Study on Psychological Burden of Driving on Load Curves Using Volumetric Pulse Waves

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Abstract

The accident rate in curve sections is usually higher than that in straight sections in load networks. The main cause of traffic accidents is the decision delays, operational errors, and human errors of drivers. Fatigue and stress gives drivers the psychological burden. The burden affects the transmission of the operation information required for driving behavior. In the volumetric pulse wave measurement used in this study, near-infrared light is irradiated to the earlobe, to detect the transmitted or reflected light by a light receiving element. By using the fact that transmitted light and borrowed light can be changed by bloodstream, the change of the bloodstream is evaluated. By using embedding theorem and orbit parallelism gauging method, the authors tried to clarify the relationship of the traffic environment and driver behavior.

Keywords: Traffic accident, pulse wave, Orbit parallelism gauging method

1. Background

The accident rate in curve sections is higher than that in straight sections as shown in Fig1. Accidents in curves are 3.0% of the whole in the statistics of the traffic accident in fiscal year 2013 according to the National Police Agency[1]. But the composition rate of the fatal accident will be about 16 % highly. The main cause of traffic accidents is the decision delays, operational errors, and human errors of drivers. Percentage of traffic accidents caused by human errors is more than 90%. Fatigue and stress gives drivers the psychological burden. The burden affects the transmission of the operation information required for driving behavior.

2. Pulse Wave Measurement[2]

In the volumetric pulse wave measurement used in this study, near-infrared light is irradiated to the earlobe as shown by Fig.2, to detect the transmitted or reflected light by a light receiving element. By using the fact that transmitted light and borrowed light can be changed by bloodstream, the change of the bloodstream is evaluated. Furthermore, measured volumetric pulse waves are differentiated twice to get acceleration pulse waves. The chaos analysis is to

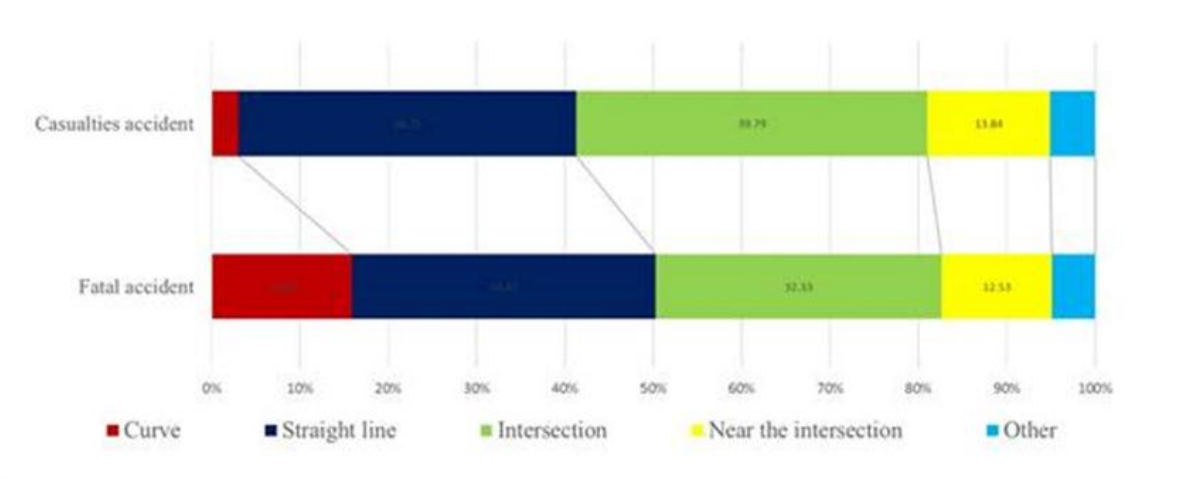analyze the complex time-series from the standpoint of deterministic chaos.

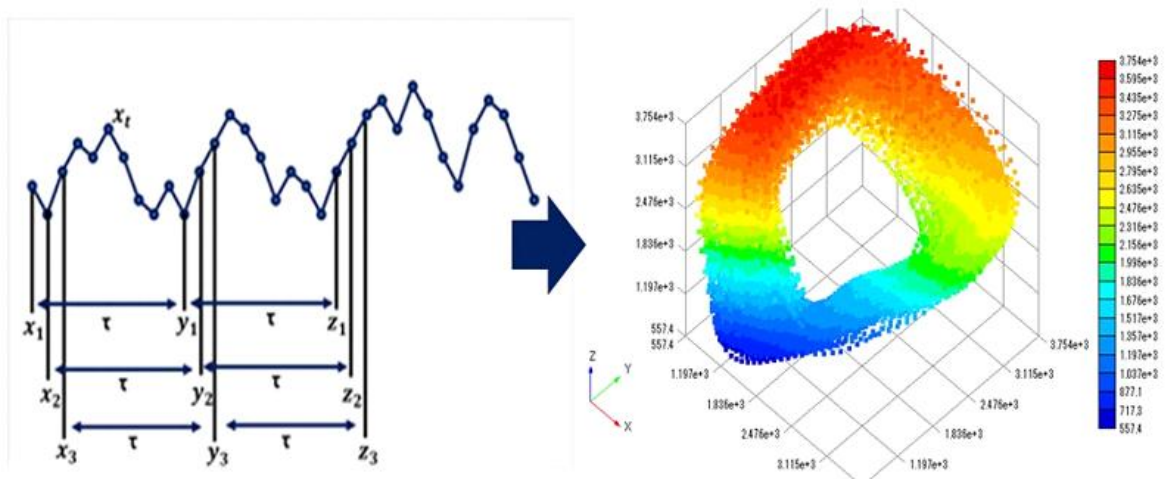Fig.1: Comparison of accident rates in various sections on all the loads in Japan (FY2013)

Fig.2:   Measurement of volume pulse waves

3.   Embedding Theorem[3)]

Embedding theorem is a theorem that uses the coordinate transformation by the difference of every predetermined time delay. The time delay value is a parameter of the time to be embedded in a multi-dimensional state space for drawing the trajectory of the attractor. The time series data is set as x (t). A vector is made by using the time-series data as follows:

$$(x\,(t),\,x(t-\tau),\,\cdots,\,x(t-(n-1)\tau))$$

In this case, τ represents the time delay, n indicates the number of dimensions, t indicates the time. By sequentially plotting the vector in n-dimensional state space, the orbit is drawn as shown by Fig.3 and Fig.4.
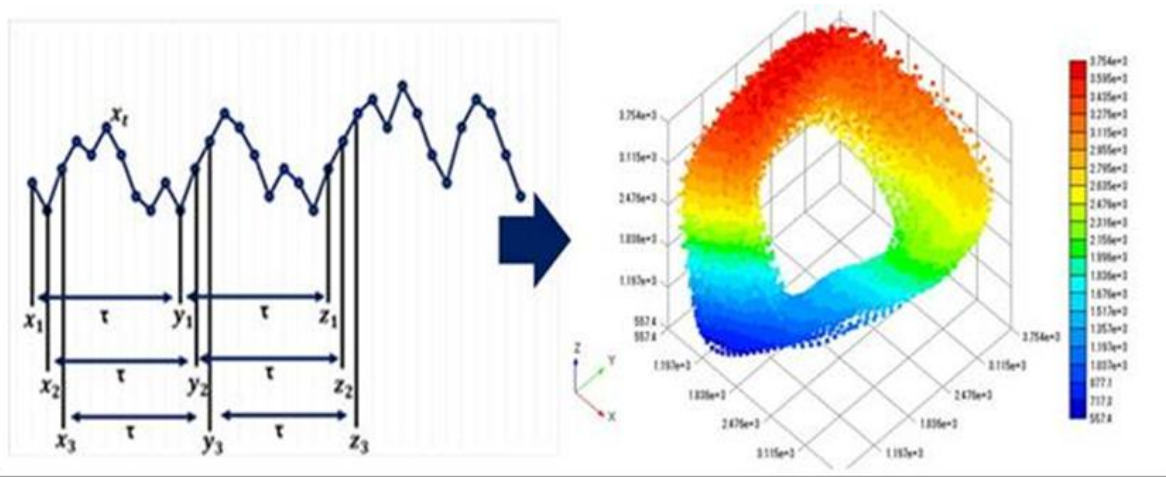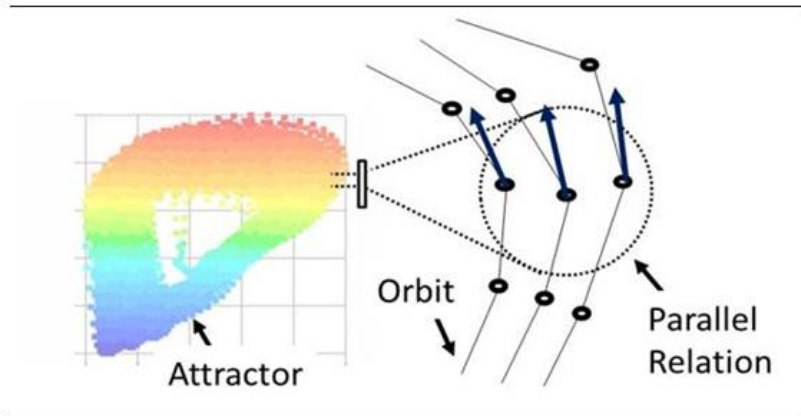
Fig.3:   Embedding theorem and attractor

Fig.4:   Conceptual view of orbit parallelism gauging method

4.   Orbit Parallelism Gauging Method[4]

The waveform of the pulse wave is chaotic. Therefore, in this study, the orbit parallelism gauging method is used. This method is effective to estimate the ability for external environment adaptation. In this approach, Based on Takens implantation theorem, the time delay coordinate is produced and then attractor is constituted. Then, deriving a unit orbital vector from the orbit of the constituted attractor, the parallelisms with the vector of adjacent orbits.

Orbit parallelism (Γ) is defined by the expression (1)

$$\Gamma = \frac{1}{k} \sum_{i=1}^{k} |\gamma_i| \quad \cdot \cdot \cdot (1)$$

In addition, γ is defined from an orbital vector (T_i) and the orbital adjacent vector (T_j).

$$\gamma_i = \frac{1}{4m} \sum_{j}^{m} ||T_i - T_j||^2 \quad \cdot \cdot \cdot (2)$$

When the ability for outside adaptation is low, the orbit parallelism approaches 1.0. The degree

approaches zero when the ability is high. A conceptual diagram of orbit parallelism gauging method shown in Fig4.

5. Experimental outline

In this study, in order to clarify the relationship of the traffic environment and driver behavior of road linear, etc., highway roads with relatively simple environment was chosen as the target. The Shinjuku Route 4 shown by Fig.5 on the Metropolitan expressway was chosen as the subject route, since many accidents occurred in some curves on the route.

The test subjects to drive on the route are eight students of our university. The following shows the conditions in the experiment. In addition, in the present study, we carried out the implementation of the self-diagnosis OD-type safety test in order to take into account the individual characteristics of the subject. In general, drivers changing driving lanes need information on road environment, which means that they are subjected to additional burden. Driving without sufficient sleep may lead drivers to dangerous sleepiness as well as uncertain fluctuation of the pulse wave. Then all the subject are required to meet the following conditions to get accurate data of the pulse wave safely.

- Not perform the lane change
- The day before the sleep time is 6 hours or more
- Not a day before drinking
- Remove the noble metal, such as earrings and necklaces
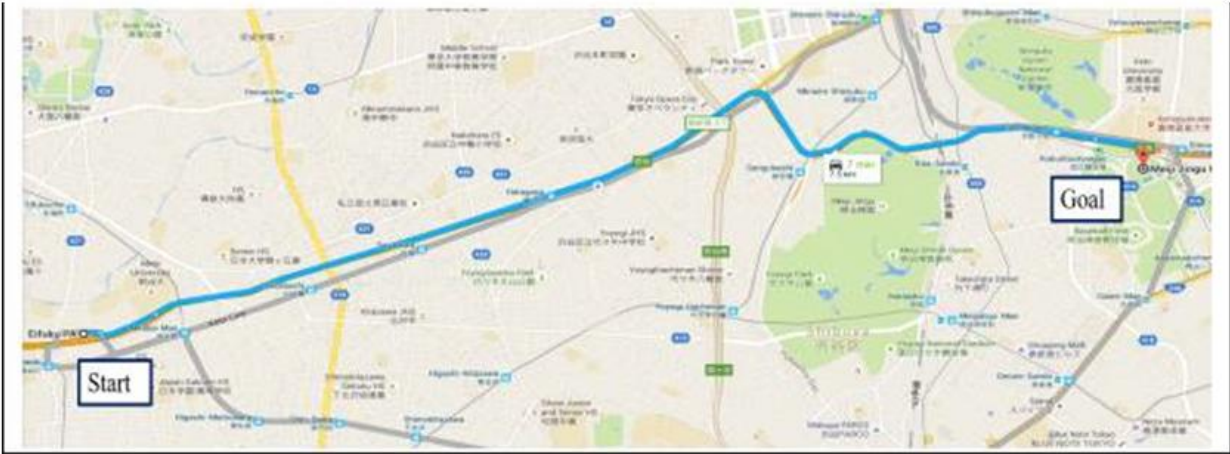- Adjustment of the temperature inside the vehicle

Fig.5:   Experimental subjects course (Shinjuku Route 4).

Point	Curve No.1	Curve No.2	Curve No.3	Curve No.4
Driving time	12~13(sec)	12~13(sec)	15~17(sec)	5(sec)
Curve direction	Right	Left	Right	Left
Curve radius	85m	88m	157m	74m
Visibility	Usually	Bad	Good	Bad
Characteristic	•Attention color paving •Curve warning zebra plate •Large attention plate Curve destination confluence	•Attention color paving •Curve warning zebra plate •Large attention plate High wall	•Attention color paving •Curve warning zebra plate It can be predicted curve direction by the back of structure	•Curve warning zebra plate Possible next curve direction of the prediction by the back of the tree

Fig.6: Characteristics of the curves chosen as the targets

Figure 6 shows the characteristics of the curves as the research targets.

- Curve No.1

Curve No.1 is the right curve with the radius of 85m. Since the right wall is made of wire mesh material, the curve destination can be easily confirmed while traveling. In this curve, a variety of facility for traffic safety exists.

- Curve No.2

Curve No.2 goes gently down to the left with the radius of 88m. Because of the existence of the soundproof wall on the left side, the curve destination can not be easily confirmed. A variety of facility for traffic safety exists.

- Curve No.3

Curve No.3 is the right curve with the radius of 157m. Because of the existence of low guardrail on the right side, it is easy to check the curve destination. In addition, the direction of the following curve can be easily predicted by the building in the parking area of the background.

- Curve No.4

Curve No.4 is the left curve with the radius of 74m. Because of the existence of the soundproof wall on the left side, the curve destination can not be easily confirmed. In addition, the direction of the following curve can be easily predicted by the trees in the background.

Table 1: Orbit parallelism of the entire course and each curve section

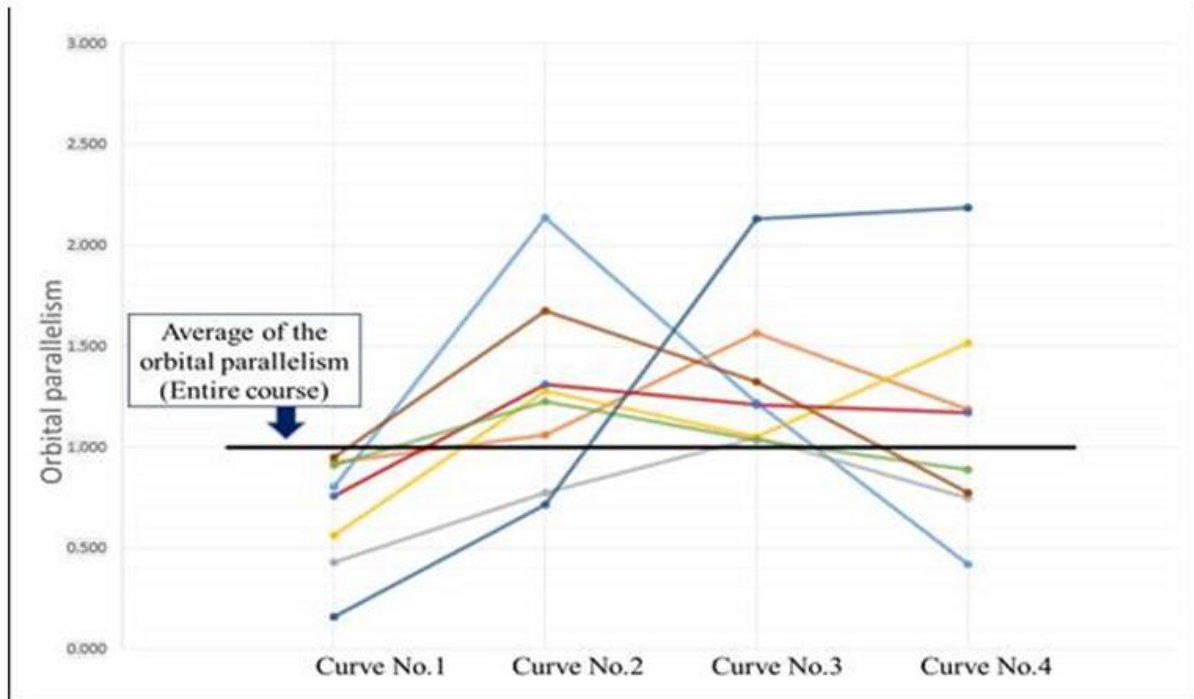| Driver	Average of the entire course	Curve 1	Curve 2	Curve 3	Curve 4
A	0.204	0.164	0.436	0.249	0.086
B	0.196	0.181	0.208	0.307	0.233
C	0.186	0.080	0.144	0.195	0.139
D	0.209	0.118	0.267	0.22	0.317
E	0.203	0.154	0.266	0.246	0.238
F	0.390	0.355	0.478	0.403	0.346
G	0.162	0.026	0.116	0.345	0.354
H	0.178	0.169	0.298	0.236	0.138

Fig.7: Orbit parallelism of each curve section divided by Orbit parallelism of the entire course

6. Experimental Results

6.1 Comparison of the target the entire course and the curve

The mean values of the orbit parallelisms of the test subjects are shown in Table-1 and Fig1. Although the individual difference is significant, the trajectory orbit parallelisms in the curve No.3 for all test subjects are higher than those in the other curves. In the curve No.3, drivers can predict the direction of the curve from visual information on buildings behind the curve and a building in the parking area. However, there is relatively little information on the existence of a curve in advance compared with the curves No.1 and No.2. Furthermore, the degrees tend to be high because test subjects cannot afford to observe circumstances of the

Table 2: The number of positive answers for each item (OD-type safety test)

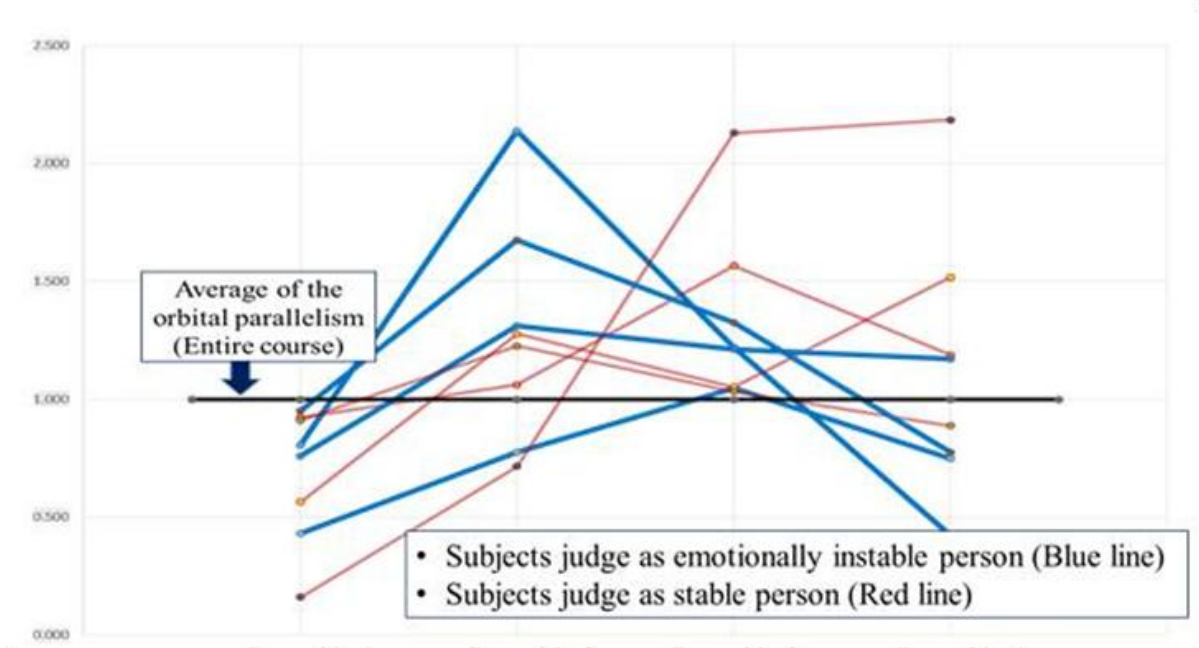| item / Driver	Emotional instability	Impulsivity	Egocentricity	Nervousness·Hypersensitivity	Ostentation	Unsafe attitude
A	5	2	1	3	4	0
B	2	4	0	5	4	3
C	5	1	1	5	3	2
D	3	2	4	1	4	1
E	5	4	4	4	4	4
F	2	2	1	2	3	0
G	2	2	3	5	3	1
H	5	5	3	2	4	0

Fig.8: Orbit parallelism of each curve section divided by Orbit parallelism of the entire course between Emotionally instable and stable

curves since the curve No.3 appears just after the curve No.2. Also the curve No.2 has a small radius of curvature with 88m and with poor visibility if the test subjects drive on the left traffic lane with the left curve. As a result, a driver burden and an orbit parallelism increased.

6.2 Comparison of the properties by the subject the entire course and the curve

The results obtained by the OD-type safety tests performed after the driving experiment are shown in Table 2, which classify the subjects by each characteristics. In the OD-type tests, five questions are given for each one of six items to all the subjects. If any subject answers "yes" four times or more for any one of items, the item is judged positive for the subject.
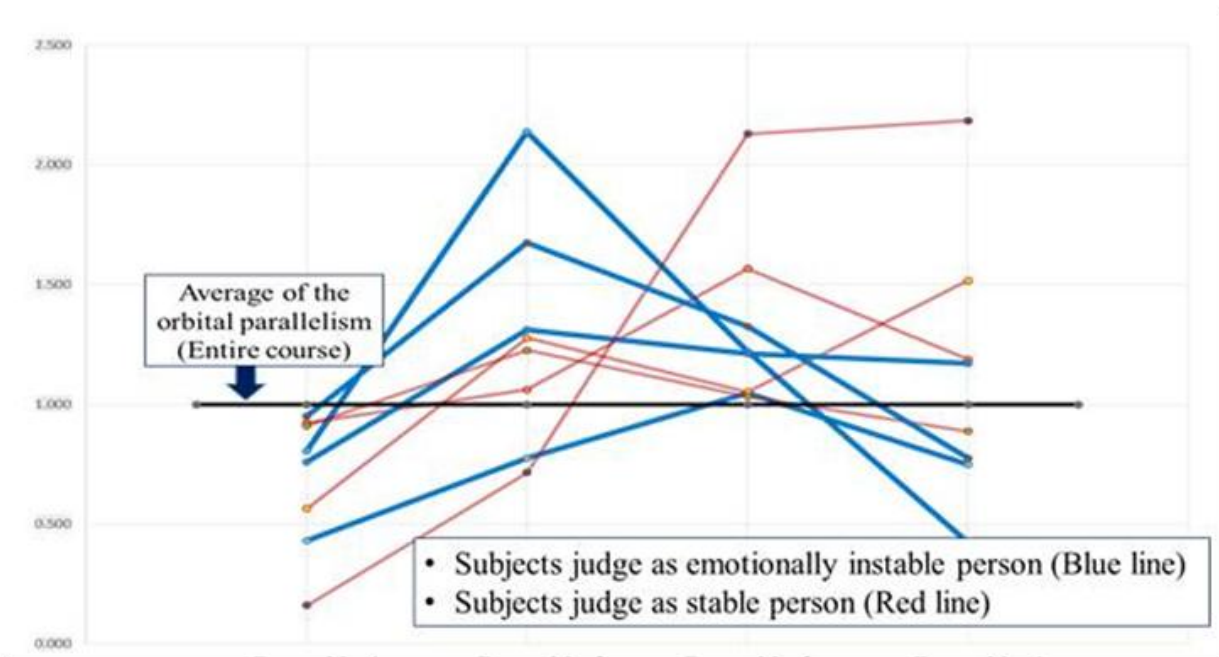
Fig.9: Orbit parallelism of each curve section divided by Orbit parallelism of the entire course between Nervous/hypersensitive and unnervous/unhypersenstive

Then if the item is positive for more than four subjects, we chose the item and constituted the subject groups. Finally, we chose "Emotionally instable" subject group and "Nervous/ hypersensitive" subject group.

- Emotionally instable subject group

Subjects who are judged emotionally instable are A, C, E and H. In the case of this subject group, the value of orbit parallelism for the curve No.2 is higher than the value for the other curves, since the existence of the soundproof wall on the left side raised the burden of the drivers.

- Nervous/ hypersensitive subject group

Subjects who are judged nervous/ hypersensitive are B, C, E, G. In the case of this subject group, the value of orbit parallelism for the curve No.3 and No.4 is higher than the value for the other curves, since the appearance of the curve No.3 just after the curve No.2 raised the burden of the drivers.

7. Conclusions

The main cause of traffic accidents is the decision delays, operational errors, and human errors of drivers. Fatigue and stress gives drivers the psychological burden. By using embedding theorem and orbit parallelism gauging method, the authors tried to clarify the relationship of the traffic environment and driver behavior. As far as highway roads with relatively simple environment are concerned, the relationships between the results of OD-type safety tests and the value of orbit

parallelism obtained from volumetric pulse waves were confirmed qualitatively.

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