measures, it is advisable to study and implement accident prevention measures in terms of preventive safety technology that is initiated while the road is under construction, to reduce the number of traffic accidents.

Currently, locations on roads where near-miss incidents have occurred are renovated to prevent the recurrence of such incidents. Unfortunately, it is problematic that the reported information on these near-miss incidents is not sufficient to predict a possible accident. Moreover, since the risk of accident is already apparent in near-miss incidents, it is unfruitful to evaluate whether a countermeasure is sufficiently preventive or not.

This study focuses on hazards (or sources of risk) that cause accidents or near-miss incidents. The definition of the hazard is different in various disciplines. Here, hazard is defined to be a source of risk, such as unsafe conditions and behavior, i.e., unsafe conditions result in unsafe behavior, thus causing an accident or near-miss incident. Furthermore, here, driver's anxiety is defined as an index used to assess unsafe conditions. This study investigates the relation between driver's anxiety, which varies from time to time, and unsafe conditions, and the type of unsafe behavior caused by anxiety using an indoor driving test. The identification of the relation between driver anxiety and unsafe driving conditions can be used to assess potential risk of an accident and near-miss incident prior to their occurrence.

2. INDOOR DRIVING TEST

2.1 Outline of the Test

The indoor driving test was conducted for 16 days (November 15–16, 19–22, 26–30, and December 03–07, 2018) with a total of 32 examinees (drivers), i.e., two examinees per day. The 32 examinees were regular drivers, aged 30–50 years.

2.2 Experimental Method

A road model (Figure 1) simulating the road around the ramp F at the Chuo junction on the Tokyo-Gaikan Expressway (hereinafter, referred to as Gaikan Expy.) the ramp from the northbound main lane of the Gaikan Expy. toward the outbound lane of the Chuo Expressway, was used for the driving test.

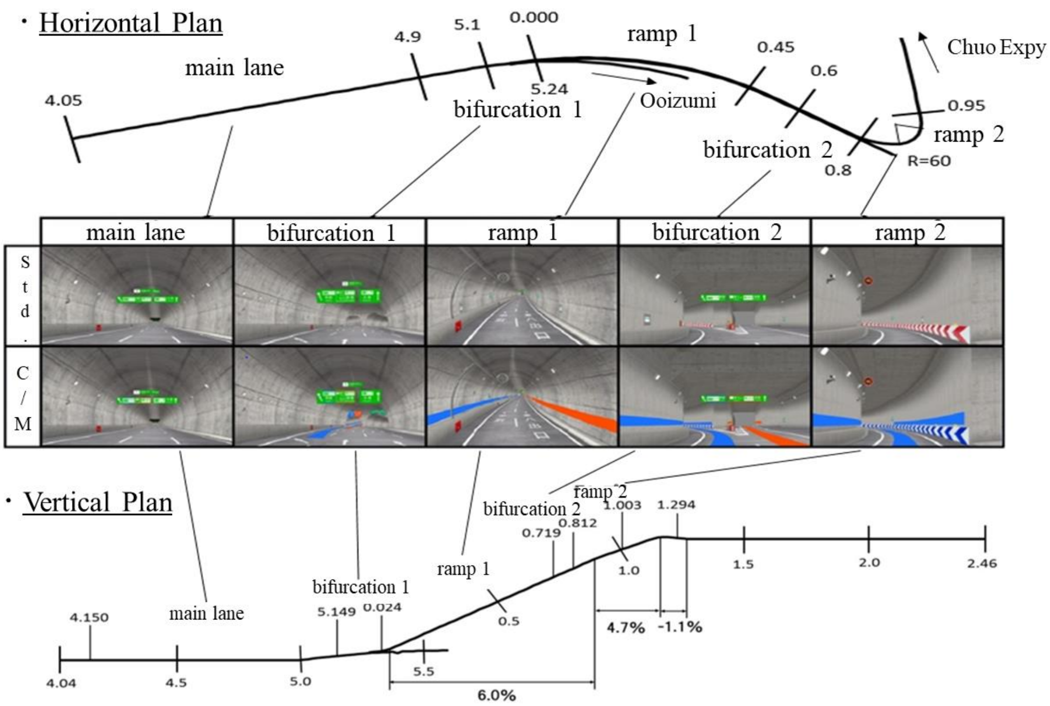

Figure 1. Road diagram

This road model is composed of a three-lane tunnel on the Gaikan Expy., two-lane ramp departing from the Gaikan Expy., and a one-lane ramp departing from the two-lane ramp toward the main lane of the Chuo Expressway. Two road conditions of the same course—with and without color-coordinated destination indicators—were used in the tests. Hereinafter, the condition of the course with the color-coordinated destination indicators is referred to as Gaikan Expy. (C/M)), and the other is referred to as Gaikan Expy. (std.)). The color-coordinated destination indicator is used to show the directions by painting the signs and the tunnel wall with different colors depending on the destination. In addition to the Gaikan Expy. model, another road model, which simulated the ramp similar to the ramp departing from the outbound lane of the Meishin Expressway toward the inbound lane of the Keiji Bypass, was prepared to prevent the drivers from driving the Gaikan Expy. consecutively. On this road model, two courses were prepared. One course (Dummy 1) had the destination information boards at 500 m, 250 m, and immediately before the bifurcation. Another course (Dummy 2) had only one destination information board immediately before the bifurcation. Note that the data obtained by running on these alternate road models were not analyzed.

Every examinee drove the test car four times. To prevent an alleviation of anxiety from being disproportionate toward a particular course by driving the same course(s) consecutively, the courses and the order of driving them were arranged as follows (Table 1).

Table 1. List of model and course combinations

First	Second	Third	Fourth	Number of examinees
std.	Dummy 1	C/M	Dummy 2	4
std.	Dummy 2	C/M	Dummy 1	4
C/M	Dummy 1	std.	Dummy 2	4
C/M	Dummy 2	std.	Dummy 1	4
Dummy 1	std.	Dummy 2	C/M	4
Dummy 2	std.	Dummy 1	C/M	4
Dummy 1	C/M	Dummy 2	std.	4
Dummy 2	C/M	Dummy 1	std.	4

Vehicle behavior data was collected using the drive simulation system (DS), and after the test drive, the drivers were asked about their levels of anxiety and focus, and bases for such ratings. The collected data is detailed in Section 2.7.

2.3 DS System

The DS system used in this test was composed of a PC, an LCD projector, a multi-screen system, a simulated driver's seat, and a sound system (Figure 2). The multi-screen system was composed of a 120-inch front screen and 150-inch left and right screens on which the driver’s front, left, and right views were projected, respectively. On the simulated driver's seat, LCD displays were mounted to simulate the left and right-side mirrors and rear view mirrors, each of which featured the driver’s rear view.

The driver’s operations of the steering wheel, gas pedal, and brake pedal were detected using the DS system with the resolution of one degree (the control of steering wheel was limited to +/−160°, and the angle of pedals was limited to 22° at the maximum) and then sent to the PC at a frame rate of 1/66 s. The vehicle's acceleration rate was calculated by adding the following parameters to the acceleration calculated based on the amount of operation of gas and brake pedals: longitudinal gradient of the road on which the test car is running, air resistance, and cornering resistance.

The speed, position, and driving orientation of the vehicle were determined based on the aforementioned parameters. The images calculated based on them were projected on the screens, and the driver was able to hear driving sounds from the speakers mounted on the simulated driver's seat. Iida et al. confirmed that this system provides reproducible driving speed, driver's heart-rate, and attention probability near the entrance of a tunnel（Iida, 1999）, and the follow-up behavior in the road section that includes the sagging zone, at which point the slope changes from −3.2% to +3.7%（Ooguchi, 2001).

A passenger car was used as a vehicle model, and the driver's eye was located at 1.1 m from the road surface.

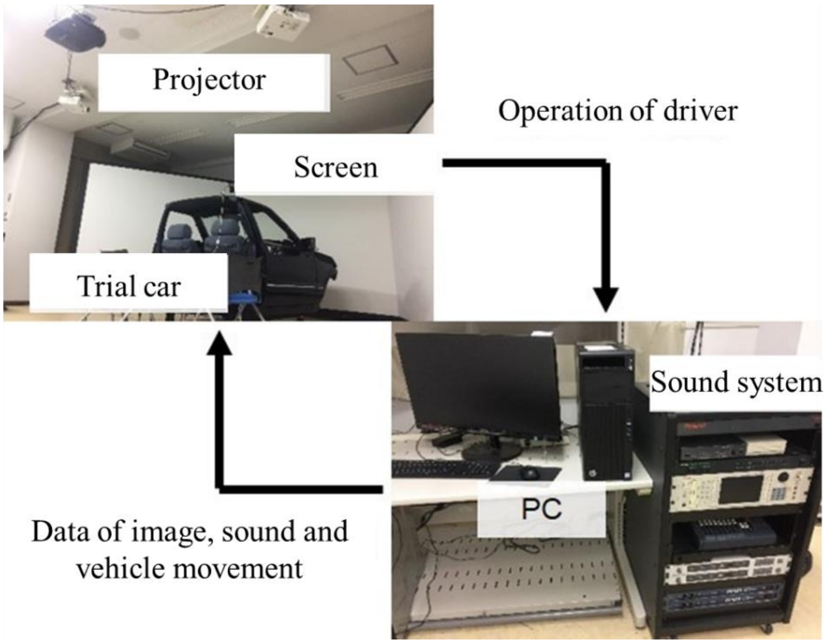

Figure 2. Configuration of DS system

2.4 Road Section Used in the Analysis

As shown in Figure 1, data in the following five road sections were analyzed: a section of the main lane of the Gaikan Expy. (hereinafter, referred to as main lane), the bifurcation departing from the main lane of the Gaikan Expy. toward the two-lane ramp (hereinafter, referred to as bifurcation 1), a section of the two-lane ramp (hereinafter, referred to as ramp 1), the bifurcation extended from the end of ramp 1 (hereinafter, referred to as bifurcation 2), and a section of the one-lane ramp after bifurcation 2 (hereinafter, referred to as ramp 2). The kilometric point value (kp) in Table 2 is tentative because the road is not in service yet.

Table 2. Road sections used in the analysis

Section name	Section (kp)	Feature	Design speed
main lane	4.050~4.900	Large tunnel	80km/h
bifurcation 1	5.100~0.000	Change of cross section	80km/h
ramp 1	0.000~0.450	Steep slope	40km/h
bifurcation 2	0.600~0.800	Branch	40km/h
ramp 2	0.800~0.950	Sharp curve	40km/h

2.5 Driving Conditions

Other autonomous driving vehicles running in the vicinity of the test car were placed only on the main lane. Specifically, a line of vehicles driving at 90 km/h with an inter-vehicular distance of 80 m was placed on the fast lane. In the second (middle) lane, a line of vehicles driving at 85 km/h with an inter-vehicular distance of 100 m was placed in front of the test car. At the start of the test drive, the test car was 100 m behind the last car of the line. Additionally, 150 m behind the test car in the second lane, another vehicle was driving at the same speed as the test car, to avoid collision with the test car. The test car has to switch to the first driving lane to reach Kofu on the Chuo Expressway. To prevent the examinee from hesitating to change lanes, no vehicle was located on the first driving lane in the neighborhood of the test car. The system was set such that the vehicles in the vicinity of the test car would not change lanes but instead continue driving on bifurcation 1 in the main lane toward Ooizumi (Figure 3).

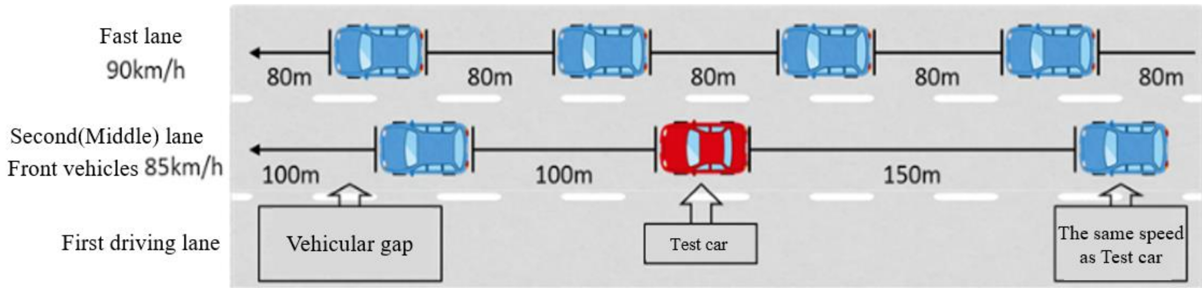

Figure 3. Location of vehicles on the main lane in the vicinity of the test car

If a driver took the wrong lane at bifurcation 1, the driver was asked to redo the test. However, if the driver took the wrong lane at bifurcation 2, the driver was not asked to redo the test.

2.6 Test Procedure

First, every examinee was informed of precautions of the driving test and how personal information would be handled; then, they were asked to sign the letter of consent and seal the letter. After signing the letter of consent, every examinee was instructed on how to control the DS.

Second, an examinee wore the physiological index measuring device and conducted two practice runs on the model road simulating a section from Shin-shimizu IC on the outbound lane of Shin-Tomei Expressway to the neighborhood of the Shin-shimizu junction to familiarize himself with the control of the DS and the tunnel. In the first practice run, the examinee drove under the instructions of the examiner, and in the second practice run the examinee drove freely. If the examinee was uncomfortable with the driving sound being different from the sound he hears when driving his own car, the sound was adjusted. To further familiarize the examinee with the feel and control of driving the test car on the curved roadway, the examinee made two practice runs on the road model simulating the neighborhood of the ramp departing from the inbound lane of the Meishin Expressway to the outbound lane of the Shin-Tomei Expressway. During these two practice runs, the examiner instructed the examinee only with driving directions.

Third, an examinee wore an eye movement recorder (EMR) made four test runs on the course shown in Table 1. Just before starting every test run, a flip chart detailing the driving route was shown to the examinee. The examinee was also informed that he could use the information board and traffic signs on the road, and that if he took a wrong road, he would be able to repeat the test run. The examinee was also informed that the speed limit in the main lane was 80 km/h, which should be maintained for the sake of safe driving. Furthermore, in case of collision with a tunnel wall or a surrounding car he had to repeat the test run, and that he should drive as usual.

At the end of every test run, the examiner interviewed the examinee.

2.7 Collected Data

2.7.1 Vehicle behavior data

The following data were collected every 0.1 s and recorded in the DS: elapsed time since the start of the test (s), driving lane, kp (km), speed (km/h), acceleration rate (m/s^2), and the distance from the center of the lane (m). In analyzing these data, data points were linearly interpolated to ensure that there was data for each 0.001 kp.

2.7.2 Driver behavior data

The EMR collected data regarding gazed objects and line-of-sight coordinates, which could be used to calculate the gazing time. As in a previous study (Fukuda, 1996), here we define the following: the examinee was considered to be gazing when the line-of-sight remained on an object for 0.165 s or longer and when the speed of the eye movement tracking the object was 10 deg/s or less. The examinee's cardiac electrocardiogram and breathing pattern were collected with the physiological index measuring device while he was driving the DS. Prior to the driving, the examinee's cardiac electrocardiogram and heart-rate were measured while he was sitting; this was used as reference data (i.e., under resting conditions).

2.7.3 Interview data

After the completion of every test run, the examinee was required to answer the questions listed in Table 3 for every road section.

Table 3. Questionnaire

Question	Contents
Level of anxiety	How much anxiety did you feel? (7 level) (1 : I didn't feel anxiety at all., 7 : I felt anxiety very much.)
Reason for the level of anxiety	Why did you select this level? (Open-ended question method)
Near-miss feeling	Did you feel near-miss feeling? (YES/NO)
Level of attention	How much attention did you pay? (7 level) (1 : I didn't need attention at all., 7 : I needed attention very much.)
Reason for the level of attention	Why did you select this level? (Open-ended question method)

3. SELECTION OF EXAMINEES TO BE ANALYZED

The examinees were classified via cluster analysis (Ward's method) using their level of anxiety for every five road sections on the Gaikan Expy. (std.) and Gaikan Expy. (C/M) courses. The cluster distance was defined to be the Euclidean distance. The dendrogram is shown in Figure 4.

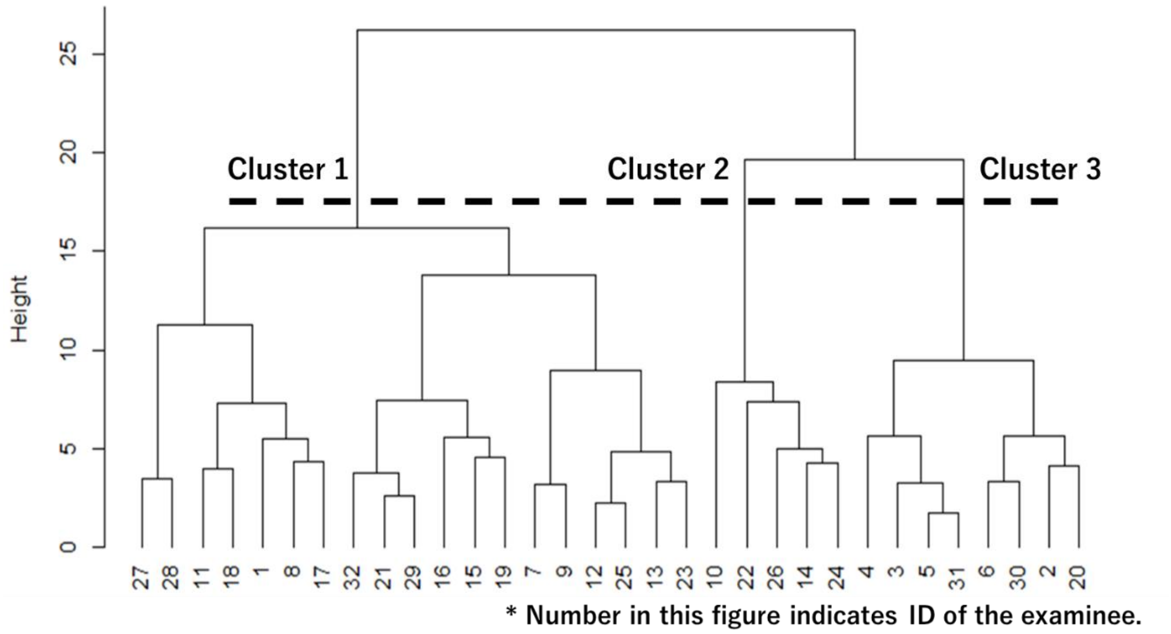

Figure 4. Dendrogram

It was found that, when the examinees were classified into three clusters, the classification was the easiest to interpret. The examinees were classified into three clusters over all road sections (from the main lane section to the ramp 2 section) based on the average level of anxiety (levels 1 through 7 are defined as shown in Table 3). Cluster 1 is the group of examinees whose level of anxiety is low regardless of whether the color-coordinated destination indicator was present or not; cluster 2 is the group of examinees whose level of anxiety was high regardless of whether the indicator was present or not; and cluster 3 was the group of examinees whose level of anxiety was alleviated with the introduction of the indicator. When the examinees were classified into two clusters, the features of each cluster were more obscure than that for the three-cluster classification because the sum of squares increases when the examinees are classified into two clusters. An examination of the distribution of the anxiety level average over the entire interval shows that it can be applied to a normal distribution. In the distribution, the average value is 2.8, but 2.8 is a number not used in the interview, and it is difficult to imagine because it is a decimal. Therefore, in this paper, in order to make it easier to interpret, the boundary of anxiety was set to be level 3 (rounded off from 2.8) as shown in Table 4.

Here, we focused our attentions on how the level of anxiety of the same examinee changed. Level 3 anxiety, which is the average level calculated via the Ward method, is set to be the reference or baseline of the anxiety level. We focused on the examinees whose average level of anxiety on all of the road sections of the Gaikan Expy. (std.) course was higher than the reference level (i.e., 3) that on all of the road sections of the Gaikan Expy. (C/M) course was lower than the reference level (i.e., 3). These examinees are referred to as the group of high on std., hereafter. The levels of anxiety of these examinees between the two courses were compared. Since this comparison cannot tell if the changes in the vehicle behavior is caused by the driver’s anxiety or characteristics of the course, we also focused on the examinees whose average level of anxiety on all of the road sections of the Gaikan Expy. (std.) course was less than the reference level (i.e., 3) and that on all of the road sections of the Gaikan Expy. (C/M) course was higher than the reference level (i.e., 3). These examinees are referred to as the group of high on C/M hereafter. The levels of anxiety of these examinees between the two courses were also compared. In other words, the examinees in the group of high on std. had a level of anxiety that is opposite to that of the examinees in the group of high on C/M. By comparing the vehicle behavior of the car driven by the driver in the former group with that in the latter group, we identified if the change in the vehicle behavior was caused by anxiety. There were 10 examinees in the group of high on std. and six examinees in the group of high on C/M. We focus our attention on these 16 examinees in the rest of our analysis.

Table 4. Average level of anxiety over all of the road sections in every cluster

Average level of anxiety over all of the road sections			
	Cluster1 (n=19)	Cluster2 (n=5)	Cluster3 (n=8)
std.	2.24	3.88	3.93
C/M	2.42	4.56	2.15

4. UNDERSTANDING UNSAFE CONDITIONS

4.1 Variance of Jerk

Jerk is the rate of change in acceleration with respect to time, and in this study, it is calculated by dividing the change in acceleration per 0.001 kp (Δa) by the change in time (Δt). The variance of jerk over all of the road sections was calculated based on the jerk calculated at every 0.001 kp and for every examinee. The reason why we focused on the variance of jerk is because discontinuity in the jerk has a negative influence on human feeling, i.e., the ride quality, similar to anxiety (Saito, 2004). When the variance of jerk is large, it is understood that jerk tends to be discontinuous, making smooth acceleration and deceleration unattainable. The variance of jerk and the p value ($p < 0.05$) obtained by the F test for every examinee is listed in Tables 5 and 6. Table 5 shows the variance of jerk and p values of the group of high on std., and Table 6 shows those of the group of high on C/M.

Table 5. Variance of jerk and p values for the group of high on std. examinees.

		Variance	*p* value
ID 2	std.	0.049	1.62E-13
	C/M	0.030	
ID 3	std.	0.240	< 2.2e-16
	C/M	0.144	
ID 4	std.	0.038	< 2.2e-16
	C/M	0.055	
ID 5	std.	0.080	< 2.2e-16
	C/M	0.020	
ID 6	std.	0.472	< 2.2e-16
	C/M	0.220	
ID 11	std.	0.135	< 2.2e-16
	C/M	0.262	
ID 17	std.	0.042	0.2253
	C/M	0.044	
ID 18	std.	0.090	6.62E-05
	C/M	0.075	
ID 30	std.	0.063	< 2.2e-16
	C/M	0.024	
ID 31	std.	0.077	3.13E-05
	C/M	0.066	

Table 6. Variance of jerk and p value of group of high on C/M examinees.

		Variance	*p* value
ID8	std.	0.101	0.1803
	C/M	0.106	
ID10	std.	0.072	< 2.2e-16
	C/M	0.132	
ID12	std.	0.053	< 2.2e-16
	C/M	0.160	
ID13	std.	0.047	< 2.2e-16
	C/M	0.097	
ID22	std.	0.172	< 2.2e-16
	C/M	0.088	
ID23	std.	0.297	< 2.2e-16
	C/M	0.452	

Table 5 indicates that seven out of nine examinees, who exhibited a significant difference in the variances between the two courses, had larger variances when they were driving on the Gaikan Expy. (std.) course, where they had higher levels of anxiety. Table 6 indicates that four out of five examinees, who exhibited a significant difference in the variances between the two courses, had larger variances when they were driving on the Gaikan Expy. (C/M), where they had higher levels of anxiety. Based on these observations, we concluded that more anxious the driver is, larger the variance of jerk will be.

4.2 Distance from the Center of the Lane

Beede and Kass (2006) used the standard deviation of distance (in meters) from the center of the lane as an index to evaluate the influence of the distraction of a driver's attention caused by the use of a cellphone on the vehicle behavior. They reported that while a driver was using a cellphone, the standard deviation of the distance from the center became smaller. We used the same index in this study and performed the analysis at ramp 1. The main lane and bifurcation 1 were not analyzed because the driver had to change lanes. Bifurcation 2 and ramp 2 were also excluded from the analysis because these courses have severe changes in horizontal alignment that force the driver to steer substantially; therefore, the distance from the center is determined by the driver's capability to control the steering wheel to properly follow the curves on the courses rather than by the driver's anxiety. Additionally, five examinees (two examinees in the group of high on std. and three examinees in the group of high on the C/M) were excluded from the analysis because they changed lanes while driving through ramp 1. Table 7 indicates the standard deviation and p value ($p < 0.05$) of every examinee in the group of high on std., and Table 8 indicates the standard deviation and p value ($p < 0.05$) of every examinee in the group of high on C/M.

Table 7. Standard deviation and p values for the group of high on std.

		ramp 1	*p* value
ID3	std.	0.163	0.004182
	C/M	0.187	
ID5	std.	0.171	0.0372
	C/M	0.155	
ID6	std.	0.160	8.28E-14
	C/M	0.228	
ID11	std.	0.163	0.3237
	C/M	0.171	
ID17	std.	0.173	1.03E-07
	C/M	0.134	
ID18	std.	0.172	2.19E-13
	C/M	0.121	
ID30	std.	0.090	< 2.2e-16
	C/M	0.178	
ID31	std.	0.114	0.5577
	C/M	0.117	

Table 8. Standard deviation and p values for the group of high on C/M

		ramp 1	*p* value
ID8	std.	0.148	2.48E-05
	C/M	0.121	
ID12	std.	0.115	0.005398
	C/M	0.101	
ID22	std.	0.210	< 2.2e-16
	C/M	0.136	

Table 7 indicates that three out of six examinees, who exhibited a significant difference in the standard deviations between the two courses, had smaller standard deviations when they were driving on the Gaikan Expy. (std.) course, where they had higher levels of anxiety. Table 8 data shows that for the Gaikan Expy. (C/M) course, the standard deviation of the distance from the center became small in all examinees exhibiting significant difference in the standard deviations between the two courses. This observation reveals that the standard deviation of the distance from the center of the lane will become small when a driver feels strong anxiety.

5. UNDERSTANDING UNSAFE BEHAVIOR

5.1 Average Speed in a Road Section

The average speed in one road section (hereinafter, referred to as average road section speed) was calculated based on the vehicle behavior data per 0.001 kp for each examinee and for each road section used in the analysis. The average road section speed and standard deviation for the group of high on std. were calculated for each road section using the average road section speed as a reference. Table 9 indicates the average road section speed and standard deviation for the group of high on the Gaikan Expy. (std.), and Table 10 indicates the average road section speed and standard deviation for the group of high on C/M.

Table 9. Average road section speed and standard deviation of the group of high on std.

std. (High)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Average section speed [km/h]	Ave.	88.62	91.10	82.86	77.22	62.78	84.75
	S.D.	6.44	4.97	8.29	9.75	11.06	6.47
C/M (Low)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Average section speed [km/h]	Ave.	85.67	87.31	81.17	77.77	63.66	82.91
	S.D.	5.46	10.88	10.05	9.71	9.10	7.20

Table 10. Average road section speed and standard deviation for the group of high on C/M

std. (Low)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Average section speed [km/h]	Ave.	88.29	86.75	72.75	61.98	51.76	78.55
	S.D.	4.91	8.00	11.14	13.16	11.06	6.88
C/M (High)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Average section speed [km/h]	Ave.	87.25	88.33	77.60	71.96	54.31	81.36
	S.D.	6.46	9.40	15.04	15.36	9.86	9.57

For every road section, there was a difference in the population variance between the two courses. When no significant difference was found (F test, $p < 0.05$), the Student's t-test was conducted, and if there was the significant difference, the Welch's t-test was performed to find the difference in the population mean. The results for the average road section speed for group of high on std. and C/M are presented in Tables 11 and 12, respectively.

Table 11. Average road section speed for the group of high on std.

Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Statistical method	Student	Welch	Student	Student	Student	Student
Significance level	5%	5%	5%	5%	5%	5%
p value	0.309	0.359	0.700	0.906	0.855	0.575

$*p<0.10$, $**p<0.05$

Table 12. Average road section speed for the group of high on C/M

Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Statistical method	Student	Student	Student	Student	Student	Student
Significance level	5%	5%	5%	5%	5%	5%
p value	0.781	0.780	0.576	0.296	0.709	0.606

$*p<0.10$, $**p<0.05$

There is no road section where the significant difference is found.

5.2 Maximum Acceleration in Road Section

The maximum acceleration in one road section (hereinafter, referred to as maximum road section acceleration) was calculated based on the vehicle behavior data per 0.001 kp for each examinee and for each road section used in the analysis. The maximum road section acceleration was calculated in the road section for the group of high on std. using the maximum road section acceleration as a reference. Table 13 lists the maximum road section acceleration and standard deviation for the group of high on std., and Table 14 indicates the maximum road section acceleration and standard deviation for the group of high on C/M.

Table 13. Average maximum road section acceleration and standard deviation for the group of high on std.

std. (High)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Road section acceleration	Ave.	0.45	0.14	0.15	0.09	-0.01	0.46
[m/s²]	S.D.	0.18	0.17	0.11	0.06	0.26	0.16
C/M (Low)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Road section acceleration	Ave.	0.49	0.11	0.21	0.07	-0.01	0.50
[m/s²]	S.D.	0.26	0.11	0.11	0.09	0.13	0.24

Table 14. Average maximum road section acceleration and standard deviation for the group of high on C/M

std. (Low)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Road section acceleration	Ave.	0.37	0.14	0.13	0.06	0.16	0.38
[m/s²]	S.D.	0.06	0.09	0.11	0.04	0.23	0.07
C/M (High)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Road section acceleration	Ave.	0.53	0.07	0.16	0.10	0.02	0.53
[m/s²]	S.D.	0.16	0.16	0.15	0.08	0.15	0.16

A test similar to the test of the average road section speed was conducted. Table 15 indicates the result of the test for the group of high on std., and Table 16 lists the results for the group of high on C/M.

Table 15. Maximum road section acceleration of the group of high on std.

Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Statistical method	Student	Student	Student	Student	Student	Student
Significance level	5%	5%	5%	5%	5%	5%
p value	0.723	0.715	0.306	0.592	0.976	0.709

*p<0.10, **p<0.05

Table 16. Maximum road section acceleration of the group of high on C/M

Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Statistical method	Student	Student	Student	Student	Student	Student
Significance level	5%	5%	5%	5%	5%	5%
p value	0.056*	0.422	0.704	0.298	0.295	0.079*

*p<0.10, **p<0.05

In Table 15, it is clear that none of the road sections were significantly different. However, the data in Table 16 indicates that there is a trend ($p < 0.1$) toward a significant difference in the main lane and for all of the road sections. Although it is only partially, it is found that the maximum acceleration tends to become higher on the course on which the driver has a high level of anxiety.

5.3 Maximum Deceleration

The maximum deceleration in one road section (hereinafter, referred to as maximum road section deceleration) was calculated using the vehicle behavior data per 0.001 kp for each examinee and for each road section used in the analysis. The maximum road section deceleration and standard deviation are calculated on the road section for the group of high on std. using the maximum road section as a reference. Table 17 presents the maximum road section deceleration and standard deviation for the group of high on std., and Table 18 shows the maximum road section deceleration and standard deviation for the group of high on C/M.

Table 17. Average and standard deviation of maximum road section deceleration for the group of high on std.

std. (High)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Road section deceleration	Ave.	0.41	0.26	0.62	1.20	1.22	1.59
[m/s^2]	S.D.	0.41	0.19	0.44	0.52	0.63	0.49
C/M (Low)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Road section deceleration	Ave.	0.63	0.25	0.45	1.14	0.97	1.26
[m/s^2]	S.D.	0.44	0.32	0.35	0.51	0.41	0.43

Table 18. Average and standard deviation of maximum road section deceleration for the group of high on C/M

std. (Low)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Road section deceleration	Ave.	0.60	0.43	1.00	0.84	1.03	1.35
[m/s^2]	S.D.	0.47	0.49	0.48	0.53	0.43	0.30
C/M (High)	Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Road section deceleration	Ave.	0.44	0.56	0.75	1.28	1.19	1.60
[m/s^2]	S.D.	0.34	0.48	0.47	0.55	0.41	0.14

A test similar to the test of the average road section speed was conducted. Table 19 indicates the result of the test for the maximum road section deceleration of the group of high on std., and Table 20 indicates the result of the test for the maximum road section deceleration for the group of high on C/M.

Table 19. Maximum road section deceleration for the group of high on std.

Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Statistical method	Student	Student	Student	Student	Student	Student
Significance level	5%	5%	5%	5%	5%	5%
p value	0.292	0.943	0.382	0.800	0.330	0.149

$*p<0.10$, $**p<0.05$

Table 20. Maximum road section deceleration for the group of high on C/M

Section	main lane	bifurcation 1	ramp 1	bifurcation 2	ramp 2	All section
Statistical method	Student	Student	Student	Student	Student	Student
Significance level	5%	5%	5%	5%	5%	5%
p value	0.539	0.692	0.425	0.225	0.565	0.116

$*p<0.10$, $**p<0.05$

The data in Tables 19 and 20 indicates that there is no road section with a significant difference in the maximum road section deceleration.

6. CONCLUSION

Here, we focused our attention on the changes observed in each examinee and tried to understand the relations between an examinees' anxiety and unsafe driving conditions and between unsafe driving conditions and his unsafe behavior. The following summarize the results of this study:

- Results indicate that when the examinees were asked to rate their anxiety on a scale of 1 to 7, level 3 of anxiety is the boundary for the conditions used in this study.
- The conditions where variance of jerk was large and the standard deviation of the distance from the center of the lane was small, which were observed when the level of anxiety was high, and were not suitable for safe driving. This indicates that there is a relation between anxiety and unsafe conditions.
- Based on the analysis of maximum acceleration, it appears that unsafe conditions tend to be the source of unsafe behavior, though this tendency was only partially verified.

To fully understand the relations, other approach that uses other index such as driver's behavior data (e.g., movement of line-of-sight) and changing the test conditions may be required. We were unable to thoroughly investigate if the state in which the variance of jerk is large and the state in which the standard deviation of the distance from the center of the lane is small can occur simultaneously or if only one of these states can occur. Moreover, if we use 2.8 as a threshold, the number of examinees to be analyzed changes, so the classification method would also be reanalyzed. These are issues to be investigated in the future.

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