AroNap: A Scent-based Nap Promotion System

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Keywords: Nap, Sleep Onset, Wake-up, Health Promotion System, Work Efficiency.

Abstract: Compared to other countries, Japanese sleep time is insufficient, and many people have reduced work efficiency due to daytime sleepiness caused by lack of sleep. The government recommends taking a nap as a countermeasure, but few Japanese do. This study developed a wearable sleep-onset / wake-up promotion system, "AroNap," that supported a short, effective nap and verified its effect. AroNap is a system that promotes falling asleep and waking up during a nap at an appropriate timing by attaching a computer-controlled scent diffusion device to a neck pillow. To verify the usefulness of AroNap and scent, we conducted an evaluation experiment to compare the effect on sleep quality of presence or absence of AroNap, the type of scent, and the sleep state according to the timing of use. We also evaluated the system using the system usability scale (SUS). Proper use of AroNap has been shown to improve sleep quality compared to other cases.

1 INTRODUCTION

Compared to other countries in the world, Japanese sleep time is insufficient. Figure 1 shows a comparison of average sleep times in each country according to a 2019 survey by the Organization for Economic Co-operation and Development (OECD, 2020). According to this survey, the average sleep time in Japan was 7 hours and 22 minutes. There is a difference of more than 2 hours between South Africa and Japan, which have the longest average sleep time. In addition, there is a difference of nearly 20 minutes compared to South Korea, which has the shortest average sleep time next to Japan. Therefore, Japan has the lowest sleep time in the OECD member countries and can be the country with the shortest sleep time globally. In addition, the 2019 National Health and Nutrition Survey shows that 37.5% of men and 40.6% of women sleep less than 6 hours (MHLW, 2020). When asked about sleep quality in this survey, 32.3% of men and 36.9% of women answered that they felt drowsy during the day.

There is a power nap as a countermeasure against the decrease in work efficiency due to daytime sleepiness (PHILIPS, 2019). Power naps are short naps during the day, and NASA has demonstrated the scientific effect of improving cognitive ability by 34% and attention by 54% (Barry and Phillips, 2006). Global companies such as Google and Apple actively encourage naps by installing nap spaces and sleep devices in their offices to improve work efficiency. In Japan as well, the Ministry of Health, Labor and Welfare stated in the "Sleep Guidelines for Health Promotion 2014" that "a short nap of 30 minutes or more in the early afternoon is effective in improving work efficiency due to drowsiness."(MHLW, 2014). However, in Japan, 67.9% of the respondents answered "I do not have many days" or "I do not do it at all" when asked, "Do you take a nap during work or lunch break?" (PRTIMES, 2015). Possible reasons for this not being established include the negative image of taking a nap at work, securing a nap place, and the cost of dedicated equipment.

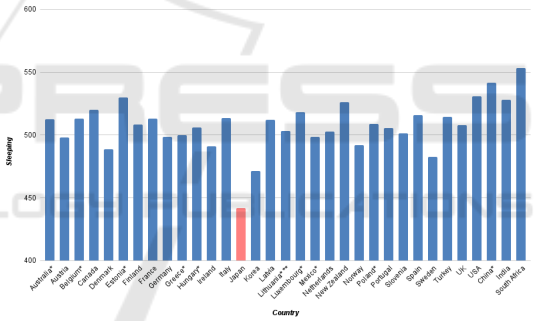

Figure 1: Comparison of average daily sleep time in OECD member countries(Created based on the survey data of (OECD, 2020)).

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In this study, we developed and verified the usefulness of AroNap, a wearable system for promoting falling asleep and waking up, which supports effective napping for a short time to improve work efficiency. The results of the evaluation experiments confirmed that the correct use of the scent by the subjects during naps has a long-lasting, relaxing effect. The subjects also confirmed that the scent reduced drowsiness on waking, helped them recover from fatigue, and enabled them to take a good nap. From the evaluation experiments, we also clarified the issues to be solved in practical use.

2 RELATED RESEARCH

2.1 Study on Nap

Kaida et al. examined the effects of forced awakening and self-awakening to reduce sleep inertia after a short nap (Kaida et al., 2001). Experiments suggest that self-awakening is effective in suppressing sleep completion after a nap. Hayashi et al. point out that the self-awakening of a short nap enhances the effect of a short nap (Hayashi and Hori, 2007).

A study by Unoki investigating whether short-term naps relieve psychological and physical stress showed that psychological stress reactions such as tension and physical stress reactions such as stiff shoulders and eye strain were relieved (Unoki, 2017). In addition, a study comparing the effects of sleep time on the eve suggests that a short nap during the day may be effective not only for people who lack sleep time but also for people who have average sleep time(Unoki, 2018). Koyama et al. conducted a study of a short nap in a chair (Koyama et al., 2019). It was found that there was no difference between the chair and bed naps in the short nap, and the same drowsiness reduction effect was obtained.

2.2 Nap Introduction System

There are many systems for introducing naps that have been put into practical use. Yamaha Corporation has developed a nap support system ”nap system” that uses sound and conducts a prototype trial at Narita Airport in 2019 (Yamaha, 2019). The nap system supports falling asleep with a ”good sleep sound” linked to the biological rhythm.

There is also a nap introduction system called ‘Energy Pod,’ a chair dedicated to power naps, which have been proven to improve workplace well-being (Dore et al., 2021). The Energy Pod is designed to relax, such as weightless position, sleep music, and gentle light and vibration for comfortable awakening. However, these systems are expensive and require ample space for installation, making them difficult to introduce into a company.

2.3 Fragrance Sleep Induction

There are many studies using scents in sleep induction studies. Yamamoto et al. Applied the sympathetic nerve activity-suppressing effect of the aroma component cedrol in the essential oils of coniferous trees such as cedarwood to sleep situations (Yamamoto et al., 2003). In a comparative experiment between placebo and cedrol conditions conducted by Yamamoto et al., Total sleep time tended to be significantly prolonged under cedrol conditions, sleep latency was shortened considerably under cedrol conditions, and sleep efficiency tended to increase under cedrol conditions. The sedative effects of cedrol on sympathetic nerve activity tended to reduce evident arousal for more than 1 minute in the first half of sleep. From the above, cedrol’s sympathetic nerve activity inhibitory effect can create an environment where it is easy to fall asleep.

Yada et al. clarified the influences of ethnic and regional characteristics and differences in perception on the cedrol effect on autonomic nerve activity (Yada et al., 2007). They found that the miosis rate (ratio of pupil diameter variation after the light stimulus to initial pupil diameter) significantly increased after cedrol exposure compared to that before exposure in all three countries (Norway, Thailand, and Japan), suggesting that the parasympathetic nervous system became dominant.

Ohno et al. examined the effect of the scent of black tea on sleep in stress-conscious women (Ohno et al., 2020). In comparison experiments with placebo solution and tea aroma solution by Ohno et al., the quality of subjective sleep, sleep onset, sleep maintenance, fatigue, psychological action to reduce the improvement and stress awareness of satisfaction with sleep time was seen. These experiments strongly suggested that the scent of black tea reduced stress consciousness and facilitated sleep.

2.4 Fragrance Injection Mechanism

There are various methods for presenting scents. Aroma is one of the typical methods. The aroma can use in a variety of ways, including candles and diffusers. Some commercially available aroma diffusers, such as aroma sticks, are smaller and more convenient to carry [1].

[1] Aromastic, Sony, https://scentents.jp/aromastic/

Figure 2: Neck pillow and aroma stone used in AroNap.

In addition, scents have been familiar to Japanese people since ancient times, and there have long been a small scent presentation method called a scent bag and an instrument used for a Kodo called an incense burner. In the Kodo experience system proposed by Yokokubo et al., an interactive incense burner has been developed, and it is thought that there is still room for development in the efforts of scent and his interaction (Yokokubo et al., 2019).

3 PROPOSAL SYSTEM:AroNap

AroNap is a system that aims to support short naps to improve work efficiency by promoting sleep onset and awakening by taking advantage of the characteristics of the scent. The name of AroNap is a combination of the smell ”aroma” and the nap ”nap.” The target users of AroNap are those who need a nap but cannot easily fall asleep or get up comfortably. Use for a short nap while sitting in a chair. Also, AroNap does not require as much space at a high cost as existing nap systems. You can purchase the products you are using at mass retailers, and you do not need a dedicated place such as your seat or an empty conference room. AroNap consists of two M5StickC [2], a smartphone, a commercially available neck pillow [3] shown in the figure 2 and aroma stone [4]

3.1 AroNap Configuration

The hardware of AroNap consisted of an M5StickC with a Servo HAT mounted sensor and a box for storing aroma stones (after this referred to as the AroNap module)(Figure 3). The M5 Stick C controls the opening and closing of the AroNap module lid

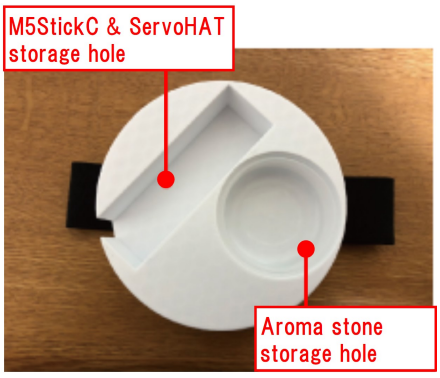

Figure 3: AroNap module created with a 3D printer.

Figure 4: M5StickC and ServoHAT connected.

(Figure 4). Servo HAT is a servo motor that opens and closes the lid.

The AroNap module produced this time has a cylindrical box with a diameter of 10 cm and a height of 2.5 cm, and the lid (Figure 5) is a drop shape of about 8 cm. The AroNap module has circular holes and rectangular holes. The circular hole is 5 cm in diameter and 2 cm in height, and the rectangular hole is 8 cm in length and 2.5 cm in width. Put aroma stones in the circular holes. Attach the M5 Stick C and Servo HAT to the rectangular holes. The AroNap module comes with rubber that is used to attach to the neck pillow.

The AroNap software was implemented as an AroNap application used on smartphones (after this referred to as the AroNap application). The smartphone and the AroNap module connect via Bluetooth, and the smartphone gives instructions to open and close the lid at the specified timing.

Figure 6 shows the system configuration of AroNap. When the user enters the nap time in the AroNap app and presses the start button, the AroNap module on the sleep onset promotion side is instructed to open the lid. After half of the nap time, the AroNap module on the sleep-onset promotion side is instructed to close the lid, and 10 seconds later, the AroNap module on the wake-up promotion side is instructed to open the lid. After waking up, pressing the stop button will instruct the AroNap module to close the lid of the currently open AroNap module.

[2]M5StickC, M5Stack, https://shop.m5stack.com/collections/m5-hat

[3]neck pillow,Muji, https://www.muji.com/jp/ja/store/cmdty/detail/4550182576221

[4]Aroma stone,Muji, https://www.muji.com/jp/ja/store/cmdty/detail/4548718959112

Figure 5: AroNap module opening / closing lid made with a 3D printer.

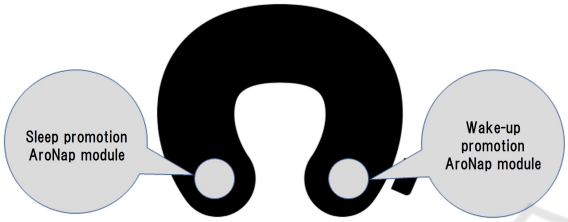

Figure 6: AroNap system configuration.

3.2 How to Use AroNap

AroNap is used by attaching the AroNap module to the neck pillow. Also, download the AroNap application to the user's smartphone and operate the AroNap module. First, attach the lid of the AroNap module, and then connect the AroNap module and the smartphone via Bluetooth. After confirming the connection between the AroNap module and the smartphone, put the aroma stone in the AroNap module and close the lid (Figure 7).

At this time, the AroNap module on the sleep onset promotion side contains an aroma stone containing a scent (like cedarwood, lavender) that has a sleep onset promotion effect. On the other hand, the AroNap module on the wake-up promotion side contains aroma stones containing a scent (like lemon) that has a wake-up promotion effect.

Also, set the initial position of the lid to close the hole containing the aroma stone. Figure 8 shows how the AroNap module is attached to the neck pillow.

Next, enter how many minutes the user wants to take a nap in the AroNap app and press the "TIME INPUT" button (Figure 9). The default nap time is 20 minutes. Finally, press the "START" button in the middle to start AroNap. When nap time is over, press the "STOP" button to close the lid of the AroNap module.

Figure 7: AroNap module with built-in various sensors and aroma stones.

Figure 8: AroNap module attached to the neck pillow.

4 EVALUATION EXPERIMENT

In order to verify the usefulness of the AroNap and the scent, we conducted an evaluation experiment to compare the sleep conditions with and without the AroNap, the type of scent, and the timing of use. In addition, we conducted a questionnaire survey after having subjects use this system.

4.1 Experimental Method

13 subjects (12 males and 1 female in their twenties and one female in her thirties) were tested to compare their sleep conditions under three experimental conditions. The minimum number of subjects was set at about 10. The reason for this is that the minimum number of subjects is about 10 in verifying the relaxation effect brought about by fragrances, as described in the ergonomics guide by Tadahiko Fukuda et al (Fukuda and Fukuda, 2009). There are three experimental conditions:

- Experiment with AroNap, in which a transition is made from the fragrance for falling asleep to the fragrance for waking up.
- Experiment without AroNap, in which a transition is made from the fragrance for waking up to the fragrance for falling asleep.

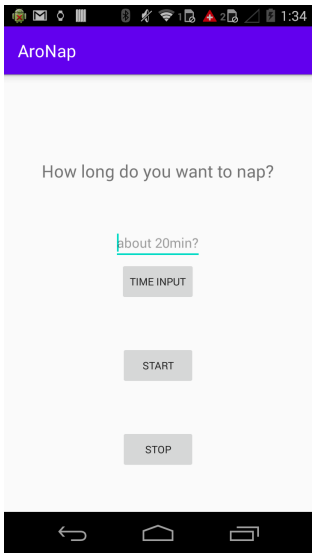

Figure 9: Screen example of AroNap app.

- Experiment without AroNap, in which no fragrance or AroNap is used.

The three conditions were the first-sleep experiment, the first-wake experiment, and the no-sleep experiment. Subjects were asked to participate in all three conditions, but they were asked to participate in only two conditions if this was not possible.

The experiment was conducted from 13:00 to 14:00 or 14:00 to 15:00. The pulse interval was constantly measured during the experiment. The schedule for each hour of the experiment was the same: 20 minutes of free time, 20 minutes of napping, and 20 minutes of free time. The first 20 minutes of free time was spent freely in the experimental classroom, but the location of the last 20 minutes of free time was not specified. In the last 20 minutes of free time, we did not specify the location of the free time and asked the participants to refrain from strenuous exercise such as running during the free time. Since we wanted to know the effect of a short nap, we did not specify the location or the behavior after the nap but checked whether the participants were motivated to work or not.

The experiment was conducted in a small classroom in a university. The classroom size was about 3.5×5, and half of the classroom was divided by a curtain, and the subjects were placed on the backside (A) and the front side (B). A chair with an extended backrest and a headrest was prepared. In the experiment using fragrances, we organized several fragrances. We asked each subject to choose their favorite one because AroNap: A System to Promote Falling Asleep and Waking Up Using Fragrance Presentation in Napping suggested that each subject's preference of fragrance may affect their napping (Iizuka et al., 2021). We prepared two fragrances for falling asleep, and two fragrances for waking up, and each subject was asked to choose one of the two fragrances. We prepared @aroma[5]'s Lavender Mint and Juniper Cedar for the sleep-in scent, and @aroma's Clean Citrus and Orange Grapefruit for the wake-up scent.

After the 20-minute nap, the participants were asked to answer the Obstructive Sleep Apnea (OSA) sleep questionnaire (Yamamoto et al., 1999). After completing two or three experiments, they answered the System Usability Scale (SUS).

4.2 Evaluation Method

In this experiment, we analyzed the degree of relaxation using the pulse interval (RRI), the quality of sleep using the OSA sleep questionnaire, and the evaluation of AroNap using SUS.

The pulse interval is compared using two methods. The first method uses the standard deviation resulting from resampling the acquired data. The 20-minute value during napping was mainly used for the pulse interval, and two or three patterns of pulse intervals were compared. If the standard deviation value is small, it is evidence that the pulse interval is calm, and it can be said that the person is in a relaxed state.

The second method is to use a Lorenz plot using the RRI of the resampled acquisition data. In Lorentz plot the value of RRI(n) is plotted on the x-axis and the value of RRI(n+1) is plotted on the y-axis. Since the heart rate increases during exercise, the RRI is small, and the RRI(n) and RRI(n+1) are almost the same, the plot is located at the lower left of the graph. On the other hand, during relaxation or sleep, the RRI(n) and RRI(n+1) values change significantly due to the large fluctuation of the heart rate sensation, and the plot position becomes the upper right of the graph.

There are five factors in the OSA sleep questionnaire, and it is thought that the higher the score, the better the sleep. Since we are targeting a short nap, we excluded the values of factors related to dreaming. The following are the factors of the OSA sleep questionnaire:

- Factor 1 Drowsiness when waking up
- Factor 2 Sleep onset and sleep maintenance
- Factor 4 Fatigue recovery
- Factor 5 sleep time

SUS was created based on 10 Things to Know About the System Usability Scale

[5] @aroma store,@aroma, https://www.at-aroma.com/store/

(SUS)(measuringU, 2013). The subjects answered each item on a 5-point scale. The higher the score, the higher the evaluation of SUS. The subjects were asked to answer each item on a 5-point scale. The higher the score, the higher the assessment of SUS. At the end of the SUS questionnaire, the subjects were asked to describe their product impressions. The following is the scale of the SUS items and responses.

1. I would like to use this system frequently. (1-not at all, 2-no, 3-don't know, 4-yes, 5-very much)
2. It turns out that the system is unnecessarily complicated. (5-easy)
3. I thought it was easy to use. (5-very much)
4. I think you need the support of a technician to use this system. (5-not at all)
5. It turns out that the various functions of this system are well integrated and scattered. (5-very much)
6. I thought there were too many contradictions in this system. (5-not at all)
7. I think most people will soon learn how to use this system. (5-very much)
8. I found this system very difficult to use. (5-not at all)
9. I was very confident in using this system.(5-think)
10. Before I started using this system, I needed to learn a lot. (5-not at all)

5 EXPERIMENTAL RESULTS

5.1 Result of Pulse Interval

Table1 shows the standard deviation of the pulse interval for each time in each experiment. The areas with a standard deviation of zero are areas with no data.

From the standard deviation, it can be considered that the standard deviation value of the pulse interval during napping is smaller than that during free time in all experiments and that the pulse interval fluctuates less and is calmer. K, the only experiment in which the standard deviation of the napping time became large, will be discussed later.

When comparing the standard deviations during napping in the first-sleep experiments and first-wake experiments, the standard deviation value in the first-sleep experiment was more petite, suggesting that using the correct scent resulted in less fluctuation in the pulse interval and relaxation. However, when comparing the first-sleep experiment with the no-sleep experiment, in some cases, the no-sleep experiment showed less fluctuation in the pulse interval. This will also be discussed later.

Figure10 shows a Lorenz plot of the pulse interval at the center position every 5 minutes in the first-sleep experiment of subject A. Next, Figure11 shows a Lorenz plot of the pulse interval at the center position every 5 minutes in subject A's first-wake experiment. Finally, Figure12 shows a Lorenz plot of the pulse interval at the center position every 5 minutes in Subject A's no-sleep experiment. If there is a plot at the upper right of the Lorenz plot, it means that the subject is relaxed at that timing, and it can be seen that the subject is relaxed after napping in all experiments. When the positions of the last 55-60 min plots were compared, the positions were (990.7, 989.1) in the first-sleep experiment, (804, 804.4) in the first-wake experiment, and (742.7, 740.8) in the no-sleep experiment, indicating that the first-sleep experiment continued to be the most relaxed.

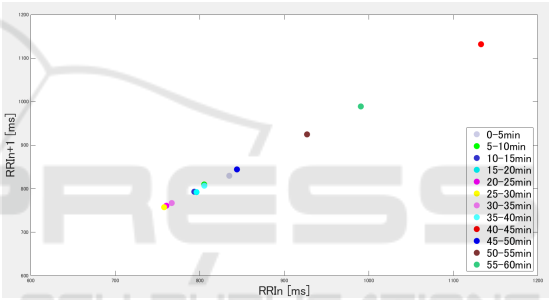

Figure 10: Lorenz plot of subject A's first-sleep experiment.

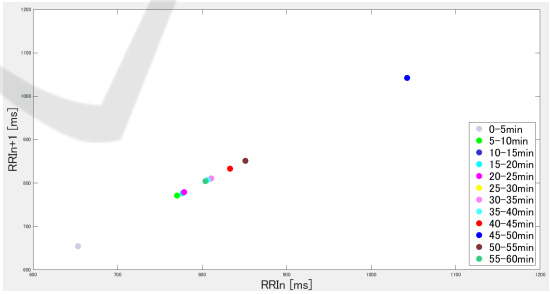

Figure 11: Lorenz plot of subject A's first-wake experience.

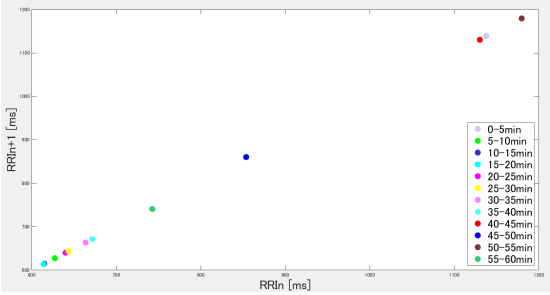

Figure 12: Lorenz plot of subject A's no-sleep experiment.

Table 1: Standard deviation of RRI at the begining, in the middle, and at the end of the nap in each condition (from left to right: first-sleep experiment, first-wake experiment, no-sleep experiment).

	0-20min	20-40min	40-60min	0-20min	20-40min	40-60min	0-20min	20-40min	40-60min
A	357	281	427	346	299	376	333	292	447
B	377	133	495	-	-	-	235	102	352
C	326	149	424	247	150	355	261	617	321
D	451	178	462	-	-	-	447	159	351
E	391	70	440	410	149	428	302	78	441
F	136	88	227	260	106	349	213	95	253
G	389	110	465	369	156	410	390	131	389
H	242	130	357	249	240	355	329	183	394
I	450	174	439	-	-	-	257	156	365
J	317	112	288	340	208	341	-	-	-
K	321	145	287	393	408	370	-	-	-
L	270	99	257	-	-	-	242	66	208
M	419	125	424	-	-	-	372	342	397

Table 2: Result of OSA sleep questionnaire (standardized score).

	First sleep	First wake up	No AroNap
Factor 1	50.89	49.14	45.46
Factor 2	39.86	44.95	37.06
Factor 4	52.95	51.25	48.28
Factor 5	40.59	45.71	41.55

5.2 Result of OSA Sleep Questionnaire

The table 2 is the result of the OSA sleep questionnaire. The numbers in the table are the standardized scores, and 50 points are the average score.

- Factor 1: drowsiness upon waking, exceeded the mean score of 50 points only in the first sleep experiment, indicating that the correct use of the fragrance resulted in a comfortable waking. Comparing the results of the experiments with and without scent, it can be said that sleepiness upon awakening is more comfortable when the scent is used, even when it is not used correctly.
- Factor 2: falling asleep and staying asleep, is the best result of the previous waking experiment. The questions for factor 2 were "I was able to sleep well," "I was not in a state of stupor before falling asleep," "I was able to fall asleep easily," "I did not wake up during sleep," and "I slept deeply." In the first-sleep experiment, where the last 10 minutes of the napping period was the waking time, the participants felt that they could have slept a little longer, which is thought to have made it difficult for them to obtain high scores.
- Factor 4: recovery from fatigue, was higher than the average score in the experiment with fragrance, suggesting that fragrance can provide a more effective nap.
- Factor 5: sleep duration, the score of the first-sleep experiment was lower than that of the no-sleep experiment and was the lowest among the three.

As in Factor 2, the score of the first-wake experiment was higher because the participants felt that they could sleep satisfactorily because they could sleep until just before their nap time. Factors 2 and 5 were lower than the average scores, indicating that it is difficult to achieve higher scores than the average during a 20-minute nap.

From the above results, it can be said that the correct use of fragrances can suppress sleepiness upon awaking, recover fatigue, and provide a comfortable waking. However, even if the fragrance is not used correctly, it is still possible to wake up comfortably compared to the case where no fragrance is used. In addition, the order of the fragrances can be intentionally switched depending on the purpose because the satisfaction with the sleep time increases when the fragrance for falling asleep is used later.

5.3 SUS Result

Table3 shows the result of SUS evaluation. The score of each item was the average of the scores of all subjects, and the total value was calculated by the method of sum of each answer-1 × 2.5. The average score for AroNap was 84.8 points, which was over 80%. However, the mean score for the item "I was confident in using the system" was particularly low, suggesting that the system was not easy for users to use at first sight. The mean scores for "I would like to use this system frequently," "I found it easy to use," and "I found the various functions of this system well integrated" were also low, although they exceeded 4 points, suggesting that the desire to use the system

Table 3: SUS result (average score).

Question Number	Result
1	4.15
2	4.54
3	4.15
4	4.46
5	4.15
6	4.62
7	4.69
8	4.54
9	3.85
10	4.77
Calculation result	84.81

needs to be increased by making it easier to use. On the other hand, the mean scores for "I think most people will learn how to use this system quickly" and "I needed to learn a lot of things before I started using this system" were high. In particular, the latter score was 4.8, indicating that AroNap can be used without any particular knowledge required.

5.4 Comments in the Free Description Column

We received many opinions on the impression of using AroNap, which was conducted together with the SUS questionnaire. Positive feedback included comments such as "I woke up feeling good" and "I felt relaxed," as well as words on the system such as "easy to use" and "just the right amount of fragrance." Negative comments included "difficult to change position as it seems to block the lid of the AroNap," "surprised by the sound of the system," and "heavy." One comment was, "Instead of the wake-up scent being emitted 10 minutes before, could the wake-up scent be emitted 3 minutes before?" We will keep these comments in mind for future reference.

6 CONSIDERATION

From the standard deviation of the pulse interval, it can be considered that in all experiments, the pulse interval during napping is calmer with less fluctuation in the pulse interval than the free time. However, in K of the wake-up experiment, the only experiment in which the standard deviation of the napping time became large, an incident such as the M5StickC falling during the experiment occurred, and it is thought that the standard deviation became prominent due to surprise. In response to the fall of the M5StickC, we took measures such as taping the M5StickC to the box and lid, but it turned out that the M5StickC would fall depending on how the AroNap user slept. In addition, when comparing the first-wake experiment with the no-sleep experiment, it is thought that the pulse interval may have fluctuated due to the surprise caused by the operating noise of the AroNap system, as the pulse interval fluctuated less in the no-sleep experiment in some cases.

From the results of the pulse interval, it was found that the correct use of AroNap resulted in a state of calmness and that the state of relaxation lasted for a long time. The questionnaire results indicate that the introduction of sleep by fragrance is practical for a good sleep in terms of sleepiness upon waking and the degree of recovery from fatigue. However, only a few subjects took a nap, and it was difficult to fall asleep within 20 minutes. From the Lorenz plot, the subjects were relaxed regardless of the presence or absence of sleep, and the subjects were relaxed because the plot position after napping was in the upper right corner of the graph. Even if it is difficult to sleep, it is possible to improve work efficiency by relaxing the body and mind so that AroNap can improve work efficiency.

7 CONCLUSION

In this study, we developed "AroNap," which uses fragrances to assist in falling asleep and waking up for short naps. As a result of evaluation experiments, it was confirmed that the correct use of the scent had a long-lasting, relaxing effect. In addition, the reduction of drowsiness and recovery from fatigue upon waking was confirmed, indicating that it is possible to take a good nap. As a whole, we received the opinion that the scent makes us feel relaxed and easy to sleep. However, some people believe that the system is heavy and the operating noise is anxious, and there are some parts where such a reaction appears in the results of the measured pulse interval. In the future, while collecting opinions and data from more test subjects, we would like to improve the fact that AroNap restricts the sleeping position, the operating noise, and the weight. AroNap is expected to be used to improve work efficiency even if it does not lead to napping, but we would like to enhance its functions as a system that can introduce napping.

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