IMPROVED DELIVERY OF OLFACTORY STIMULUS TO KEEP DRIVERS AWAKE

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ABSTRACT

In our research, we aim to construct an olfactory delivery system for cars that can be used to keep a driver who is at risk of falling asleep awake. This system releases aromas at a specific time and at a specific place. Furthermore, as this system delivers pleasant aromas, it improves passengers' levels of comfort. Some researches have examined the effect of aromas on levels of alertness. We further assume that the way used to deliver the aroma is also very important because of the rapid adaptation of the human olfactory perception system. We examine whether temporary and spatially located delivery of aromas can wake up sleepy subjects better than when aromas are delivered at a constant rate.

1. INTRODUCTION

Have you ever had the experience of falling asleep when driving? When you find you are so tired, you should stop driving and take a rest immediately. Aromas are widely believed to be able to keep sleepy drivers awake.

There has been a wealth of well documented research on the role of odor. Researchers have examined the impact of a variety of aromas. Motomura et al. examined the effects of lavender odorant [1], and their results show that lavender odorants were associated with reduced mental stress and increased arousal rate. Baron & Kalsher examined the role of aroma on driving performance [2]. The results suggest that using a pleasant odorant can improve some aspects of driving performance.

We think that how aromas are delivered is also important. General air fresheners deliver aromas continuously until it runs out. However, as the olfactory response adapts to the same aroma almost immediately, the period of perceiving the aromas is very short. Even if a car is filled with plenty of aroma, we still cannot expect there to be any significant effect on the driver. If the amount of aromas is too large, we perceive them as bad smells although a good fragrance. Therefore, the aroma should be delivered intermittently.

Moreover, the types of aromas expected by the driver may be different from those expected by the passengers. In Japan, drivers often use air fresheners and/or deodorants in a car [3]. They tend to use them to remove an odor, e.g., smells of smoke, molds, dusts, and so on.

On the other hand, they use also air fresheners to make their space more comfortable and/or as a means of personal expression similar to changing the features of the car, such as body color, design of seat covers, and so on. Generally, people are aware of the smells in other people's car as well as their own. Thus, the aroma that is meant to awaken a sleepy person should be delivered to the driver and the aroma that makes people comfortable should be delivered to the other passengers in the car. Therefore, the aroma should be delivered to a temporary and spatially localized area.

Yanagida, et al. constructed a projection-based olfactory display [4] [5]. This device allows us to deliver aromas to a specific place and for limited periods by carrying scented air within a vortex ring launched from an air cannon. The scented air is delivered from a point near the user's nose through the space. It is possible to switch between different scents within a short period and limit the region in which the scent can be detected.

We discuss the efficacy of an aroma delivered from the projection-based olfactory display to a sleepy driver. We examine whether delivering aromas in this specific way is sufficiently strong to wake up sleepy subjects who are working on simple visual tasks.

In the next section, we will explain the air cannon, and in Sec.3, we show four conditions of the experiment. In Sec.4 we show the results of the tasks performed. We will then discuss whether the aromas launched from the air cannon may improve the subjects' levels of alertness. Finally, we will summarize this article in Sec.6.

2. AIR CANNON

Figure 1 shows the olfactory delivery system. The entire system is composed of the following components: a nose tracker, an air cannon platform, an air cannon, and a scent generator [4]. The vision-based nose tracker is used to detect and track the target user's nose position. In our examination, however, we do not need to use it because subjects sitting a reclining chair and using an air pillow can keep still and do not move their head.

The air cannon is a chamber with a round aperture. The simplest way to make an air cannon is to use a cardboard box, cutting out a hole and sealing the seams with packing tape. If we fill the box with smoke and push it gently, a smoke ring will be observed moving smoothly forward. This ring demonstrates the toroidal vortex generated by the air cannon.

In this paper, we use a compressor and a vial with an aroma to give off scent. The compressor fills the chamber with scented air just before the air cannon launches an amount of air.

Thus the air cannon allows the olfactory delivery system to deliver the aromas only within a limited range of space and at a certain time. We can deliver the aroma to specific people, i.e., the driver or the passengers. Furthermore, the driver does not adapt to the same aroma because we can significantly reduce the amount of aromas compared with when simply diffusing it into the entire interior of a car.

Fig.1 Olfactory display (Air cannon).

3. EXPERIMENT

3.1. Conditions

Table 1 shows the four sets of conditions used in this experiment. In *AC-Aroma* (Condition 1), subjects received aroma twice from the air cannon of the olfactory delivery system during a trial. In *Fill-Aroma* (Condition 2), subjects were in a room filled with the aroma throughout the trial. We prepared the aroma-filled room before the trials by using an air freshener[1]. In *AC-None* (Condition 3), subjects received aroma free air twice from the air cannon of the olfactory delivery system within a trial. In *None* (Condition 4), subjects were in an aroma-free room throughout the trial.

The order of the four conditions in our experiment is *None*, *Fill-Aroma*, *AC-None*, and *AC-Aroma*. We used a lemon aroma that is said to have an effect on levels of alertness in the *AC-Aroma* as well as the *Fill-Aroma*. The lemon aroma was obtained from the "Aroma Environment Association of Japan [7]." After each experiment we removed smells from the experimental room fully by using a circulator and deodorization equipment as well as opening a window.

Table 1. Experimental conditions

Air cannon	aroma	no aroma
with	Condition-1	Condition-3
	AC-Aroma	*AC-None*
without	Condition-2	Condition-4
	Fill-Aroma	*None*

3.2. Participants and design

Ten subjects participated in the four conditions. Thirty-three subjects were hired from a temporary agency and received a small compensation. Four of them participated in all four conditions. However, seven subjects who belong to ATR Cognitive Information Science Labs did not receive any compensation.

Our target of the experiment is to examine whether the aroma awakens the sleepy subjects. Therefore, we made a comfortable environment that was highly conducive to sleep. We used a small room at ATR with a window as our experimental room. We made the room very dark and prepared a comfortable reclining seat for the subjects. They were asked not to drink coffee before the experiment.

Figure 2 illustrates the setting of the experimental room and Figure 3 shows a photograph of it. A plasma display showed various visual tasks that the subjects were asked to do. A mouse that the subjects clicked to answer the

[1] We used "Aromageur [6]", a device that can be used to control the amount of aroma released and how long it is released for. We thus set the aroma in the experimental room at almost the same consistency for all subjects.

tasks was set in the right arm of the reclining seat. To block off sounds from outside as well as to simulate a pseudo-driving environment, the subjects wore headphones that played sound recorded from inside a moving car. They were also asked use an air pillow to help them to relax. In the *AC-Aroma* and *AC-None*, there was an olfactory delivery system in front the subject on the left side (Fig.3). Before each experiment at the *AC-Aroma* and *AC-None*, we adjusted the aperture direction towards each subject's nose using aroma-free air. In addition, we equipped an emergency buzzer and the subjects were asked to call us if they felt unwell.

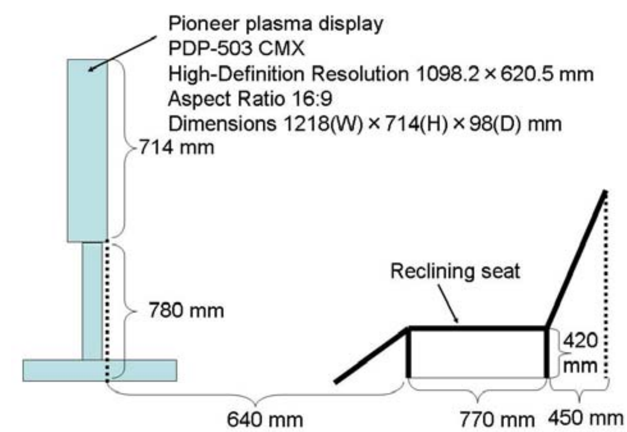


Fig. 2. Setting of the experiments.

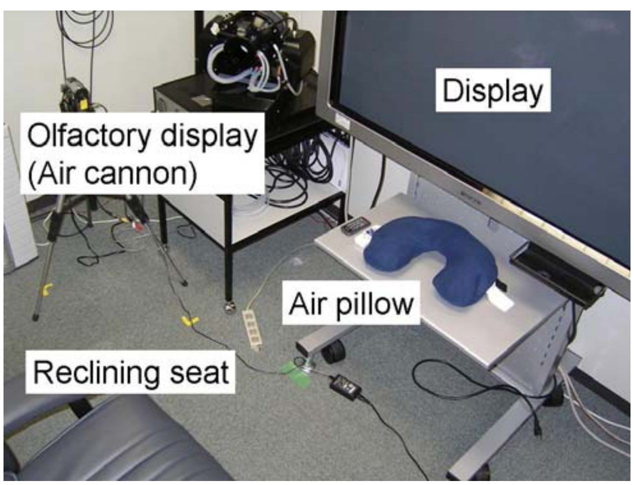


Fig. 3. Experimental room.

3.3. Procedure

Before participating in the experiment, the subjects received an explanation of the experiment and signed an acceptance form to confirm that they had understood the experimental procedures. The subjects performed the tasks alone in the room. We allowed each subject eight minutes in the preliminary experiment as well as thirty-two minutes in the main experiment.

They were asked to click a right button of the mouse when an intended target was shown in the display. If the other type of targets were shown, they had to click the left button of the mouse. There are four kinds of stimuli: a red vertical bar, a red horizontal bar, a white vertical bar, and a white horizontal bar. These bars are 20 mm on one side and 10 mm on the other side. The intended target was the red vertical bar, and subjects were instructed to click as quickly and as accurately as possible when the target was showed. They were also asked not to re-click even if they realized that they had made a mistake.

We showed the intended targets twice in all eight stimuli for one forty-second block in the main experiment. Each block was composed of a blank time, i.e., only a fixation point was showed on the display for twenty seconds, and the duration of displaying stimuli was twenty seconds.

In the *AC-Aroma* and the *AC-None* conditions, the air cannon was used to deliver air with and without the lemon aroma to the subject after sixteen minutes and twenty-four minutes. Fifteen seconds before launching air in the *AC-Aroma*, and for exactly ten seconds, the compressor filled the chamber with lemon scented air.

We obtained accuracy rates based on the reaction times and which button the subjects clicked on each trial.

After the experiment the subjects completed the following multiple-choice questionnaire:

Question 1. Did you notice any smells while performing the task?

a. Noticed no smell from the beginning through to the end.
b. At first did not notice any smell but gradually noticed some smells.
c. Noticed a smell at first but it gradually became less noticeable.
d. Sometimes noticed smells.
e. Noticed some smells from the beginning through to the end.

Question 2. Did you get tired in performing the task?

a. Not at all.
b. Fine at first, but gradually got more tired.
c. Tired at first but gradually recovered.
d. Sometimes tired.
e. Tired from the beginning through to the end.

4. RESULTS

First, we calculated average and standard deviations of reaction times, and accuracy rates in every four minutes at each subject. Then, the z-values of them are calculated as follows:

$$z = \frac{X - \overline{X}}{\sigma} \qquad (1)$$

After that, a total score for four minutes is calculated as follows:

$$T = z_{AR} - z_{RT} - z_{STD} \qquad (2)$$

T is the total score in a four-minute period. z_{AR} is a z-value of the accuracy rate in a four-minute period. z_{RT} is a z-value of the average of the reaction time in a four-minute. z_{STD} is a z-value of the standard deviation of the reaction time in a four-minute period.

We assume that the longer the reaction time gets, the more the subjects are tired and/or sleepy. On the other hand, the lower the total score and/or the accuracy rate gets, the more the subjects are tired and/or sleepy.

We decided to omit one subject who participated in the *AC-Aroma* from our analysis because he was almost completely asleep.

Figures 4 and 5 show the results of the reaction time for each group, the *AC-Aroma*, *Fill-Aroma*, *AC-None*, and *None*, denoting the averages and the standard deviations, respectively. Figures 6 and 7 show the results of the accuracy rates, denoting the raw data and the z-value, respectively. Figure 8 shows the total score for each group. The x-axis illustrates eight blocks and tow arrows indicates the time when the olfactory delivery system launched the odor. We analyzed each four-minute block within total thirty-two minutes, which results in eight blocks for each group.

We can see that the averages of reaction times are getting longer over time in the *AC-Aroma*, *Fill-Aroma*, and *None* conditions, as shown in Fig.4. The averages of the reaction times of Block-5 to 8 are significantly longer than that of Block-1 to 4 in *None* (t = 4.93, p< .05). As the subjects usually get tired in the *None* condition, reaction times typically get longer. In others, however, the averages tend to be a little shorter from Block-7 to 8 (see Fig.4).

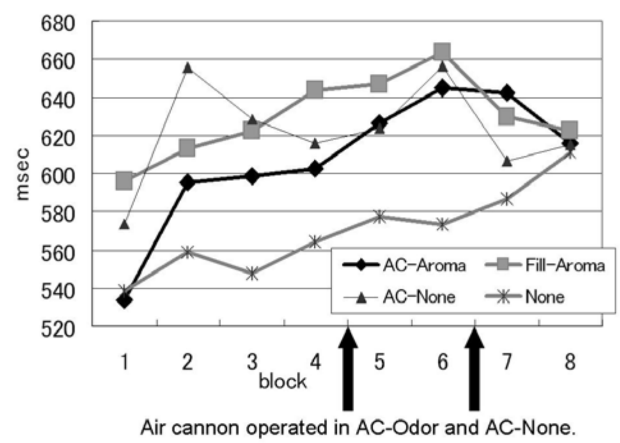
Furthermore, we can see that the averages of the reaction times of the *None* condition are significantly shorter than those of the *AC-Aroma* (t = 2.52, p < .05). Those of others are not different to those of the *AC-Aroma* (see Fig.4).

The averages of standard deviation of the *AC-Aroma* are significantly different from with that of the *None* (t = 2.31, p<.05). Moreover, in Block-1 to 4, they are also significant different between them (t = 2.33, p<.07) although an *AC-Aroma* environment is the same as that of *None* (see Fig.5).

Fig.6 and 7 show that the accuracy rates clearly increase at Blocks 5 and 7, which occur after the aroma in the *AC-Aroma* has been launched. The decrease of the accuracy rates from Block-1 to Block-4 shows that almost all the subjects are tired or/and got sleepy. The rates of the *AC-None* also increase at Block-7, which is after the launch of the air without the aroma (see Figs.6 and 7).

Fig.8 shows that the total score of the *AC-None* and that of the *AC-Aroma* increase at Block-7 clearly as well as that of the *Fill-Aroma*. On the other hand, the total score of the *None* decrease smoothly overtime.

Table 2 shows the results of a questionnaire for checking whether the subjects noticed either some or no smells. In the *AC-Aroma and* the *Fill-Aroma* conditions, some subjects did not notice any aroma throughout the experiment. In the *AC-None*, three subjects noticed some smells although any aromas did not deliver to the subjects. Table 3 shows the results of a question relating to whether the subjects were tired because of the task. In the *AC-Aroma*, most subjects got tired gradually. In the *Fill-Aroma* as well as the *None* conditions, four subjects answered that they were not tired through to the end. On the other hand, five subjects of the *Fill-Aroma* answered that they got tired gradually. It should be noted that their accuracy rates come down sharply and/or the standard deviations of them come up sharply at around Block-5.



Their rates then increase.

Fig. 4. Average of reaction time.

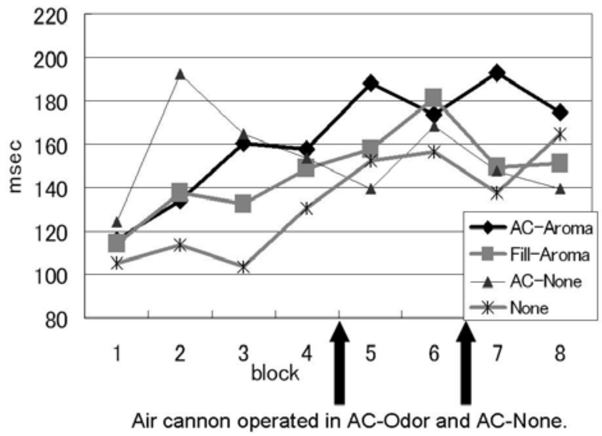


Fig. 5. Standard deviation of reaction time.

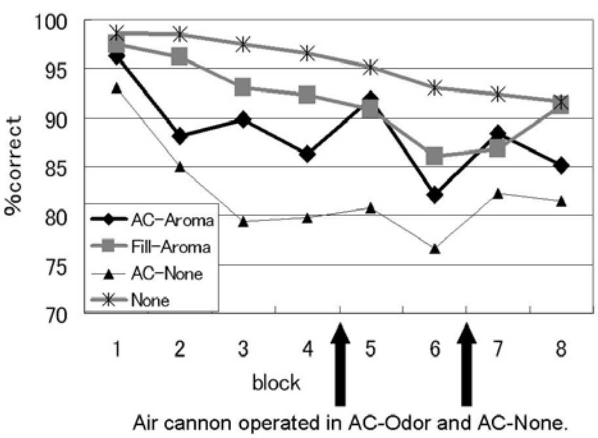


Fig. 6. Accuracy rate.

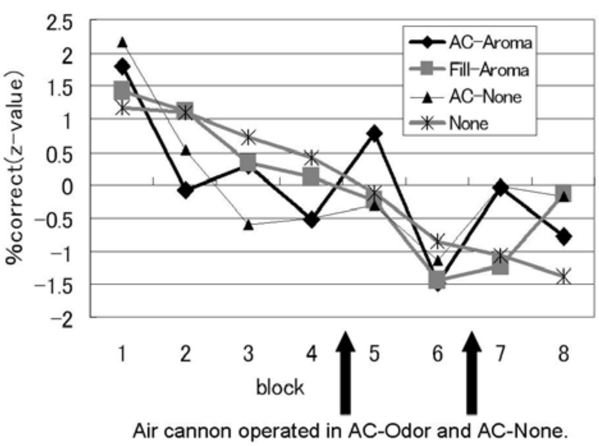


Fig. 7. Accuracy rate transformed into z-value.

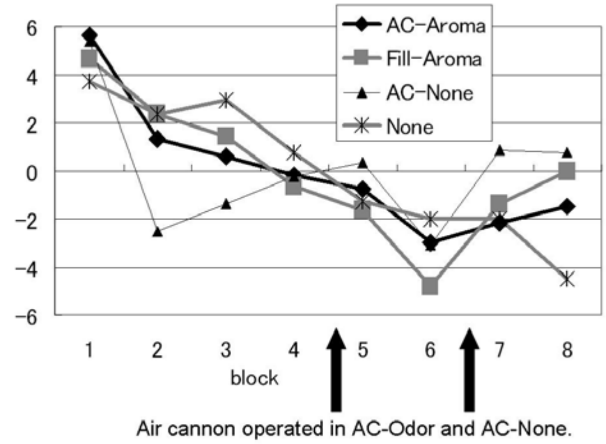


Fig. 8. Total score

Table 2. When did you feel any smells? (Question-1)

	a	b	c	d	e
AC-Aroma	3*	1	0	6	0
Fill-Aroma	4	0	5	0	1
AC-None	7	0	0	3	0
None	10	0	0	0	0

Table 3. Did you get tired in performing the task? (Question-2)

	a	b	c	d	e
AC-Aroma	1	7*	0	2	0
Fill-Aroma	4	5	0	1	0
AC-None	3	4	0	3	0
None	4	2	0	3	1

5. DISCUSSIONS

The results of the accuracy rates and the total scores suggest that the air launched from the air cannon wakes up sleepy subjects. The accuracy rates of subjects in the *AC-Aroma* and *AC-None* conditions decreased about 10% until Block-4. They then increased after the launch of the air.

These results cannot show how the effects of the *AC-Aroma* and *AC-None* conditions differed. The subjects' answers suggest that the amount of aroma may not be enough to arouse sleepy subjects and also suggest that the lemon aroma may not be suitable for this purpose.

On the other hand, the total scores of the *Fill-Aroma* condition also increased at Block-7 although the environment around the subject did not change. Some subjects' accuracy rates and standard deviations rapidly worsened because of their tiredness around Block-5 (see Sec.4). The performance increase from Block-7 can be explained as the results of the subjects' conscious efforts once they were aware that their performance was decreasing.

The averages of the reaction times of the *None* condition is significantly shorter than that of others (see Fig.4). We think that conducting the experiments in the *None* condition affected the results. In this experiment, we could not arrange the conditions in a random order for the subjects participated in all four conditions. This might have affected the results of the reaction times.

6. CONCLUSION

We conducted experiments to determine how well an aroma delivered from a projection-based olfactory delivery system aroused a sleepy driver. Subjects were asked to work on simple visual tasks, which made them tired and sleepy. The results suggest that air launched from the air cannon has an effect on sleepy subjects. On the other hand, the results of the condition with aroma delivered on a temporary basis and that of aroma delivered on a constant basis indicated no significant difference in performance in each condition. We think that the amount of aroma may be insufficient to induce a stronger effect of arousing a sleepy subjects and/or the type of aroma may not be well suited for this purpose. To test these possibilities, we need to conduct further experiments with increasing the number of subjects.

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