Estimation of psychosomatic condition and evaluation regarding fatigue of vehicle driver

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Abstract
The frequency of drowsy driving situation and aimless driving situation are high in reason for traffic accidents currently. For that reason, it is necessary to clarify the mutation of psychosomatic condition and physical fatigue of vehicle driver. Authors thought that mental and physical condition or driving posture of vehicle driver is related to the mutation of psychosomatic condition and physical fatigue of vehicle driver. Therefore authors investigated the mutation of psychosomatic condition and physical fatigue of vehicle driver based on measuring a biomedical signal or questionnaire in many driving postures. The psychosomatic condition means the status, such as sleeping, awaking or being relaxed. In order to investigate the mutation of psychosomatic condition, we used the biomedical signal. In addition to this, authors investigated the accumulation level of fatigue and fatigued part of human body. As a result, it was clarified that accumulation level of fatigue or the psychosomatic condition was different at every driving posture. The fatigued part which feels the ache was clarified by questionnaire and fluctuation of pulse waves. Accordingly, it was suggested that mental and physical condition or driving posture of vehicle driver is related to the mutation of psychosomatic condition and physical fatigue.

Keywords: estimation of psychosomatic condition, physical fatigue, automatic nerves, biomedical signal

1. Introduction
The research regarding the evaluation of automatic nerves and physical fatigue by using biomedical signal were reported in preceding studies\(^2\). By those researches, the appraisal method of physical fatigue and the estimation method of psychosomatic condition based on measuring the biomedical signal were reported.

However, there are few reports regarding the evaluation of physical fatigue and the mutation of psychosomatic condition in many driving postures. Therefore, authors conducted the evaluation of fatigue and the estimation of psychosomatic condition of vehicle driver in many driving postures by measuring the biomedical signal. Based on this result, it was clarified that the mental and physical condition or driving posture of vehicle driver is related to the mutation of psychosomatic condition and physical fatigue.

2. Experimental method
2.1 Outline of experiment
We conducted the experiment by setting up three driving postures meaning that the angle of seat back is different, in order to investigate the mutation of psychosomatic condition and physical fatigue of vehicle driver. In this investigation, we measured the biomedical signal and asked the participants to answer the questionnaire. The sequence of experiment is shown in Fig 1. Experimental participants were required to keep the awaking condition at “Rest”. However, in order to investigate the mutation of psychosomatic condition, participants were not required to keep the awaking or sleeping in measuring. The measuring was conducted 30 minutes. Experimental participants answered to the questionnaire at every 5 minutes. The fluctuation of back pressure, brain waves, pulse waves and an electrocardiogram of experimental participants were measured. The measuring was conducted at every driving posture. A total of three measuring was conducted at every experimental participant.

2.2 Evaluation indexes
In this chapter, we explain the evaluation indexes for the estimation of psychosomatic condition and evaluation of fatigue. Evaluation indexes are quantified based on the measuring result of the biomedical signal. The biomedical signal includes the fluctuation of back pressure, brain waves, pulse waves and an electrocardiogram.

2.2.1 Fluctuation of R-R Interval, HF and LF/HF
We investigated the fluctuation of R-R Interval (RRI), HF and LF/HF in order to estimate the activation level of sympathetic or parasympathetic nerve. The RRI was quantified by analyzing an electrocardiogram. HF and
LF/HF were quantified by analyzing RRI. The method of evaluation regarding automatic nerve is shown in Table 1.

Table 1 the method of evaluation regarding automatic nerve.

<table>
<thead>
<tr>
<th>RRI</th>
<th>sympathetic</th>
<th>parasympathetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF</td>
<td>decrease</td>
<td>increase</td>
</tr>
<tr>
<td>LF/HF</td>
<td>prominent compared with LF/HF</td>
<td></td>
</tr>
</tbody>
</table>

2.2.2 Frequency distribution of brain waves
We investigated the frequency distribution of brain waves, in order to estimate the awaking or sleeping condition. Authors evaluate the awaking condition when $\alpha$ waves surpass 50% of distribution rates and $\theta$ wave increase. Authors evaluate the sleeping condition when $\alpha$ waves fall below 50% of distribution rates and $\theta$ wave decrease. The method of estimation regarding awaking and sleeping is shown in Table 2.

Table 2 The method of estimation regarding awaking and sleeping.

<table>
<thead>
<tr>
<th></th>
<th>awaking</th>
<th>sleeping</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$ wave</td>
<td>surpass 50%</td>
<td>fall below 50%</td>
</tr>
<tr>
<td>$\theta$ wave</td>
<td>increase</td>
<td>decrease</td>
</tr>
</tbody>
</table>

2.2.3 Gradient wave of Power value and Lyapunov exponent.
In order to estimate the drowsiness and sleeping condition, authors quantified the gradient wave of “power value” and “lyapunov exponent”. Authors used the analyzing method of preceding study, in order to quantified “power value” and “lyapunov value”. The method of estimation regarding drowsiness and sleeping condition is shown in Table 3.

Table 3 The method of estimation regarding the drowsiness and sleeping.

<table>
<thead>
<tr>
<th>Gradient waves</th>
<th>drowsiness</th>
<th>sleeping</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>amplitude is large and antiphase</td>
<td>amplitude is little and coordinate phase</td>
</tr>
</tbody>
</table>

2.2.4 Fatigue curve
It was reported by preceding study that the fatigue curve expresses physical fatigue$^{[2]}$. The fatigue curve was quantified by integrating the gradient of “power value”. Authors thought that the fluctuation regarding gradient of fatigue curve expresses fluctuation of physical fatigue. The fatigue curve is shown in Fig 2.

2.2.5 Fluctuation of frequency
The estimation of psychosomatic condition by using the fluctuation of back pressure is reported by preceding study$^{[3]}$. We quantified the fluctuation of frequency and gradient regarding fluctuation of frequency of back pulse by analyzing the fluctuation of back pressure. The method of estimation regarding the awaking and sleeping is shown in Table 4.

Table 4 The method of estimation regarding the awaking and sleeping.

<table>
<thead>
<tr>
<th></th>
<th>awaking</th>
<th>sleeping</th>
</tr>
</thead>
<tbody>
<tr>
<td>fluctuation of frequency</td>
<td>increase</td>
<td>decrease</td>
</tr>
<tr>
<td>fluctuation of gradient</td>
<td>fluctuation is large</td>
<td>fluctuation is low</td>
</tr>
</tbody>
</table>

2.3 Questionnaire
In order to investigate the fatigued parts which feel the ache, the questionnaire was conducted at every 5 minutes in measuring. This questionnaire includes the drowsiness and the ache of the head, neck, shoulder, waist and hip. Experimental participants answered to the questionnaire based on the score. This score of questionnaire means the level of ache.

2.4 Driving posture and vehicle seat
In order to investigate the mutation of psychosomatic condition and physical fatigue of vehicle driver in many driving postures. We set up three driving postures. This means that the angle of seat back is different. The specifications of driving posture are shown in Table 5.

Table 5 The specifications of driving posture.

<table>
<thead>
<tr>
<th></th>
<th>the angle of back seat</th>
</tr>
</thead>
<tbody>
<tr>
<td>U posture</td>
<td>12.5</td>
</tr>
<tr>
<td>N posture</td>
<td>22.5</td>
</tr>
<tr>
<td>R posture</td>
<td>32.5</td>
</tr>
</tbody>
</table>

The experimental vehicle seat and driving posture is shown in Fig 3.
2.5 Experimental participants

In this investigation, experimental participants were seven male students (A~G) who got informed consent in advance.

3. Experimental result

3.1 Estimation of psychosomatic condition

We estimate the psychosomatic condition regarding N posture of experimental participant #A by using the evaluation indexes which was explained in chapter 2. First, we estimate the automatic nerves by using the evaluation indexes of RRI and LF/HF. The RRI and LF/HF of N posture regarding experimental participant A is shown in Fig 4.

Fig 4. RRI and LF/HF of N posture regarding experimental participant #A

The sympathetic nerve is prominent in (a). The parasympathetic nerve is prominent in (b). The sympathetic nerve is prominent in (c). As a result, the mutation of automatic nerves was clarified by using the RRI and LF/HF. Second, we conduct the estimation of physical mutation by using the evaluation indexes of brain waves, pulse waves and fluctuation of back pressure. The brain waves, pulse waves and the fluctuation of back pressure of N posture regarding experimental participant #A is shown in Fig 5.

Fig 5. Brain waves, pulse waves and fluctuation of back pressure of N posture regarding experimental participant #A

The drowsiness is appearing (d), (e) and (f). At the same time, it was estimated that experimental participants is sleeping at the (g). Subsequently, it was confirmed that experimental participant is awaking at the (h) and (i). As a result, the drowsiness, awaking and sleeping were confirmed by using the brain waves, pulse waves and fluctuation of back pressure.

3.2 Psychosomatic condition each of driving posture

The tendency regarding the mutation of psychosomatic condition was different at every driving posture by estimating the psychosomatic condition. The mutation of psychosomatic condition regarding #A posture and #R posture were few. The mutation of psychosomatic condition regarding #N posture was frequent compared with other postures.
3.3 Evaluation of fatigue

3.3.1 The fatigued part of human body

We thought that gradient of fatigue curve means the fluctuation of physical fatigue. For that reason, we investigated the fatigued part of human body by using the item of questionnaire when fluctuation regarding gradient of fatigue curve is large. The fatigued part of each experimental participant and driving posture is shown in Table 5.

Table 5: The fatigued part of each experimental participant and driving posture. “n” means the nothing of fatigue.

<table>
<thead>
<tr>
<th></th>
<th>U posture</th>
<th>N posture</th>
<th>R posture</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>neck</td>
<td>hip</td>
<td>hip</td>
</tr>
<tr>
<td>B</td>
<td>back</td>
<td>head</td>
<td>neck</td>
</tr>
<tr>
<td>C</td>
<td>shoulder</td>
<td>shoulder</td>
<td>neck</td>
</tr>
<tr>
<td>D</td>
<td>neck</td>
<td>shoulder</td>
<td>waist</td>
</tr>
<tr>
<td>E</td>
<td>n</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>F</td>
<td>neck</td>
<td>neck</td>
<td>waist</td>
</tr>
<tr>
<td>G</td>
<td>neck</td>
<td>hip</td>
<td>hip</td>
</tr>
</tbody>
</table>

Based on this result, the neck, shoulder and hip were suggested as the fatigued part of human body.

3.2 Accumulation level of fatigue

We investigated the accumulation level of fatigue by using the final value of fatigue curve. The accumulation level of fatigue at every experimental participant is shown in Fig 6.

Fig 6. The accumulation level of fatigue

Based on this result, it was clarified that the accumulation level of fatigue regarding #N posture is high in the six participants and the accumulation level of fatigue regarding #R posture is low in the four participants.

4. Discussion

The psychosomatic condition was different at every driving posture. For that reason, authors think that driving posture is related to the mutation of psychosomatic condition. The fatigued portion and accumulation of fatigue were different at every driving posture. Based on this result, authors think that driving posture is related to the physical fatigue. We think that a reason for accumulation level of fatigue regarding #R posture is related with these two factors. First, the mutation of psychosomatic condition is few. Second, #R posture is normally used when we rest on the driving seat or chair. Additionally, the mutation of psychosomatic condition is frequent and the accumulation level of fatigue is high in #N posture. Therefore, it was indicated that a reason for accumulation level of fatigue regarding #N posture is related to the mutation of psychosomatic condition.

5. Conclusion

In this research, the mutation of psychosomatic condition and physical fatigue were investigated in many driving postures by using biomedical signal and questionnaire.

5.1 Estimation of psychosomatic condition

Authors conducted the estimation of psychosomatic condition by using the pulse waves, brain waves, an electrocardiogram, the fluctuation of back pressure. As a result, the tendency regarding the mutation of psychosomatic condition was different at every driving posture.

5.2 Fatigued part of human body

Authors investigated the fatigued part of human body by using the questionnaire and fatigue curve. Accordingly, authors clarified that the fatigued parts are “neck”, “shoulder” and “hip”.

5.3 Accumulation level of fatigue

Authors investigated the accumulation of fatigue by using the final value of fatigue curve. Based on this result, the accumulation of fatigue was different at every driving posture. Additionally, it was suggested that the difference of accumulation of fatigue is related to the mutation of psychosomatic condition.

Based on these result, it was clarified that the mental and physical condition or driving posture are related to the mutation of psychosomatic condition and physical fatigue. In the future, we will increase the experimental participants. In addition to this, we will conduct the evaluation of fatigue and estimation of psychosomatic condition during driving situation.

6. Reference

[1] Etsunori FUJITA, Yumi OGURA, and coworkers, Development of the measurement method of the prediction of sleep by finger plethysmogram data, Japan Ergonomics Society, Vol41, No4, 2005
