A Study of the alarm at the time of dump truck operation

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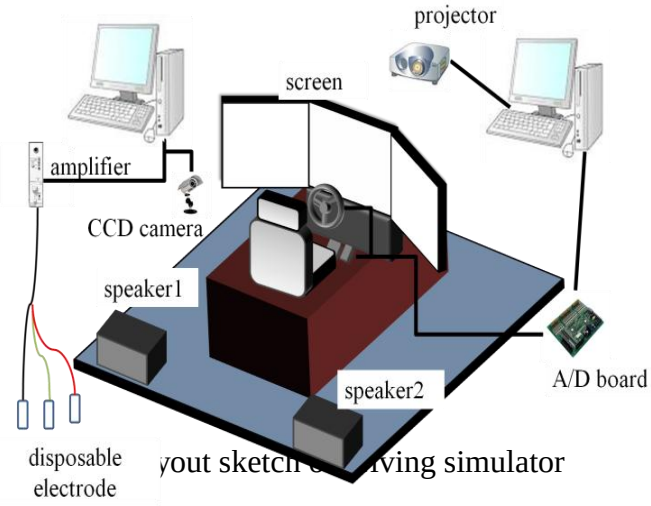
1. Introduction

For resource extraction and land development, a mining machine works 24 hours a day, 365 days a year. Although the improved road for construction is located in a mine, a traffic system like a local street does not exist. So there are many dangerous factors. Additionally if an accident occurs, it causes a heavy loss. A mining machine is expensive and work efficiency is lowered. From mentioned above, we have to consider warning system to prevent accidents. There are many researches about warning system in ordinary vehicles. On the other hand, there is still little number of researches of the mining machine. Therefore, we pay our attention to warning system to decrease the slight accident and collision with the dump truck. The purpose of this study is to determine the effective index of alarm to make the operator notice dangerous information quickly and precisely. So we use brake reaction time and heart rate variability as index to evaluate degrees of response and tension. In this study, we use beep sounds as alarm. The beep sound is designed using a few kinds of frequencies and blow interval. We simulate accident in operating dump truck by using driving simulator(DS), and measure brake reaction time and heart rate variability.

2. Experimental equipment

Experimental equipment is shown in Fig.1. This DS consists of handle, seat, accelerator pedal and brake pedal that are arranged along the vehicle. Three screens are installed in the front of seat. By three projectors, the image of road is described on each screen. The two speakers that emit alarm sounds and engine noise are placed behind the seat. We use two Personal computers. The one is used for showing driving situation and logging data. Another computer is used for monitoring electrocardiogram(ECG). The CCD-camera records the face for measuring degrees of eye closure. The distance between screen and handle is 1.7m, and the distance between screen and speaker is 2.6m.



yout sketch ving simulator

3. Procedures

In this experiment, the subjects operate the DS. The subjects continue stepping on the accelerator pedal like the actual operation of the dump truck. Furthermore we set the speed of DS to 50km/h, based on the specification of the maximum speed of the dump truck. Total extension of simulation course is about 3km. While subjects operate simulator, we generate danger on screen and emit alarm at the same time. Then subjects step brake pedal as soon as alarm is sounded. During operating DS we measure data of operation and ECG at all time. Additionally we monitor the face of subjects.

Table.1 shows the specifications of alarm sounds. We set the sound pressure in the room to 50db(A-weighted sound pressure level), and set sound pressure of alarm to about 65db(A-weighted sound pressure level). So we don't worry about that the alarm is buried in the background sound.(1)

Table1. Alarm sound specifications

Frequency	500Hz～4000Hz
Wave shape	Sine curve
Sound interval	0.5sec, 0.0625sec
sound pressure	65db(A)

The blowing time of the alarm sound and silent time are same interval as shown in Fig.2. The alarm sound and the dangerous

subjects occur at the same time, and the alarm sounds for 4 seconds. When dump truck runs through 50m front of occurrence position of danger, the alarm sounds. We made three type of danger conditions as shown in Fig.3. Type A is collision with the vehicle crossing in front of own dump truck. Type B is collision with the vehicle from the opposite side. Type C is collision with sand.

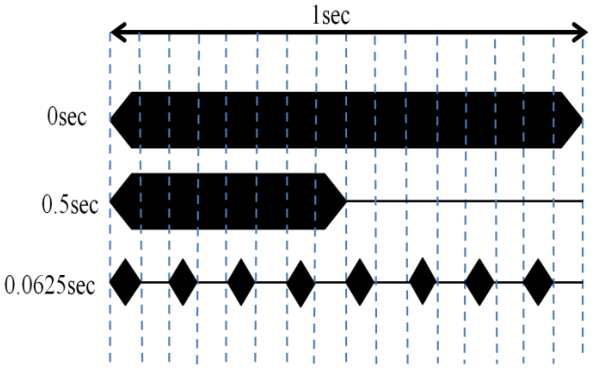
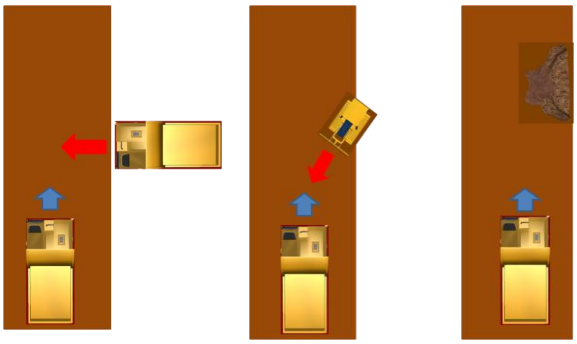


Fig.2 Sound interval



Type A **Type B** **Type C**

Fig.3 Conditions of dangers

Subjects run three times a dangerous course, as shown in Fig.3. Moreover, subjects run the course in which only alarm sounds, supposing dangerous subject has occurred in the dead area. So subjects run four times in total. The order of the occurrence of alarm sound has become all random. Number of subjects is five people, and they are all early 20s.

4. Estimative Index

4-1. Heart rate variability

There are many reports that physiological index is effective to evaluate a sense of driver.[2] In this study, I chose degrees of eye closure and heart rate variability as a physiological index. The reason I choose the heart rate variability as physiological index is that heart rate variability is greatly reduced by fatigue and mental stress.

4-2. Degree of eye closure

When suddenly surprised as near misses, eye-lid a little opens at the same time. We use this property to measure degrees of tension at alarm.

4-3. Brake reaction time

In the operation of dump trucks, stepping the brake to stop at emergency is the highest priority. So we need faster brake reaction time to prevent an accident. We show a model of brake reaction time in Fig.4.

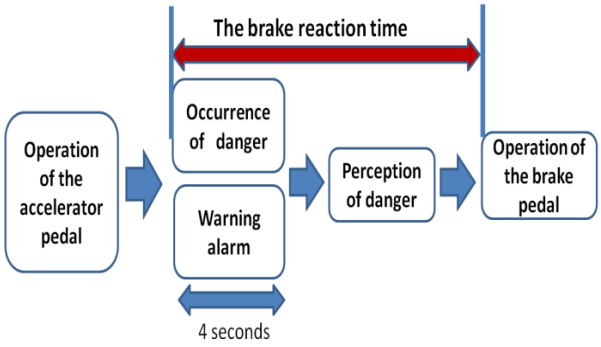


Fig.4 Model of the brake reaction time

5. Experimental Result

5-1 The result of brake reaction time

We examined the effects of the frequency of alarm sound against brake reaction time. The result is in Fig.5. In this experiment, there are three subjects. Eight kinds of alarms sounded one time respectively in a simulation. In these alarm sounds, the sound interval is fixed to 0.5 second. Subjects operate simulation course five times. During the simulation, dangerous subjects did not occur but only the alarm sounded.

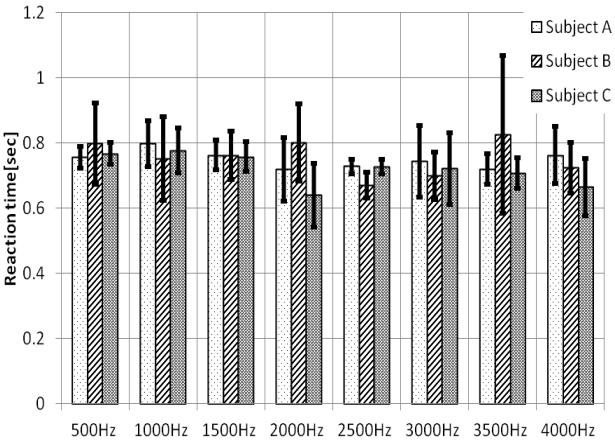


Fig.5 Brake Reaction Time for frequency

This result is five averages of reaction time.

In this result, Subject A and C get the fastest reaction in alarm sound of 2000Hz-1/2[sec]. Subject B gets the fastest reaction in alarm sound of 2500Hz-1/2[sec]. We cannot get significant difference in this result. In next experiment, we investigate the influence of the sound interval of alarm. We use two kinds of sound intervals and frequencies. Number of subjects is five peaple. They run the course three times, where dangerous subject occurs. Furthermore they run another course which only alarm sound generates. This course is supposed that dangerous subjects occur in dead area. We show the reaction time in Figure.6 when dangerous subjects occur in dead area. This result is four averages of reaction time. Subject K, T and W get the fastest reaction time in the 4000Hz-1/16[sec]. Subject M gets the fastest reaction time in the 1000Hz-1/16[sec]. Subject R gets the fatest reaction time in the 4000Hz-1/2[sec]. From this result, there were many subjects whose reaction time became the fastest at 4000Hz-1/16[sec]. But significant difference cannot confirmed in this experiment.

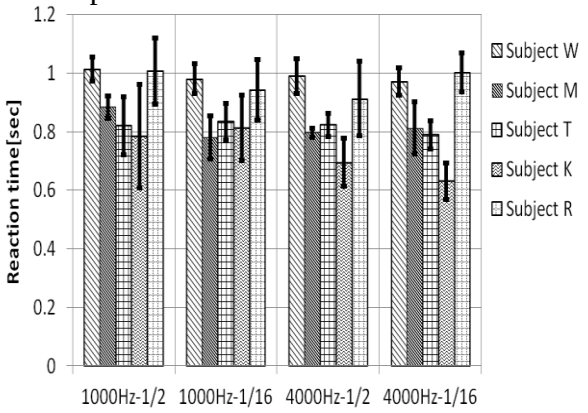


Fig.6 Brake Reaction Time at dead area

5-2 The result of Heart rate variability

We don't measure only brake reaction time but also Heart rate variability. We use R-R Interval(RRI) as Heart rate variability.

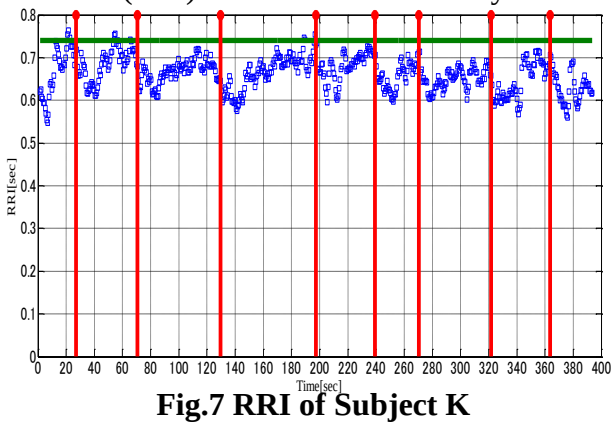


Fig.7 RRI of Subject K

RRI was measured when subjects run the course where dangerous subjects didn't occur but only alarm sound generated. In this course, we used four kinds of alarm sounds and they are sounded twice. We show the RRI of subject K in Fig.7. In Fig.7, vertical line means the starting time of alarm sound and horizontal line means the average of resting RRI.

In the Table.2, We show the value which subtracted RRI at the time of resting from RRI at the time of alarm sound generating. The calculation range of RRI at the time of alarm sound generating is for four seconds. In this calculation range, we prepared the time-lags of four patterns. We can know that RRI decreases by alarm sound. Subject W and M get a minimum at 1000Hz-1/2[sec]. Subject Y and R get a minimum at 1000Hz-1/16[sec]. Although RRI was low value at alarm sound of 1000Hz, we cannot get significant difference in this result.

Table.2 RRI difference from rest

Subject W	1000Hz-1/2	1000Hz-1/16	4000Hz-1/2	4000Hz-1/16
6 seconds lag	−0.0613	−0.0517	−0.0363	−0.0417
8 seconds lag	−0.0247	−0.0070	−0.0446	−0.0440
10 seconds lag	−0.0123	0.0137	−0.0437	−0.0297
12 seconds lag	−0.0083	−0.0037	−0.0477	−0.0153
Subject M	1000Hz-1/2	1000Hz-1/16	4000Hz-1/2	4000Hz-1/16
6 seconds lag	0.0172	−0.0520	−0.0727	−0.0647
8 seconds lag	−0.0897	−0.0300	−0.0728	−0.0540
10 seconds lag	−0.1517	−0.0347	−0.0796	−0.0612
12 seconds lag	−0.1244	−0.0517	−0.1347	−0.0776
Subject Y	1000Hz-1/2	1000Hz-1/16	4000Hz-1/2	4000Hz-1/16
6 seconds lag	−0.0403	−0.0367	0.0013	−0.0173
8 seconds lag	−0.0250	−0.0511	−0.0570	−0.0183
10 seconds lag	0.0308	−0.0834	−0.0320	−0.0237
12 seconds lag	0.0337	−0.0889	0.0203	−0.0430
Subject K	1000Hz-1/2	1000Hz-1/16	4000Hz-1/2	4000Hz-1/16
6 seconds lag	−0.0946	−0.1098	−0.1240	−0.1117
8 seconds lag	−0.0946	−0.1300	−0.1358	−0.1069
10 seconds lag	−0.0931	−0.1306	−0.1349	−0.0969
12 seconds lag	−0.1000	−0.1233	−0.0900	−0.0863
Subject R	1000Hz-1/2	1000Hz-1/16	4000Hz-1/2	4000Hz-1/16
6 seconds lag	−0.0607	−0.1069	−0.0400	−0.0403
8 seconds lag	−0.0627	−0.1383	−0.0743	−0.0773
10 seconds lag	−0.0483	−0.1240	−0.1086	−0.0843
12 seconds lag	−0.0507	−0.1273	−0.1103	−0.0843

References

(1) Y.IMORI, "The research example about the safety measures of construction machinery" *Construction Planning (2007)*

(2) S.OKAZAK, K.WATANABE "Automobile driving security Correlation of the amount of heart rate variability and a fatigue degree" *Document of Sensing forum(2002)*