SEAT BELT VIBRATION AS A STIMULATING DEVICE FOR AWAKENING DRIVERS

ABSTRACT

This paper presents a safety driving system that uses a seat belt vibration as a stimulating device for awakening drivers. The vibration stimulus was composed of pulsation tension, which was applied by the seat belt motor retractor. Magnitude, duration and repetition rate of the additional tension were the major parameters that determined the awakening effect of the stimulator. We constructed a driving stimulator, which was able to induce driver’s drowsiness. In the experiment using the driving stimulator the driver’s drowsiness was detected by changes in the driver’s body movements measured by electrooculography (EOG) and/or changes in facial expression of the driver monitored by the ex-parameters through a video camera, subjective evaluation, and lane deviation.
INTRODUCTION

Driving while drowsy is one of the main causes of car accidents. In order to prevent drivers from drowsy driving strong demand has arisen for safety driving systems. In the present research, a safety driving system that detects the driver’s drowsiness before it leads to dangerous driving has been developed. This system consists of three components: sensing, evaluation and stimulation.

The sensing component monitors the driver's physiological data and surroundings, and the evaluation component determines whether or not the driver is drowsy. When the driver becomes drowsy, the stimulation component is activated to awaken the driver. This system was combined with a driving simulator to evaluate the drowsiness detection algorithm and effectiveness of the stimuli in keeping the driver awake.
Methods for detecting driver's drowsiness can be classified into two categories: 1) analysis of driver's body motion such as head motion and driving ability and 2) analysis of physiological data such as saccadic eye movements and heart rate. When a driver becomes drowsy, the driver's head begins to sway or tilt, and the car may drift off course. These physical symptoms, however, become apparent only after the driver starts to doze off. Meanwhile, physiological signals start to change in earlier stages of drowsiness. Therefore, physiological data are more suitable for drowsiness detection for prevention of dangerous driving. It is known that the power in low frequency of eye movements increase when people become drowsy.

We have defined all alertness level indication $KE$ by the following equation. The value of $KE$ nears 1 when the driver becomes drowsy.

$$KE = \frac{\text{Power (0~0.3 Hz)}}{\text{Power (0~0.3 Hz) + Power (3~10 Hz)}}$$

We have chosen electrooculography (EOG) for measuring eye movements. The permanent electric potential difference between the cornea and the retina generates electrical field related to the orientation of the eyes in the surrounding tissues of the eyes. Horizontal eye movement was measured by placing a disposable silver chloride electrode on the outer corner of each eye, and the third electrode at the center of the forehead for reference. Electric potential difference between the two electrodes at the comers was
amplified by an instrumentation differential amplifier. The analog output was digitized at a sampling frequency of 100Hz.

DRIVING SIMULATOR

A driving simulator was constructed from a complete set of a driving cockpit taken from a real car, including the dashboard, steering wheel, seat, seat belt, and pedals, as shown. A screen was placed in front of the driver's seat to display a computer-generated motion picture of monotonous freeway driving, which induces drowsiness in the driver. The simulator was covered with a curtain in order to insulate the driver from surrounding information. A projector was set outside the curtain, in order to prevent temperature rise in the simulator. The seat was adjustable to the driver's body with reclining and sliding the seat as it is in the real vehicle. When the driver needed to stop the seat belt vibration, he/she could stop it by pushing the button, which was set beside the seat.
CONSTRUCTION OF A SEAT BELT MOTOR RETRACTOR

We applied the seat belt motor retractor, which is currently being used for pretensioner in stock cars, to the driving stimulator. To develop the stimulator with a component of a real car is feasible for reducing driver's discomfort in a practical use. Therefore, the seat belt motor retractor provided the stimulus to the driver's upper torso restraint portion. The fig shows the construction of the seat belt motor retractor.

The fig shows the construction of the motor. The vibration stimulus was composed of pulsating tension in the seat belt. The control computer varied tension, period of tension, interval, and number of pulses to change the vibration patterns. The tension was adjusted by percentile of the maximum tension.
APPROPRIATE PATTERNS OF SEAT BELT VIBRATION TO REDUCE DROWSINESS

Although seat belt is a basic safety system, some drivers do not wear seat belts because of pain and discomfort. If the new stimulation of seat belt vibration causes excessive discomfort to the point where drivers refuse to wear the seat belt the effect will be contrary to that intended. Therefore, we examined the appropriate pattern of seat belt vibration while considering the effect of drowsiness prevention and discomfort. The patterns of seat belt vibration can be varied by regulating four parameters of the seat belt motor retractor: magnitude of tension, period of a pulse, interval between pulses, and number of pulses. We defined three target requirements: 1) raise no obstacles to driving; 2) reduce unnecessary discomfort; and 3) awaken drivers comfortably within a short period of time. In this paper, we focused on examining the basic vibration pattern of it.

EFFECTIVE DURATION FOR KEEPING DRIVERS AWAKE WITH SEAT BELT VIBRATION

The design process in Section V identified vibration patterns that may be strong enough to alert the driver without causing discomfort. Our next step was to evaluate how long this stimulus would keep the drivers awake. The target duration was 15 min, which is the average time to reach the next rest stop on. Effective duration of seat belt vibration was compared with the results of 13 other stimuli, which stimulated the five senses of humans. For comparison, the same subjects were given the other 13 stimuli. The two subjects were in their 20s: a male and a female. The subjects were asked to make an oral report on their, subjective drowsiness level every
minute while driving in the simulator. An audio notice to report the drowsiness level was given every minute. Drowsiness level was classified into five ratings as given in Table VI. This rating referred to the subjective evaluation method, which evaluates the drowsiness level from a driver's facial appearance.

The vibration stimulus was activated when the subject's drowsiness level became 3, and the experiment was terminated when the drowsiness level reached 5. If the subject's drowsiness level stayed at 3 or higher, the vibration stimulus was activated every minute. Effective duration was defined as the lapsed time from drowsiness levels 3-5. Fig shows the average effective durations of the seat belt vibration and the other 13 stimuli. The duration of the awakening effect with seat belt vibration was 8.5 min. Singing subject’s favorite songs to music (karaoke) kept the subjects awake for 41 min, and chewing caffeine gum kept them awake for 33 min. Although the duration of the seat belt vibration was shorter than that of karaoke, chewing caffeine gum, and some other stimuli, subjects remarked that the instant awakening effect was the same as that obtained by chewing and it cleared the head.

Those stimuli, which cause muscle movements and vibration, have influences for EOG and KE. If the data from EOG are inaccurate, it is hard to evaluate driver's drowsiness level with KE. Therefore, the correlation between KE and the lane deviation while those stimuli were activated were compared.

We analyzed lane deviation to evaluate the awakening effect of seat belt vibration assuming that the increase in lane deviation is related to driver's drowsiness.
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CONCLUSION

A subjective evaluation test and lane deviation analysis has demonstrated the effectiveness of seat belt vibration for preventing driver’s drowsiness. Exerting additional tension of 130 N for 3 cycles at duration and interval of 100 ms was the most effective pattern for awakening the driver without causing discomfort. The awakening effect lasted 8.5 min on average. This new safety feature will provide an added value to the safety systems for cars and encourage drivers to wear seat belt.

In this paper, we strived to develop the driving simulator with the seat belt motor retractor, which was used in a commercial vehicle to provide the vibration stimulus to the drivers. We could also investigate the availability of this simulator to examine effect of new vibration stimulus with a small number of subjects.
REFERENCES


