Effects of Sleep Deprivation and the Odor of 100% Lavender Oil and 100% Peppermint Oil on Unexpected Situation while Driving

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Abstract
This study was aimed to find out whether there was some difference comparing driving performance and the autonomic nervous system between normal state and sleep deprivation state, between sleep deprivation state and 100% Lavender oil exposed state and between sleep deprivation State and 100% Peppermint oil exposed state, while driving in a driving environment using a driving simulator. The subjects were 10 male drivers between 20 and 45 years age whose average age was 30.9±7.7 years and who had been driving for 7±6.6 years, the road situation of three-lane road was copied as a driving environment, and the subjects were instructed to keep 1st lane, to keep a constant speed of 110km/h. In this driving condition, the subjects were instructed to step on the brake until the speed of car is 0km/h, according to "STOP" sign shows in red which displayed on the screen suddenly. As a result of analyzing the reaction distance, there was a significant difference (p<0.05) between normal state and sleep deprivation state. Also, as a result of analyzing the speed average, there was no significant difference all groups. As a result of analyzing the LF/HF ratio, there was no significant difference before and after in all groups. As a result of analyzing the LF/HF ratio after unexpected situation, there was a significant difference (p<0.1) between sleep deprivation state and peppermint state. The results suggest that it could be judged that expressway accidents at 0 a.m. - 6 a.m. are closely related to drowsy driving. This phenomenon is thought monotonous driving environment and lack of sleep is coupled to lower the driving performance, and the peppermint has a statistically significant difference on the change in driving performance comparing sleep deprivation, such as the reaction distance. this means that the odor may be possible to temporarily driving performance improve.

Keywords: Sleep Deprivation, Reaction Distance, Odor, Driving Performance, Unexpected Situation.

Introduction

In 2013, a total of 215,354 traffic accidents occurred in Korea. This is 3.7% lower than the number of traffic accidents in 2012. The number of road traffic deaths during the last 10 years tends to be reduced from 6,563 in 2004 to 5,092 in 2013 constantly. But Comparing the number of deaths per 100,000 population between Korea and OECD member countries, Korea's traffic accident death rate of 10.5 for every 100,000 people is 1.6 times higher than traffic accident death rate of OECD member countries average of 6.6 for every 100,000 people. This means that although Korea's road traffic safety level is getting better, but Comparing with OECD members Korea's road traffic safety level is still low[1].

Driving a vehicle is a work which is completed with a repetitive feedback to the operation necessary to keep driving performance well, after judging and predicting the information rapidly within a short time based on the accepted information, accepting the information presented consistently from the external environment [2].

So the driving a car requires continuous attention from a driver. A temporary degradation of attention such as drowsy driving could be caused the road traffic accident. And especially drowsy driving on the expressway is the cause of fatal traffic accidents. Because driving speed is much higher on the expressway (100km/h ~ 110km/h) than on general roads (60km/h ~ 80km/h) in Korea, the fatality rate (the number of deaths per 100 accidents) is also considerably higher in expressway accidents.

Sleepiness caused by impaired and shortened sleep is known to provide a major cause of accidents in industry and transport [3, 4].

The total of 645 traffic accidents took place, caused by drowsy driving accident in spring, resulting in 30 deaths and 1,272 injured annually in Korea. Especially the fatality rate of drowsy driving accident (4.3%) is two times higher than that of a total road traffic accident (2.1%) [5].

The autonomic nervous system is responsible for maintaining the body's balance by the interaction of the sympathetic and parasympathetic. In addition, the sympathetic is activated on emergency circumstances to protect the human body from a change in the external environment. But if arousal condition persists for longtime, human body has a negative influence like cold, due to break the balance of body. So homeostasis of body is very importance.

The LF/HF ratio was known as the sympathetic activation factor and as a representative indicator of the autonomic nervous system. LF/HF ratio can give the information that the condition of body is whether arousal or relaxed condition.

Because driving speed is much higher on the expressway (100km/h ~ 110km/h) than on general roads (60km/h ~ 80km/h) in Korea, the fatality rate (the number of deaths per 100 accidents) is also considerably higher in expressway accidents.
Low frequency (LF : 0.04Hz~0.15Hz) is involved in the sympathetic nervous system and high frequency (HF : 0.15Hz~0.4Hz) is involved in the parasympathetic nervous system. So if the LF/HF ratio is high, than arousal condition is dominant in the human body, the other hand if the LF/HF is low, relaxed state is dominant in the human body [6].

The odor is sensed by olfaction which is the most sensitive sensory receptors in the human body, and the odor affects the human emotions such as pleasantness / unpleasantness, arousal (tension) / sleep (relaxation). And the odor has been studied that affect the central nervous system and the autonomic nervous system [7].

The goals of this study are there as follows. First, it is to observe the difference, comparing the driving performance of sleep deprivation state and normal state under unexpected situation. Second, comparing the autonomic nervous system measured by the pulse wave system of sleep deprivation state and normal state under unexpected situation. Finally, comparing the effect of arousal and relaxing odor stimulus on the driving performance and the autonomic nervous of sleep deprivation.

Method

Subjects

The subjects were 10 male drivers between 20 and 45 years age whose age in average was 30.9±7.7 years and who had been driving for 7±6.6 years. They were the subjects who had a normal or corrected vision with which they had no trouble in perceiving the image of a simulator and who free of any sleep disorder and simulation sickness. In order to minimize the factors which may affect the test, Subjects had a sufficient sleep before the day and a good general health condition.

Test Environment and Vehicle Simulator

As for lab environment, the room temperature was kept 25±2℃ and humidity was done 35–52%. Driving noise was presented 48dB.

The driving simulator was GDS-300S manufactured by Grid space Co.(Korea) and the front and left /right visual information was provided through three 32” LCD monitors. The model name of the simulator was “Click” model of Company H and driving devices (handle, accelerator pedal, brake pedal, etc.) and display devices(turn signal lamp, speedometer, RPM meter, etc.) were the same as those of a real vehicle. The motor control system of motor driven power steering(MDPS) was used as a handle device as Figure 1.

Bio-Signal Measuring Device and Selected Odors

Vital Meter which is manufactured by TAOS Institute in Japan was used to measure the pulse wave. The sampling frequency is 1kHz. Vital Meter is measurement devices of earlobe pulse wave and wireless. So this is useful when the subject is in situation in moving and driving.

Odors used in this test were manufactured by KIMEX Co.(Korea) Two natural oils were used such as 100% Lavender oil and 100% Peppermint oil. Lavender oil is effective in sleep / relaxing in the human body, Peppermint oil has the effect of arousal / tension in the human body.

Driving Scenario

The expressway which was composed of 3-lane road was used in this test for the graphic driving simulation environment, and there are not many vehicles on the road. So driving environment was a very monotonous like the expressway at 2 a.m. – 6 a.m.

There are two missions in this test. One is unexpected situation. In a straight section which is near the second corner, according to “STOP” sign shows in red which displayed on the screen suddenly, the subject steps on the brake until the speed of car is 0 km/h.

The other mission is cruising 110km/h and keeping 1st lane in the expressway, in order to measure the continuous attention of drivers.

Figure 1. Graphic Driving Simulator

Figure 2. Driving Scenario
Test Procedure

This study was designed to find out whether there were some difference in changes for comparing the driving performance and autonomic nervous system between a normal state and a sleep deprivation state, between a between a normal state and a sleep deprivation state and a lavender oil exposed state and between a sleep deprivation state and a peppermint oil exposed state while driving in a driving environment using a driving simulator.

Before the test, subjects were adequately informed about the purpose and contents of the test and after they signed a test participation confirmation, the test was conducted.

In order to minimize the factors which may affect the test, the subjects had a sufficient sleep, and heavy alcohol and caffeine intake was restricted before the test day. The test was conducted from 5 p.m. to 7 a.m. the day after their arrival at LAB.

A brief questionnaire such as the current degree of sleepiness, age, driving experience so on, was filled in and practice driving was conducted to get used to driving simulation environment. After 10 minute break time, the first driving in normal state was conducted for 5 minute and Autonomic Nervous System was measured for 10 minute. This was started 5 minute earlier than driving.

To make sleep deprivation, the subjects were rested in LAB form the 5 p.m. to 7 a.m. in the next day and they were doing something like reading a book, watching movies and playing internet games freely. And their exit and entrance was strictly controlled after 4 a.m.

The second driving in sleep deprivation state is conducted for 5 minute at 5 a.m. and Autonomic Nervous System was measured for 8 minute. This was started 3 minute earlier. The driving like the above was conducted 2 times more in case of Lavender oil exposed and Peppermint oil exposed state. To reduce the effect on the previous test, there was a 10 min break in the middle of the test. To prevent the test procedures from affecting the subjects, it was counterbalanced.

The odor was placed 20cm away from the nose of the subjects and the lid of the odor was open for one minute to take on the smell, and the test was carried out in the odor remaining in air. After each test was done, then the odor in the air was removed by adequate ventilation.

Data Analysis

The section 1 where before and after unexpected situation was conducted was used for analysis. And the section 2 where keeping speed was conducted was used for analysis.

For reaction distance, Paired T-test: Paired T-test was conducted, where between Normal State and Sleep Deprivation State, Sleep Deprivation State and 100% Lavender Oil Exposed State and Sleep Deprivation State and 100% Peppermint Oil Exposed State.

For speed average, Paired T-test: Paired T-test was conducted, where between Normal State and Sleep Deprivation State, Sleep Deprivation State and 100% Lavender Oil Exposed State and Sleep Deprivation State and 100% Peppermint Oil Exposed State.

In bio-signal measures, Paired T-test: Paired T-test was conducted, where between Normal State and Sleep Deprivation State, Sleep Deprivation State and 100% Lavender Oil Exposed State and Sleep Deprivation State and 100% Peppermint Oil Exposed State.

Result

Reaction Distance

The comparison of the reaction distance may be used as an indicator to determine the minimum distance margin the vehicle ahead in unexpected situation while driving. As a result of analyzing the reaction distance, there was a significant difference (p<0.05) between Normal State and Sleep Deprivation State like Figure 4. But there was no significant difference other group.

![Figure 4. Result of Reaction Distance (** : p<0.05)](image-url)

Table 1. paired T-test of Reaction Distance for Normal sleep state and Sleep deprivation state

<table>
<thead>
<tr>
<th>Source</th>
<th>Mean</th>
<th>S.D.</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>25.30</td>
<td>3.11</td>
<td>-2.30</td>
<td>.046**</td>
</tr>
<tr>
<td>Sleep Deprivation</td>
<td>29.34</td>
<td>3.40</td>
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<td></td>
</tr>
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</table>

Figure 3. Test Procedure
**Speed Average**

The second mission given to the subject was keeping constant speed of 110Km/h while driving on the express way. This is an indicator to know the constant attention of the driver during driving.

As a result of analyzing the speed average, there was no significant difference all groups. Also in the odor exposed state like Lavender oil or Peppermint oil, there were no significant changes in the driving performance of the driver. The results are shown in Figure 5.

![Figure 5. Result of Speed Average](image)

**LF/HF ratio of before and after unexpected situation**

To find out the change in sympathetic and parasympathetic nervous system before and after unexpected situation, the LF/HF ratio was analyzed.

As a result of analyzing the LF/HF ratio, there was no significant difference before and after unexpected situation in all groups.

But interesting data was found that the LF/HF ratio after unexpected situation at normal state (2.17) and Peppermint oil exposed state(2.23) is much higher than the LF/HF ratio before unexpected situation at normal state (1.31) and Peppermint oil exposed state(1.68). On the other hand the LF/HF ratio after unexpected situation at sleep deprivation state (1.34) and Lavender oil exposed state(1.59) is a little lower than the LF/HF ratio before unexpected situation at sleep deprivation state (1.52) and Lavender oil exposed state(1.65). The results are shown in Figure 6.

![Figure 6. Result of LF/HF ratio before and after unexpected situation](image)

**LF/HF ratio of before unexpected situation**

As a result of analyzing the LF/HF ratio before unexpected situation, there was no significant difference all groups. But the other group has no significant difference. The results are shown in Figure 7.

![Figure 7. Result of LF/HF ratio before unexpected situation](image)

**LF/HF ratio of after unexpected situation**

As a result of analyzing the LF/HF ratio after unexpected situation, there was a significant difference (p<0.1) between sleep deprivation state and peppermint oil exposed state. but the other group has no significant difference. The results are shown in Figure 8.

![Figure 8. Result of LF/HF ratio after unexpected situation (**: p<0.1)**](image)

<table>
<thead>
<tr>
<th>Source</th>
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<th>S.D.</th>
<th>t-value</th>
<th>p-value</th>
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<tr>
<td>Sleep Deprivation</td>
<td>1.34</td>
<td>0.43</td>
<td>-1.93</td>
<td>0.85 * (p&lt;0.1)</td>
</tr>
<tr>
<td>Peppermint</td>
<td>2.23</td>
<td>0.45</td>
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<td></td>
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</table>
Conclusion

This study was aimed to compare and analyze the effect of the normal state, the sleep deprivation state, the Lavender exposed state and the Peppermint exposed state on unexpected situation and autonomic nervous system while driving.

As the result of comparing reaction distance which is one of the driving performance in this test. It was found that reaction distance is significantly increased in sleep deprivation state. And when driving a express way at least about 35m distance margin is needed with the vehicle ahead, if the breaking performance of vehicle is same each other. This could be the minimum distance from the car ahead, because the distance that the car is moved forward until the first break reaction time while driving at 110km/h speed on the expressway environment.

The result of this test proved that there is a cognitive responses difference between the normal state and the sleep deprivation state when external environmental changed. This means that lack of sleep is directly related to road traffic accidents and especially express way on driving faster than other road.

Also comparing the cruise speed of 110km/h is to know the difference of constant attention in various situations.

As the result of comparing the cruise speed in this test, there was no significant difference between 109.68km/h at sleep deprivation state and 110.67km/h at normal state. This means that 5 minutes driving is not enough time to compare the constant attention such as graphic simulating driving environment. So comparing the constant attention needs sufficient time and real road environment. But enough time for comparing the constant attention wasn't found in this study.

As a result of analyzing the LF/HF ratio after unexpected situation, there was a significant difference (p<0.1), between Sleep Deprivation State and Peppermint state. This means that the peppermint oil odor which has arousal character effects on sympathetic and activates sympathetic in autonomic nervous system.

Comparing the LF/HF ratio before and after unexpected situation of figure 6, the LF/HF ratio after unexpected situation at normal state and Peppermint state is much higher than LF/HF ratio before unexpected situation.

On the other hand the LF/HF ratio after unexpected situation at sleep deprivation state and Lavender state is a little lower than LF/HF ratio before unexpected situation.

Referring to the previous studies, Sympathetic nerves systems are activated rapidly in external stimulus happened, But the LF/HF ratio after unexpected situation at sleep deprivation state and Lavender state is not activated in external stimulus happened. This means that the reaction of autonomic nervous system under sleep deprivation worked as abnormal.

Looking at the changes in the autonomic nervous system before unexpected situation, the LF/HF ratio is higher in sleep deprivation than in normal sleep state.

According to previous studies of the LF/HF ratio in sleep deprivation lower than the normal state of sleep has been reported[9]. Therefore, when considering biological rhythms that is the time the subjects should be in bed. However, because of compulsory sleep deprivation, the result of the LF/HF ratio in sleep deprivation is thought to be due to stress caused by the lack of sleep.

Traffic accident death rate is high at 6 p.m. - 2 p.m. on most of the road such national roads, special / metropolitan city road, provincial road and city/country road. But traffic accident death rate on the expressway was higher at 0 a.m. - 6 a.m.[1]

According to previous studies, the two times of the day, sleep tendency is increased during early morning (2 a.m. - 7 a.m.) and during midafternoon (2 a.m. - 5 a.m.)[9].

It could be judged that expressway accidents at 0 a.m. - 6 a.m. are closely related to drowsy driving. This phenomenon is thought that monotonous driving environment and lack of sleep is coupled to lower the driving performance.

The accident risk of the truck driver who work 10 hours is 2.2 times higher than the accident risk of the truck driver who work 1 hours [10]. So in case of sleep deprivation, the long distance driving should be avoided.

Modern human beings have always been exposed to sleep deprivation. Philip et al. (1996) was surveyed 567 people in Europe highway during the summer. As a result, It is reported that 50% of the driver has appeared to be a lack of sleep state [11].

The peppermint has a statistically significant difference on the change in driving performance comparing sleep deprivation, such as the reaction distance. This means that the odor may be possible to improve temporarily driving performance when the drivers are in sleep deprivation.

However, there are limits in this study as follows. First, the number of subjects is small. So variance between individuals was high. Second, to analyze difference of the driving performance in sleep deprivation, 5 minutes is not sufficient.

References
