The Development of a Diagnostic Model

To Evaluate Road-Driver Compatibility

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1. Introduction

Many studies have been published during the last decade to observe driver’s behavior and physiological responses during actual driving, in order to prevent drivers from automobile accidents presumably caused by human errors. Therefore, this study was designed to develop a model utilizing driver’s psycho-physiological signals to eventually find a probable relationship between automobile accident and physiological change during driving. Previously, a deterministic approach was used to distinguish some extreme values from normal range of physiological signals. However, such approach did not provide enough information of driver’s behavior to detect human errors due to a large variance of the data. Even a probabilistic approach did not offer a complete cue to judge the driving safety because there was not much information to interpret the extremely high or low signals that were not seemingly dependent of road conditions. Likewise, a new paradigm of interpreting physiological signals was in very much need. Therefore, in this study, a conceptual model was developed to accommodate the physiological data for diagnosing the mental compatibility between driver and road condition. Furthermore, some physiological signals were used to examine the validity of the model.

Among physiological signals, Electro-encephalogram (EEG) has been used as an index of alertness, sleepiness and workload of drivers (Kecklund & Akersted, 1993; Gundel et al., 1995; Brookhuis & Waard, 1993). Also, Electro-oculogram (EOG) has been used to evaluate driver’s eye-movement. Moreover, Richter et al.(1998) reported that the eye-blink rate decreased during car driving in a complicated road section. It is also known that the heart rate and heart rate variability are sensitive to the change of driver’s mental workload, road condition, and driving duration time (Gobel et al., 1998; Richter et al., 1998; Milosevic, 1997; De Waard et al., 1995). Based upon those previous results of driver’s physiological response, some physiological parameters were used to test the model developed in this study.

2. Demand-Effort Model

The Demand-Effort model was proposed to explain the relationship between driver’s behavior and driving condition. This model was based on an assumption that driver’s mental effort should match with a mental demand required by road environment for a safe driving. This model classified the driver’s mental effort into three categories such as “high effort”, "moderate effort", and "low effort". At the same time, the driving condition was also classified into three categories such as “high demand”, “moderate demand”, and “low demand”. It was diagrammed in Figure 1.
3. Fundamental Data

A large number of subjects were recruited to build up a baseline data for model development.

3.1 Subjects

Eighty paid subjects were recruited for the driving experiment on “Yondong” and “Seohean” highway in Korea. The anthropometric data of subjects were listed in Table 1.

Table 1). Anthropometry

<table>
<thead>
<tr>
<th>Classification</th>
<th>Age (year)</th>
<th>Stature (cm)</th>
<th>Weight (kg)</th>
<th>License (year)</th>
<th>Drive experience (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>25.35</td>
<td>174.85</td>
<td>68.79</td>
<td>4.58</td>
<td>3.38</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.17</td>
<td>4.74</td>
<td>8.10</td>
<td>2.47</td>
<td>1.95</td>
</tr>
</tbody>
</table>

3.2 Data collection

In this study, an experiment was designed and data were collected for two years to build up a baseline data of driver’s physiological responses. For a standardization of data, only a sunny or partly cloudy day were used for data collection. Rainy, foggy, or snowing day were excluded. The speed of experimental vehicle was kept at the 90 to 100 km/h. Subjects were not allowed to talk, listen to music, or smoke. An experiment was not repeated twice a day for a single subject. Drivers’ physiological data were collected at the both “Yondong” and “Seohean” Highway.

For data collecting, EEG sensors were placed on F3-F7, F4-F8 of frontal lobe, C3-Cz of central lobe, P3-Pz of parietal lobe, O1-O2 of occipital lobe and T3-T5, T4-T6 of temporal lobe respectively based on the 10-20 method of International Federation of Societies for Electroencephalography and Clinical Neurophysiology (Cooper, 1980). Electrocardiogram (ECG) sensors were placed on both wrists, while galvanic skin response (GSR) sensors were placed on the left index finger and the third finger. Skin temperature (SKT) sensor was attached on the left ankle. Electro-oculogram (EOG) sensors were located on the left and right crown of the head to measure the horizontal eye movement and above and below of the right eye ball to measure the eye blinking. Then, the subject was asked to drive the vehicle on “Yongdong” Highway for one hour or “Seohean” Highway for forty minutes after thirty minutes test driving.

3.3 Selection of physiological variables

The three steps of selecting final physiological variables are as follows: The first step was to find sensitive physiological signals based upon the results of previous researches. The second step was to find signals with a consistent pattern when it was observed in every 30 second. The third step was to find signals
with a consistent and meaningful pattern when it was observed every 10 second. Data were considered meaningful when they were interpreted with a consistent manner based upon the Demand-Effort model paradigm.

4. Selected Physiological Variables

Parameters for central-nervous system were theta spectrum value of central, parietal and occipital lobe and beta/alpha of left/right frontal and occipital lobe. Another parameters from autonomic-nervous system were selected: root mean square (RMS) value of electro-oculogram (EOG), galvanic skin response (GSR) and skin temperature (SKT). The amplitude and slope were used to quantify the magnitude of signal and pattern change over certain time period (Table 2.).

<table>
<thead>
<tr>
<th>Signals</th>
<th>Signal variables</th>
<th>Numerical parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEG</td>
<td>Left Frontal</td>
<td>$\beta/\alpha$</td>
</tr>
<tr>
<td></td>
<td>Right Frontal</td>
<td>$\beta/\alpha$</td>
</tr>
<tr>
<td></td>
<td>Central</td>
<td>$\theta$</td>
</tr>
<tr>
<td></td>
<td>Parietal</td>
<td>$\theta$</td>
</tr>
<tr>
<td>EOG</td>
<td>Horizontal</td>
<td>RMS</td>
</tr>
<tr>
<td></td>
<td>Vertical</td>
<td>RMS</td>
</tr>
<tr>
<td>GSR</td>
<td></td>
<td>RMS</td>
</tr>
<tr>
<td>SKT</td>
<td></td>
<td>RMS</td>
</tr>
</tbody>
</table>

Table 2). Bio-signal variables and parameters for analysis

In conclusion, the Demand-Effort model made the diagnostic approach possible to evaluate the road-driver compatibility, although the continuing validation process of the model should be performed in various road conditions to increase its sensitivity. Further research should address the issue of standardization of parameter selection process by using a more objective method, and also the method to improve the sensitivity among currently chosen parameters should be further discussed as well as considering other sensitive parameters.

Reference

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