Study of Adaptive Assisting Effect of Auditory-visual Alert for Elderly Drivers using Physiological Signals

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Abstract

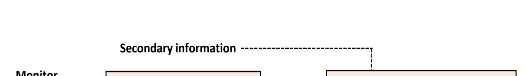
A major cause of traffic accidents has been found in the human factors involved in driver's awareness during driving, and the effect of alarm was reported as the increase of awareness and the improving effect for property of perception, cognition and judgment of the driver. The arousal stimulus for driver by auditory-visual alert also affects to the physiological condition and the autonomic nervous system (ANS). Recent developments in multi near-infrared spectroscopy (MNIRS) have enabled the arousal level apparent with brain activity by measurement of hemoglobin concentrations as cerebral blood volume, as well as the ordinary biological signals like heart beats, finger plethysmogram and pulsation waves.

In this study, the three kinds of auditory alert as pre-information, sound alert and voice guidance were used for adaptive assisting systems for the elderly driver and the influence of these alerts on the driver's psychosomatic state was examined using driving simulator for 30 minutes driving. Experiment was conducted with the subjects in a driving position as they were partially awakened by auditory-visual alert, repeatedly and measured their biological properties. As the results, after taking the effects of the adaptive assisting alert systems, the effect of arousal and awareness improvement was recognized in the subjects and the activation of cerebral blood volume was observed according to the amount of the stimulus and combination of awareness modal as auditory alert system.

Keyword : Driving Safety, Driving Assistance System(DAS), Multi Near-Infrared Spectroscopy (MNIRS), Finger Plethysmogram, Air-Pack Sensor

1. Introduction

Driving performance has been involved in the so many factors such as driving situation like a slippery road surface condition under curve driving, the gender, experiences and age under the conditions of driver's inner state. If the three axes are supposed as driving situation, driving time and driver's performance as shown in Figure 1, the lack or miss of any axis caused to lead to a fatal traffic accident. The driver who decides driving performance has also large differences in driving skills as the influence of aging or career, etc. Especially the number of accidents was increasing at the traffic intersections and spread in the elderly drivers. So, in recent years, to support the driver, DAS (Driver Assistance System) has been actively developed. However, the past researchers had only noted the improvement of driving behavior while using such DAS systems [1].



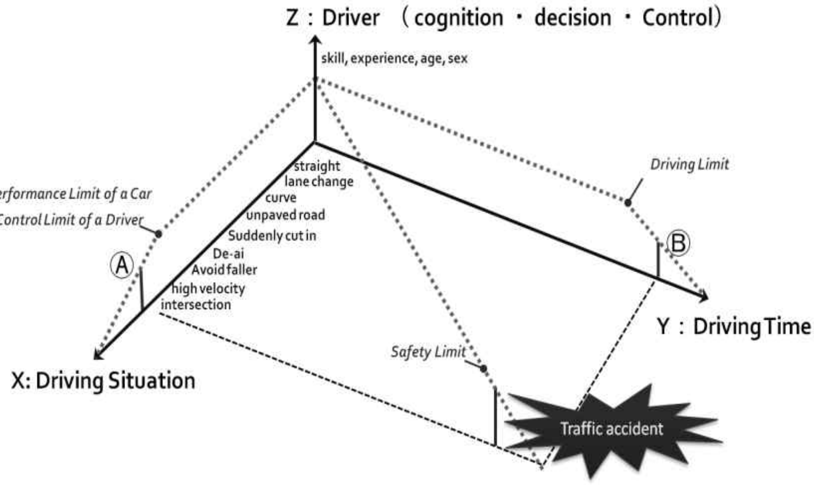


Figure.1 The multidimensional cause of driving accidents

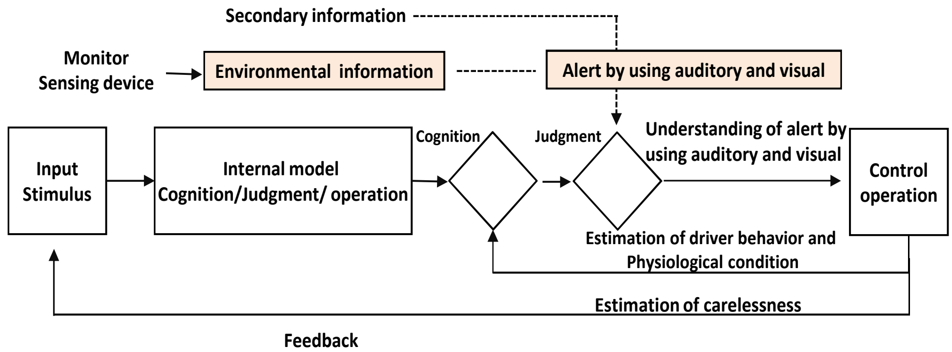


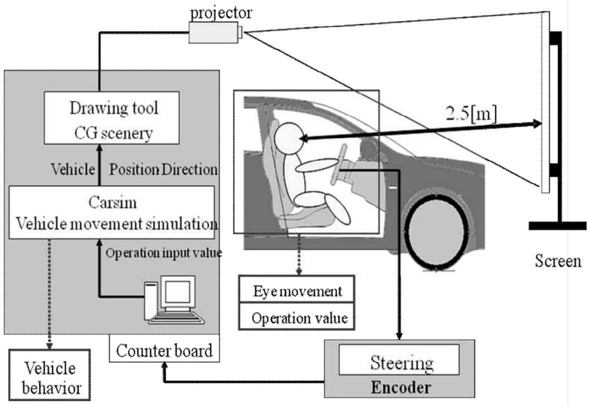
Figure. 2 Driving performance model and the role of alert system

The auditory, visual information which is not selected by the driver has been apprehended to cause the maintenance of excessive arousal, irritability and stress. Therefore researchers in this field must make effort to understand their inner condition through psycho-physiological reactions and the physiological measuring methods are also induced.

Including the galvanic skin response (GSR), electro-cardiogram(ECG), electroencephalogram (EEG), skin temperature, the inner state of driver was analyzed and estimated as an index of response from the autonomic nervous systems.

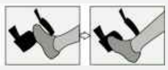
BC Min et al. (2002) conducted experiments to measure the sensibility of young passengers through autonomic responses and subjective assessment under different speeds and driving modes of a vehicle. The result of physiological signals also showed that as the speed of a car increased, the sympathetic nervous system of passengers became more highly activated. Comparing the rest and constant speed conditions with the sudden-start sudden- stop condition, the subjects reported that they felt tension, and the responses of their autonomic nervous system also show that for the sudden-start-sudden-stop condition, the sympathetic nervous system was highly activated [2].

In this study, the driving model (Figure 2) was constructed by driving process of the cognition, judgment and control. Besides, supposing assisting systems could support peripheral environment and secondary information by visual-audio alert system, which may decrease traffic accidents. We examined the effect of warning on the driver's psychosomatic state by using a driving simulator and biological indicators such as a multi near infrared spectroscopy system (MNIRS), Electro-cardiogram (ECG),photo-plethysmogram(PPG), a air-pack sensor as a non-invasive sensor system[3].



Fig,3 Driving Simulator Configuration

Table. 1 The six kinds of alert conditions and the sequence

	Condition	Step 1	Step 2	Step 3	Step 4
1	None	-	-	-	-
2	Info			-	-
3	Display	"Pong. "	"There is a stop intersection ."		
4	Low-frequency beep sound			"beep- beep--- (1.0 kHz, 0.38s purse sound)"	
5	High-frequency beep sound			"beep- beep---" (3.7k Hz, 0.2s purse sound)	
6	Voice			"Brake smoothly."	"Stop completely."

2. Experimental Method

Subjects

9 elderly drivers (65 to 75-years-old) were enrolled. They are healthy people as possible to have a professional pre-recruited, we demonstrated a test as a listening survey of personal information, a visual acuity, a color vision test and a Mini Mental State Examination (MMSE). Among them, physically and mentally healthy older group of 9 people (males) was chosen to agree with the experiment, but selected the data of 6 subjects. First, they were given a brief description of the experiment and instructed not to move or fell asleep, but rather to concentrate on the stimulus. After the electrodes were attached to their bodies, the subjects were seated comfortably in the seat of the driving simulator. Before and after the experiment, the subjects were asked to answer a questionnaire on their feelings. The pre- and post-test of subjective assessments were analyzed and compared later.

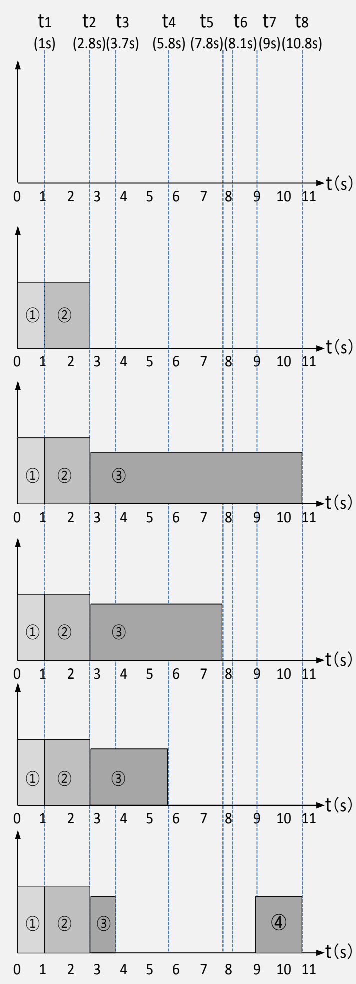
Configuration of stimuli and procedure

In this study, the experiment was executed using driving simulator (DS-2000, made by Mitsubishi Precision co. Ltd. as shown in Figure 3). Before beginning the test, the participants must conduct the practice driving for about 3 minutes in order to adapt to the driving simulator. The order of the trial was counter-balancing approximately 30 minutes. The tasking course was a two-lane straight. Subjects performed operation on a steering wheel, an accelerator, and brake with his/her usual driving posture. And they had conducted straight on, and in order to stop, brake operation focusing on a point with a stop. The speed of 60 km/h must have been maintained.

As shown Table 1, the six kinds of alert including

Table. 2 Contents and Timing chart of the alert conditions

Condition	Contents	Timing chart
1. None		
2. Info.	① Pong (sound) ② There is a stop intersection (voice).	
3. Display	① Pong (sound) ② There is a stop intersection(voice). ③ Showing a image operating a brake pedal	
4. Low-freq. beep sound	① Pong (sound) ② There is a stop intersection voice). ③ Beep–beep-beep with low frequency	
5. High-freq. beep sound	① Pong (sound) ② There is a stop intersection (voice). ③ Beep–beep-beep with high frequency	
6. Voice	① Pong (sound) ② There is a stop intersection (voice). ③ Brake moothly (voice). ④ Stop completely (voice).	



non condition were designed for driving assistant alert system by visual or auditory function. They were none condition, an info condition, a low frequency beep sound condition, a display condition, a high-frequency beep sound condition, and a voice condition. In method of supplying an alarm, for example, a voice condition was available assistants of 4 steps. The Table 2 shows the kinds of alert condition in the first column, alert methods in the second column and alert timing in the third column. At the first, the subjects are provided information that is an intersection in front using a visual stop-sign and audible voice and induced braking to stop and then commanded to operate a brake pedal, and finally, instructed to completely stop entering the intersection. In addition, all alert conditions had supported twice an experiment.

Measurement & equipment

Multi-channel near-infrared spectroscopy (MNIRS) had been measured using made by Spectratech OEG16 at two wavelengths of near-infrared light (770 and 840 nm). The probes of the NIRS machines were placed on a subject's frontal regions. The probes on the subject's frontal region measured the relative concentrations of Hb changes at 16 measuring points/channels (6 light-emitting points, 6 light-receiving points). Blood flow is measured in order to estimate the reaction of alert on the driver psychosomatic state.

Electrocardiogram (ECG) had been measured using Power Lab made by AD Instruments. The time-series data of heart beat interval (RRI) was used as one the indices. In addition, LF/HF was calculated using transform. When the value of LF/HF ratio is bigger, subjects get more stress. Since RRI is influence by autonomic nerves, it is used as an index of evaluation. LF (low-frequency component) is influenced by the sympathetic nerve and the parasympathetic nerve. HF (high-frequency component) is influenced by the parasympathetic nerve. Also, in this paper, HF had used as an index of the parasympathetic nerve and LF/HF had used as an index of the sympathetic nerve. That was moving average for 180 seconds sliding every period of 18 seconds. In addition, LF/HF was calculated using wavelet transform. When the value of LF/HF ratio is bigger, subjects get more stress.

Finger plethysmograph had been measured using measurement equipment made by CCI, Inc. It was measured at forefinger. The method of calculation of the power gradient time series waveform and the largest Lyapnov exponent gradient time series waveform which Fujita and others proposed was used for these analyses [4]. The power gradient time series waveform may be reflected by change of blood pressure and blood volume. The largest Lyapnov exponent gradient time series waveform may be reflected by the sympathetic nerve. The physical fatigue curve was computed from the integration value of the power gradient. The evocation curve was computed from the integration value of the largest Lyapnov exponent.

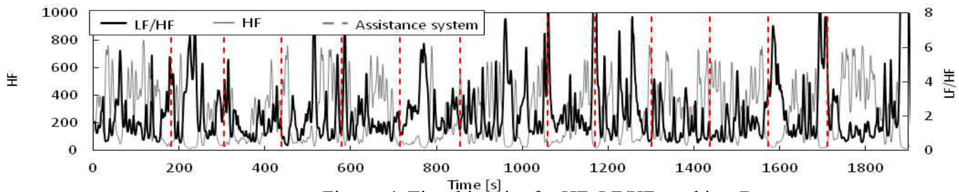


Figure. 4 Time histories for HF, LF/HF – subject D

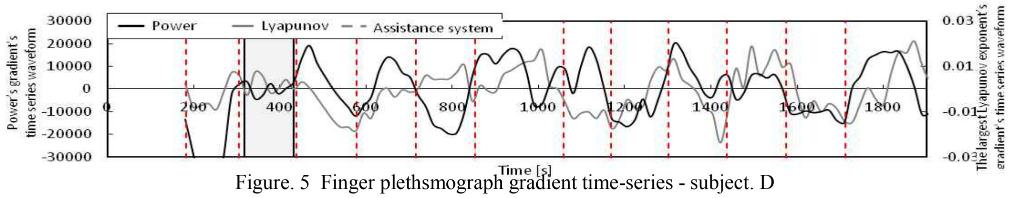


Figure. 5 Finger plethsmograph gradient time-series - subject. D

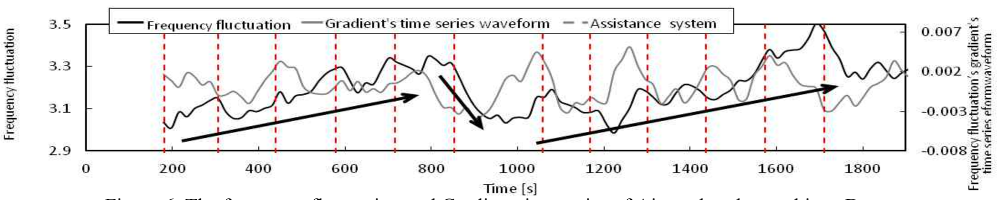


Figure.6 The frequency fluctuation and Gradient time series of Air-pack pulse - subject. D

Air-pack pulse measurement had been measured by using the air-pack sensor developed by Fujita [5]. The air pack pressure sensor was installed behind the sheet. When it sits down on a sheet, the pressure fluctuation which appears in people's waist was caught. The method of calculation of the Air-pack pulse which Fujita and others proposed was used for this analysis. What was computed is an inclination time series waveform of fluctuation of the frequency every 180 seconds, and change which shows the foretaste. The air back pulse catches the pressure fluctuation by motion of the heart. Therefore, it was influenced by autonomic nerves. By catching the frequency change of an air pack pulse, it was used as an index of the autonomic nervous system.

3. Experimental Results and Discussion

Effect of alerts in Arousal level during experiment:

In this experimental data, the physiological state was shown how to change during the whole experiment under the stimulation of various alerts. The results of an older driver (subject. D) are shown as some indexes from ECG and PPG data in Figure. 4-6

The each vertical bar in these figures shows the beginning time of presenting the alert. The turn of that for subject D was as for the first trial: none (1)-info(2)- low-freq. beep sound(4)-voice(6)-display(3)-high-freq. beep sound (5)-and as for the second trial: none (1)- high-freq. beep sound (5) - Display(3)-voice(6)- low-freq. beep sound(4)- info(2).

The state of relax by predominance of HF component for 1~200s, 650~700s, 1400~1600s, and 1700 ~1850s was estimated in Figure. 4, but it may not explain that subject. D felt drowsiness or difficulty of concentrating.

Next, as shown in Figure 5, the power gradient time series waveform and the Lyaponov exponent gradient time series waveform had large amplitude waves, it show the awaken state. However two low amplitude waves occur at about 400s, it may explain that subject D felt drowsiness or difficulty of concentrating. Hence difficulty of concentrating was estimated at approximately 900 s. It can correspond to

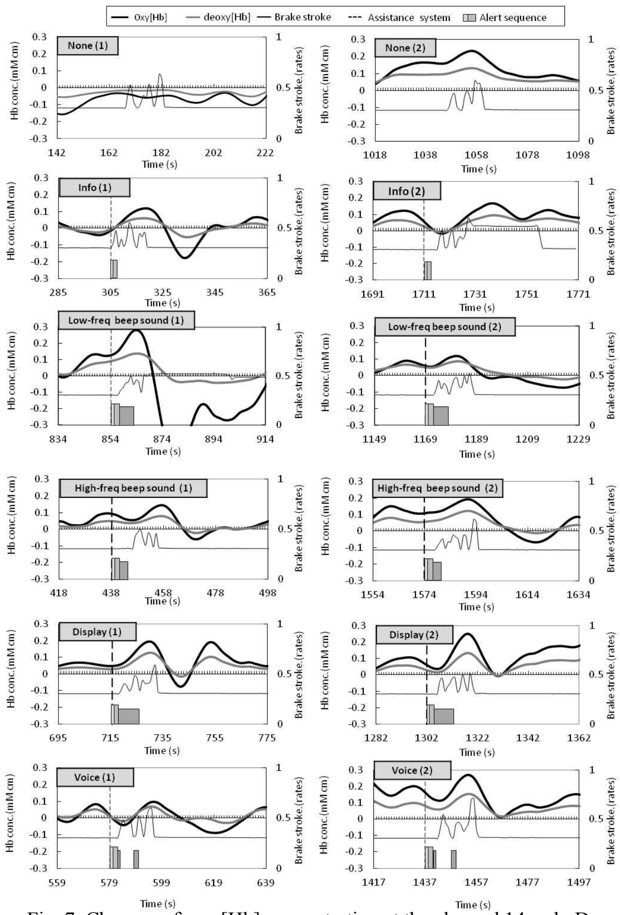


Fig. 7 Changes of oxy [Hb] concentration at the channel 14. sub. D

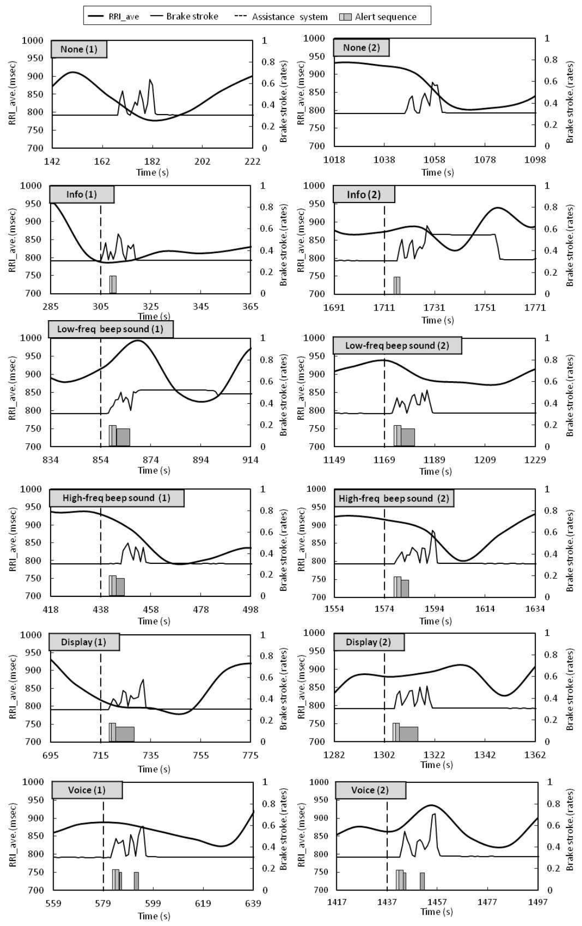


Fig. 8 RRI_ave changes. sub. D

the change of the frequency of Air-pack pulse that decreased rapidly from 800 s, and maintain low value often. This shows the fall of awakened feeling. However, alerts after has quier few effects on awakening. This result appeared in other subjects.

As the results, using subject D as an example (Figure 4-6) the LF/HF, HF, Finger plethsmograph gradient time-series, and Change of the frequency of Air-pack pulse reveal that the signal of the drowsiness or difficulty of concentrating for a short time had been found, but arousal had been maintained under the various alert conditions.

Effect for the arousal level after alert stimulation

As shown in Figure 7, grand average waveform of the results of MNIRS has expanded to the time interval of 80 seconds in the change just after alert stimulation and arranges depending on the type of alert stimulation. For instance, None(1) graph at the left top show the grand average waveforms of the oxy-hemoglobin [Hb] and the deoxy-hemoglobin [Hb] concentration, brake stroke and the alert timing, and show also the timing and how long it is, as small rectangular boxes below as shown in Table 2.

According to the results, in none conditions, the oxy [Hb] concentration had little effect. In both of info and display condition, rising of oxy [Hb] sharply was found. In info and display condition, since the driver hear the alarm, can see that oxy [Hb]'s concentrations are rapidly rising. And in low-freq. beep sound, oxy [Hb] concentration shows a very sharp increase, but the result that decreased attention about 800s would be associated. So it is difficult to explain that the increases of oxy [Hb]'s concentrations was influenced by the alarm. The noticeable increase in oxygen concentration could be found in the both first and second beep sound. However, that brake performances were affected by alert was confirmed.

Next, in the case of voice recommendation, there are very much increase in oxy [Hb] and as shown in the figure of brake stroke, the oxy concentration increase with the voice of "Brake smoothly." and the amount of increase become much greater after the voice of "Stop completely."

As shown in Figure 8, as for the results for subject D the RRI_aver age were shown in both trials, and the waveform has expanded to the time interval of 80 seconds as the same as Fig. 7. Here the decrease of the waveform of RRI_ave means the transition for the arousal state. From the results, the tendency of changes for more higher arousal level after informing the approaching to the traffic intersection in the cases of None(1), info(1), Display (1). Moreover, in the cases of High-freq beep sound (1),(2), the changes for more higher arousal level were recognized and on the contrary in the cases of Low-freq beep sound (1),(2), the changes of the arousal level were not shown, respectively. From these results, the changes after giving the various kinds of auditory-visual alerts were not the same effects for elderly drivers equally, but these results were suggesting that the methods for driving assistant system as well as the alert kinds should be select for individually and even if the same driver it is depending with her/his inner state of physical and physiological conditions.

4. Conclusion

In this study, the three kinds of auditory alert as pre-information, sound alert and voice guidance were used for adaptive driving assisting systems for the elderly driver and the influence of these alerts on the driver's psychosomatic state was examined using driving simulator. In the experiment, we measured the biological indicators such as a multi near infrared spectroscopy system (MNIRS), Electro-cardiogram (ECG), photo-plethysmogram(PPG) and air-pack sensor measurement as a non-invasive sensor system.

As the results, after taking the effects of the adaptive assisting alert systems, the effect of arousal and awareness improvement was recognized in the subjects and the activation of cerebral blood volume was observed according to the amount of the stimulus and combination of awareness modal as auditory alert system. From other results, the changes after giving the various kinds of auditory-visual alerts were not the same effects for elderly drivers equally, but these results were suggesting that the methods for driving assistant system as well as the alert kinds should be select for individually and even if the same driver it is depending with her/his inner state of physical and physiological conditions.

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